2022 City of Ann Arbor Hazard Mitigation Plan

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Section 1 - Introduction

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Background

Natural, man-made, and technological hazards are a part of the world around us, yet together we can prevent such events from turning into devastating disasters. With natural hazards, such as floods, extreme temperatures, severe thunderstorms, and winter storms increasing in frequency and intensity due to climate change, it is imperative that we work toward building a more resilient Ann Arbor that aims to reduce the impact of hazards to our people and place. A resilient future is built on a foundation of equity and environmental justice, connecting the ways we respond to disasters through community-wide investments to improve the outcomes for all residents.

The possibility of man-made and technological disasters, such as hazardous materials incidents, terrorism, and dam failure, are also present and are accounted for in this hazard mitigation plan. Hazards threaten the life and safety of residents and have the potential to damage or destroy both public and private property, disrupt the local economy, and impact the overall quality of life of individuals who live, work, and vacation in the City of Ann Arbor. While the threat from hazard events may never be fully eliminated, the goal and conscientious practice of reducing risks to people and property is a proven worthwhile effort, generally referred to as hazard mitigation.

> **Hazard Mitigation:** *Any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards.*

Hazard mitigation techniques include structural measures (such as strengthening or protecting buildings and infrastructure from destructive forces of potential hazards) and non-structural measures (such as the adoption of sound land use policies, regulations, and creation of public awareness programs). Mitigation has a strong return on investment, estimated at $6 return for every $1 invested.[i] It is widely accepted that the most effective mitigation measures are implemented at the local government level, where decisions on the regulation and control of development are ultimately made. A comprehensive mitigation approach addresses hazard vulnerabilities that exist today and in the foreseeable future. Therefore, it is essential that projected patterns of future development and population change are evaluated and considered in terms of how that growth will affect a community's overall hazard vulnerability.

A key component in the formulation of a comprehensive approach to hazard mitigation is to develop, adopt, and update a local hazard mitigation plan. A hazard mitigation plan establishes the broad community vision and guiding principles for reducing hazard risk and proposes specific mitigation actions to eliminate or reduce identified vulnerabilities. It also presents an opportunity to integrate hazard mitigation and risk reduction principles into other community plans and practices.

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City of Ann Arbor Hazard Mitigation Plan Update and Successes

The 2022 plan update is the third iteration of the *City of Ann Arbor Hazard Mitigation Plan*. Prior to the three municipal plans, the city was part of the Washtenaw County hazard mitigation plan. At its core, this plan aims to build a more resilient Ann Arbor through actions that reduce our vulnerability and risk to hazards, including those exacerbated by a changing climate, and help prepare and protect our residents. These mitigation actions go beyond simply recommending structural solutions to reduce existing vulnerability, such as elevation, retrofitting, and acquisition projects. Local policies on community growth and development, incentives for natural resource protection, and public engagement and social cohesion activities are examples of other actions considered to reduce the city's vulnerability to identified hazards. While the 2022 plan draws from the previous 2017 and 2012 plans, this update should be viewed with fresh eyes as the planning process was fully reimagined, from beginning to end. The following highlights a selection of key process updates:

- A new public outreach strategy was implemented including a Community Engagement Working Group.
- City staff attended public events to promote the plan including Earth Day, Huron River Day, and the Public Safety Open House.
- Targeted stakeholder interviews with subject matter experts to inform capability and actions.
- Goals revised with equity, climate, and community goals in mind.
- Actions consolidated and revised to be (primarily) actionable in the next five years.

The City of Ann Arbor has a long history of planning for and implementing mitigation activities that improve the resilience and overall preparedness of our community for both natural and man-made disasters. However, the city also recognizes that there is a tremendous amount of work to be done to truly integrate resilience into the community and are proactively developing this plan to be actionable in the next five years and beyond.

In the five years since the 2017 plan update, the city has successfully implemented mitigation strategies and made advances in risk reduction and sustainability including:

- Allen Creek Railroad Berm: Secured $3.7 million in FEMA grant funding and completion of the project.
- Community Rating System (CRS): Improved the city's CRS Class from a 7 to a 6 resulting in greater flood insurance discounts.
- Fire Station Number 4: Beginning the process to build a new Fire Station 4 that will advance the city's goals for sustainability, climate adaptation, and hazard mitigation.
- Dam Evacuation Plan: Updated the evacuation plan for Barton Dam and communicated the new plan to impacted residents.
- New Floodplain Management Overlay: City Council adopted a Floodplain Management Overlay District to further enhance floodplain management.

DRAFT

The city has also further invested in increasing community resilience by mitigating climate change through the creation of programs and executive actions. For example, City Council unanimously adopted a Climate Emergency Declaration on November 4th, 2019 recognizing that climate change is one of the most important issues of our time, and committed to charting a path to achieve carbon neutrality by the year 2030. The *A2Zero Carbon Neutrality Plan* was completed in 2020 and outlines this path to "achieve a just transition to carbon neutrality, community-wide, by the year 2030."

Relevant Federal Hazard Mitigation Policies and Regulations

In an effort to reduce the Nation's mounting natural disaster losses, the U.S. Congress passed the Disaster Mitigation Act of 2000 (DMA 2000) in order to amend the Robert T. Stafford Disaster Relief and Emergency Assistance Act. Section 322 of DMA 2000 emphasizes the need for state and local government entities to closely coordinate on mitigation planning activities and requires a hazard mitigation plan for any local government applying for federal mitigation grant funds. Communities with an adopted and FEMA-approved hazard mitigation plan are pre-positioned to receive available mitigation funds before and after the next disaster strikes. Additionally, the National Flood Insurance Act of 1968 that created the National Flood Insurance Program has been periodically reformed and reauthorized, also requiring a FEMA-approved hazard mitigation plan as a condition of grant eligibility.

Following a series of devastating natural disasters, the Disaster Recovery Reform Act of 2018 (DRRA) was enacted, making significant changes to federal emergency management policy and regulations to assist communities across the nation. The DRRA includes reforms that provide a larger and more reliable funding source for pre-disaster mitigation based on a percentage of total aid previously awarded. It also adjusted the language to consider "resilience" when reducing future damage through Hazard Mitigation Grant Program funding. The DRRA provides support for states, localities, tribes, and territories to develop their own emergency management capabilities, including new authority to rebuild according to the latest building codes.

Purpose

The purpose of the 2022 City of Ann Arbor Hazard Mitigation Plan Update is to:

- Update the existing City of Ann Arbor Hazard Mitigation Plan to demonstrate progress and changing priorities.
- Identify mitigation actions that increase resilience, especially the resilience of the most vulnerable.
- Increase community awareness of current and future vulnerabilities.
- Align with and reinforce existing local policies, plans and initiatives including:
    - Community Rating System (CRS) – Maintain or improve Class 6 status
    - A2Zero – City's plan to achieve a just transition to community-wide carbon neutrality by 2030
    - One Community – City's commitment to advancing racial equality
    - The City's Emergency Management Program

DRAFT

- Floodplain Management Overlay Zoning District
- Stormwater Model Calibration and Analysis Final Report

- Maintain grant eligibility.
- Maintain compliance with state and federal legislative requirements for local hazard mitigation plans.

Scope

The 2022 Ann Arbor Hazard Mitigation Plan focuses on the hazards determined to be "high" or "moderate" risks to the city, as determined through a detailed hazard risk assessment. While all potential hazards warranted some analysis and assessment, hazards that pose a "low" or "negligible" risk may not be fully addressed until they are determined to be of high or moderate risk. This enables the city to prioritize mitigation actions based on those hazards which are understood to present the greatest risk to lives and property.

The geographic planning area includes the City of Ann Arbor. The University of Michigan is not included in the plan for the analysis as it has its own hazard mitigation plan (though the university was a participant in the planning process). This is a single jurisdiction plan.

Authority

The 2022 City of Ann Arbor Hazard Mitigation Plan has been developed in accordance with current state and federal rules and regulations governing local hazard mitigation plans and has been adopted in accordance with local procedures. Copies of the adoption resolution are provided in Appendix A. The Plan shall be routinely monitored and revised to maintain compliance with the following provisions, rules, and legislation:

- Section 322, Mitigation Planning, of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as enacted by Section 104 of the Disaster Mitigation Act of 2000 (P.L. 106-390).
- FEMA's Mitigation Planning Final Rule published in the Federal Register on September 16, 2009, at 44 CFR Part 201.
- Flood Insurance Reform Act of 2012 (P.L. 112-141) and the Homeowner Flood Insurance Affordability Act.

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Summary of Plan Contents

This plan is designed to be as reader-friendly and functional as possible. While significant background information is included on the processes and studies used (i.e., risk assessment, capability assessment), effort was made to direct the reader's attention to the more meaningful planning outcomes or actions (i.e., mitigation strategy, mitigation action plan).

The *Planning Process*, Section 2, describes the process used to prepare the Plan, including the integration of Community Rating System requirements. It identifies members of the planning team and how the public and other stakeholders were involved. It also includes a summary for each of the key meetings along with any associated outcomes.

The *Community Profile*, Section 3, provides a general overview of the City of Ann Arbor, including geographic, demographic, and economic characteristics. In addition, this section discusses building characteristics and land use patterns. This baseline information provides a snapshot of the planning area and helps local officials recognize those social, environmental, and economic factors that play a role in determining the city's vulnerability to hazards.

The *Risk Assessment*, Section 4, serves to identify, analyze, and assess hazards that threaten the City of Ann Arbor. The risk assessment also addresses neighborhood specific risks, and vulnerable populations.

The Risk Assessment begins by identifying hazards that threaten the City of Ann Arbor now and in the future. Next, it establishes detailed profiles for each hazard, building on available historical data from the previous plan, past hazard occurrences, spatial extent, and probability of future occurrence. This section culminates by ranking the risks (known as the Priority Risk Index) and identifying the most vulnerable areas. The vulnerability assessment uses available hazard data to evaluate vulnerability, and the 2022 version incorporates considerations of equity and more robust climate information. In essence, the information generated through the risk assessment serves a critical function as the city seeks to determine the most appropriate mitigation actions to pursue and implement. The risk assessment enables the city to prioritize and focus its efforts on those hazards of greatest concern and those structures or planning areas facing the greatest risk.

The *Capability Assessment*, Section 5, provides an inventory and analysis of existing plans, ordinances, and relevant documents. The purpose of this assessment is to identify any existing gaps, opportunities, or conflicts in programs or activities that may hinder hazard mitigation efforts and determine activities that should be built upon to establish a successful and sustainable local hazard mitigation program. Specific capabilities addressed in this section include planning and regulatory capability, staff and organizational (administrative) capability, technical capability, fiscal capability, and political capability. Information was obtained through the use of a Capability Assessment Survey, review of plans, and stakeholder interviews.

The *Community Profile*, *Risk Assessment*, and *Capability Assessment* collectively, along with public outreach and input, serve as a basis for determining the goals for the City of Ann Arbor Hazard Mitigation Plan, each contributing to the development, adoption, and implementation of a meaningful and manageable *Mitigation Strategy* that is based on accurate background information.

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The *Mitigation Strategy*, Section 6, begins with goal statements that guide the planning process. The 2022 goals were revised to align with the goals of the community. The section also includes an overview of hazard mitigation techniques for the City of Ann Arbor to consider when reducing hazard vulnerabilities such as structural, regulatory, and technical techniques. For 2022, a social cohesion technique was added to reflect potential activities that bring the community together and promote resilience. The strategy culminates in a detailed *Mitigation Action Plan*, which links specific mitigation actions. Actions are made implementable through prioritization, assignment of a lead, anticipated timeframes, and financing mechanisms.

The 2022 Action Plan was revised to be more concise and actionable, primarily driven by a new and robust prioritization process which is further detailed in Section 6.

Plan Maintenance, Section 7, includes the measures that the City of Ann Arbor will take to ensure the Plan's continuous long-term implementation. The procedures also detail how the Plan will be regularly evaluated and updated to remain a current and meaningful planning document.

Lastly, the Appendices provide documentation including Appendix A: Adoption Resolution; Appendix B: Planning Tools; Appendix C: Plan Documentation; Appendix D: Community Rating System (CRS) Documentation; and Appendix E: Hazard Mitigation Plan Review Tool.

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Notes

[i] Multihazard Mitigation Council (2017) Natural Hazard Mitigation Saves 2017 Interim Report: An Independent Study – Summary of Findings. Retrieved July 8, 2022 from https://www.fema.gov/sites/default/files/2020-07/fema_ms2_interim_report_2017.pdf

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Section 2 – Planning Process

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Overview

Local hazard mitigation planning is the process of organizing community resources, identifying and assessing hazard risks, and determining how to best minimize or manage those risks. This process culminates in a hazard mitigation plan that identifies specific mitigation actions, each designed to achieve both short-term planning objectives and a long-term community vision.

Communities that participate in hazard mitigation planning have the potential to accomplish many benefits, including:

- Demonstrate a firm commitment to equitably improving community resilience by prioritizing the most vulnerable;
- Prevent loss of life and property;
- Cost avoidance;
- Recover quickly from disasters and bounce forward;
- Reduce future vulnerability through wise development; and
- Expedite the receipt of pre-disaster and post-disaster grant funding.

Typically, communities that participate in mitigation planning are described as having the potential to produce long-term and recurring benefits by breaking the repetitive cycle of disaster loss. A core assumption of hazard mitigation is that the investments made before a hazard event will significantly reduce the demand for post-disaster assistance by lessening the need for emergency response, repair, recovery, and reconstruction.[i] Furthermore, mitigation practices will enable residents, businesses, and industries to re-establish themselves in the wake of a disaster.

It is vitally important that any local mitigation planning process be integrated with other concurrent local planning efforts, and any proposed mitigation strategies must take into account other existing community goals or initiatives that will help complement or hinder their future implementation. The City of Ann Arbor takes a progressive approach to hazard mitigation planning, which go far beyond federal hazard mitigation grant requirements. This plan was developed with community resilience at the forefront, and identified actions were designed to achieve multiple community goals including sustainability, equity, and floodplain management among others. The planning process also included a robust engagement progress that leveraged working groups, innovative outreach tools, and cross-collaboration to disseminate information.

History of Hazard Mitigation Planning in Ann Arbor

Ann Arbor has been engaged in planning since the passage of the Disaster Mitigation Act of 2000 including regular five-plan updates to maintain eligibility for FEMA hazard mitigation funding. Prior to 2012, the city participated in the Washtenaw County's Hazard Mitigation Plan as a participating jurisdiction. In 2012, the city developed a stand-alone citywide plan to address city-specific issues and vulnerability and meet associated grant deadlines. The 2012 version of the hazard mitigation plan was the first to integrate

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the city's Floodplain Management Plan, which helps to qualify the city for Community Rating System (CRS) points. The FMP included a much more detailed flood analysis than had been included in the Washtenaw County hazard mitigation plan and was heavily focused on implementation. The 2017 update was the first version to incorporate climate change considerations throughout the plan (risk assessment, goals, mitigation strategy), and being that it was one of the first plans in the nation to do so, it served as a model plan for other jurisdictions across the nation.

Preparing the 2022 Hazard Mitigation Plan Update

Hazard mitigation plans are required to be updated every five years to remain eligible for federal mitigation funding. An approximate seven-month planning process was employed to update the 2022 version prior to its expiration. The city hired Stantec Consulting Services, Inc. (Stantec) to provide professional mitigation planning services.

At the onset of the planning process, the city reviewed each section of the plan and opted to make significant revisions throughout. Thus, all sections were revised to develop a more concise and actionable plan. The city was motivated to develop a plan that was inclusive of input from a broad planning team (the Technical Advisory Committee), a guiding Steering Committee, and a Community Engagement Working Group, which are described further below. Additional changes include a more robust consideration for climate change impacts and a focus on equity.

The consultant team followed the latest mitigation planning process recommended by FEMA: Local Mitigation Planning Handbook (March 2013) and the Local Mitigation Plan Review Guide (October 2011). Additionally, the Local Mitigation Plan Review Tool, found in Appendix E, provides a detailed summary of FEMA's current minimum standards of acceptability for compliance with DMA 2000 and notes the location where each requirement is met within this Plan. These standards are based upon FEMA's Final Rule as published in the Federal Register in Part 201 of the Code of Federal Regulations (CFR). Lastly, this plan adheres with Community Rating System (CRS) 510 elements as found in the 2017 National Flood Insurance Program, CRS Coordinator's Manual. The completed CRS 510 review guide, including the estimated scoring, is provided in Appendix E.

The hazard mitigation planning process and the 510 CRS elements were used as the foundational process to prepare this plan. These planning steps (illustrated below in Table 2-1) resulted in critical work products and outcomes that collectively make up the plan. Specific plan sections are also described in *Section 1: Introduction*.

Community Rating System

The 2022 Ann Arbor Hazard Mitigation Plan Update and the associated planning process may help the city maintain and improve its status in the Community Rating System (CRS). The CRS is an incentive-based program that encourages counties and municipalities to undertake defined flood mitigation activities that go beyond the minimum requirements of the NFIP by adding extra local measures to provide protection from flooding. Ann Arbor is currently in CRS Class 6, which allows a 20% discount for NFIP policy premiums. CRS classes are based on how many credits the jurisdiction has earned through its flood mitigation efforts. The hazard mitigation planning process was designed to earn CRS credits for floodplain management planning outlined in Section 510 of FEMA's CRS Coordinator's Manual (2013). Table 2.1 below demonstrates how Ann Arbor's hazard mitigation planning process complies with the CRS planning requirements and the planning requirements of the Disaster Mitigation Act of 2000.

Table 2-1: CRS 510 Planning Requirements versus DMA 2000 Hazard Mitigation Requirements

CRS Ten-Step Planning Process	Disaster Mitigation Act of 2000 Planning Requirements
1. Organize 2. Involve the Public 3. Coordinate	Planning Process (community profile, capability assessment, documentation)
4. Assess the Hazard 5. Assess the Problem	Risk Assessment
6. Set Goals 7. Review Possible Activities 8. Draft Action Plan	Mitigation Strategy
9. Adopt Plan	Plan Adoption
10. Implement, Evaluate, & Revise	Plan Review, Evaluation, & Implementation

To meet requirements of the Community Rating System and the Disaster Mitigation Act of 2000, the city ensured that the planning process was facilitated under the direction of a professional planner. Caroline Cunningham (Stantec) served as the project manager/lead planner for this project and is a member of the American Institute of Certified Planners (AICP). John Bucher, AICP, was also involved throughout the process and led the parallel CRS planning process. Of note, while all requirements of the CRS planning have been met, the process was not intended to maximize the available points given the timeframe. Estimated scoring can be found in Appendix E.

Ann Arbor Planning Team

The City of Ann Arbor strongly values active citizenship and is continually working to advance and improve its practices to engage its residents. Engagement, and more specifically engagement with a lens on equity, drove the planning process and justified standing up three committees to guide, inform, and review the process and plan, and to communicate with the community throughout the planning process. The Ann Arbor Planning Team was made up of three separate committees, with some overlapping participation: the Steering Committee, the Technical Advisory Committee (TAC), and the Community Engagement Working Group.

DRAFT

Table 2-2 lists the members of the Ann Arbor Planning Team, made up of three separate committees. Committee members are listed in alphabetical order by last name, and their participation on a respective committee(s) is(are) identified by an 'x'. The responsibility of each committee is further described below.

Table 2-2: Members of Planning Committees

Name	Title	City Service Area/Agency	Technical Advisory Committee	Steering Committee	Engagement Working Group
Andrew Box	Assistant Fire Chief	Fire Department	x		
Andrew Burchfield	Emergency Management Director	University of Michigan – Division of Public Safety and Security	x		
Glen Dempsey	Building Official	Construction and Building Department	x	x	
Rebecca Esselman	Watershed Manager	Huron River Watershed Council	x		
Jason Forsberg*	Deputy Police Chief	Police Department	x		
Jennifer Hall*	Executive Director	Housing Commission	x		
Jerry Hancock	Floodplain Coordinator	Floodplain Administration and Stormwater Management	x	x	
Galen Hardy*	Community Engagement Specialist	Ann Arbor Office of Sustainability and Innovation			x
John Hradsky	Applications Specialist	Information Technology	x		
Cindra James*	Emergency Preparedness Administrator	Washtenaw County Health Department	x		
Mike Kennedy	Fire Chief	Fire Department	x	x	

DRAFT

Name	Title	City Service Area/Agency	Technical Advisory Committee	Steering Committee	Engagement Working Group
Josh Landefeld	Deputy Parks Manager	Parks and Recreation	x		
Jen Lawson	Water Quality Manager	Floodplain Administration and Stormwater Management	x	x	
Brett Lenart	Planning Manager	Planning Division	x	x	
Molly Maciejewski	Public Works Manager	Public Works - Transportation	x	x	
Liz Margolis*	Executive Director Student & School Safety	Ann Arbor Public Schools	x		
Len Lemorie*	Associate Director – Facilities	Ann Arbor District Library	x		
Sydney Parmenter	Emergency Management Coordinator	Office of Emergency Management	x	x	x
Aubrey Patino*	Executive Director	Avalon Housing	x		
Ben Pinette*	Emergency Management Coordinator	Washtenaw County Sheriff's Office	x		
Evan Pratt*	Water Resources Commissioner	Washtenaw County	x		
Margaret* Radabaugh	Deputy City Attorney	Attorney's Office	x		
Zachary Sankey*		Veterans Affairs Ann Arbor Healthcare System Emergency Management	x		
Heather Seyfarth*	Special Projects Manager & Community	Public Services			x

DRAFT

Name	Title	City Service Area/Agency	Technical Advisory Committee	Steering Committee	Engagement Working Group
	Engagement Specialist				
Tom Shewchuk	Director	Information Technology	x		
Bryan Smith	Deputy CEO of Operations	TheRide	x		
Brian Steglitz*	Manager	Water Treatment Services	x	x	
Missy Stults*	Manager	Office of Sustainability and Innovations	x	x	x
Lisa Wondrash	Communications Unit Manager (PIO)	Communications Office	x		x
Carrie Wright*	Emergency Management Specialist	U-M Michigan Medicine	x		

*New additions to committees for 2022 update

Technical Advisory Committee

The TAC is a community-based planning team made up of representatives from various city departments and other key stakeholders identified to serve as critical partners in the planning process. The TAC was first organized in 2012 as part of the hazard mitigation planning process. The TAC includes members with the authority to regulate development (planning manager and floodplain manager) and regional agencies (Huron River Watershed Council), and other parties interested in mitigation (University of Michigan). TAC membership was reviewed and expanded (see Table 2-2) to include business representation, A²Zero Climate Action Plan leaders, "One Community" Equity Initiative and the Equitable Engagement Steering Committee, and champions of the Comprehensive Plan, schools, and outreach programs.

The TAC engaged in regular local meetings and planning workshops to discuss and complete tasks associated with preparing the plan. This working group coordinated on all aspects of plan preparation and provided valuable input to the process. Two formal TAC meetings were held for the hazard mitigation plan update. In addition to regular meetings, committee members routinely communicated and were kept informed through an e-mail distribution list. Meeting documentation can be found in Appendix C.

Specifically, the tasks assigned to the TAC members included:

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- Participate in TAC meetings and workshops;
- Provide best available data as required for the risk assessment portion of the plan;
- Provide information that will help complete the Capability Assessment section of the plan and provide copies of any mitigation or hazard-related documents for review and incorporation into the plan;
- Support the development and update of the Mitigation Strategy, including the design and adoption of goal statements;
- Help design and propose appropriate mitigation actions for their department/agency for incorporation into the Mitigation Action Plan;
- Review and provide timely comments on all study findings and draft plan deliverables; and
- Support the adoption of the 2022 *Ann Arbor Hazard Mitigation Plan Update*.

Steering Committee

The Steering Committee was tasked with guiding the overall plan development. All members of the Steering Committee are members of the TAC and were subject to those responsibilities. The Steering Committee participated in outreach events and initiatives, attended meetings, and amplified the messaging throughout city departments. The Steering Committee also provided input on data, reviewed mitigation actions and project ideas. The Steering Committee provided the final draft plan review. The Steering was engaged in as needed bi-weekly calls throughout the planning process.

Community Engagement Working Group

Ann Arbor established an engagement working group comprised of the city staff responsible for engagement in the A²Zero effort, representatives from the Equitable Engagement Steering Committee, and the City's Public Information Officer. This working group held a workshop prior to the public kickoff to help develop a public engagement plan and agree on appropriate and effective methods to reach frontline and fenceline populations. The engagement working group met bi-weekly as needed throughout the mitigation planning process to monitor public engagement and make improvements and adjustments, as needed, to the public engagement plan.

Plan Development Meetings

The preparation of this plan entailed a series of meetings and workshops for facilitating discussion, gaining consensus, and initiating data collection efforts with local government staff, community officials, and other identified stakeholders (including neighboring jurisdictions, the public, and those involved in hazard mitigation activities). More importantly, the meetings prompted continuous input and feedback from relevant participants throughout the drafting stages of the plan. Public meetings were well-publicized to invite a broad range of stakeholders and were supplemented with an extensive outreach/engagement initiative. The following is a

DRAFT

summary of the key meetings held during the development of the plan update with detailed meeting minutes found in Appendix C.ii Five main virtual meetings were conducted: Steering Committee Kickoff Meeting, Public Kickoff Meeting, TAC Kickoff Meeting, Public Meeting #2, TAC Meeting #2/Draft Review Meeting. In addition to these meetings, many routine discussions and additional meetings were held by local staff to accomplish planning tasks specific to their department or agency, such as the approval of specific mitigation actions for their department or agency to undertake and include in the Mitigation Action Plan.

Steering Committee Kickoff Meeting – January 12, 2022

The purpose of Steering Committee Kickoff Meeting was to review the scope of work, schedule, and path to implementation of the city's 2022 Hazard Mitigation Plan Update. It serves as the formal kickoff to the planning process. The meeting was facilitated by Caroline Cunningham, Stantec Project Manager and the Stantec Team. Following introductions, each phase of the planning process was reviewed. In addition, the team reviewed responsibilities of the Steering Committee.

Public Kickoff Meeting – April 6, 2022

The virtual Public Kickoff Meeting was held via Zoom at 3:00pm on April 6, 2022. The purpose of the meeting was to provide an introduction to hazard mitigation and described why updating the plan is important, including maintaining eligibility for FEMA grants and maintaining the city's Community Rating System (CRS) class. The overall planning process was described, including how other city plans and initiatives would be integrated, the risk assessment, mitigation strategy and the goals from the previous plan, and the plan review and adoption process. Anticipated plan improvements were also identified, including a stronger focus on climate and equity, and future stakeholder engagement opportunities were emphasized.

Sydney Parmenter, Emergency Management Coordinator, then guided an exercise through Google Jam board (Figure 2-1), where respondents added sticky notes to the jam board to answer the following three questions:

1. What is the hazard of greatest concern to you & why?
2. What hazards have you been affected by?
3. How did the August 2021 blackout impact you?

Outside of city staff, one participant from the public attended. The Steering Committee revisited the public outreach approach in response to the limited attendance and planned the future public meeting to occur after work hours. The Steering Committee also staged a series of outreach/engagement initiatives bringing information to the public instead of asking the public to come to them, as described below in the *Involving the Public* section.

TAC Kickoff Meeting – April 13, 2022

The virtual TAC kickoff meeting was held on April 13, 2022, at 1:00pm. The purpose of the meeting was to provide an overview of hazard mitigation concepts, describe the significance and process of updating the plan, and explain roles and responsibilities of the committee members. Activities to date were described to the TAC including leadership groups, the plan's web presence on Social Pinpoint, the survey, the public kickoff meeting, and the data request. The meeting also provided an overview of mitigation techniques, clustered into broad categories, and provided examples of each. This led to the mitigation ideas exercise, in which Google Jam Board (Figure 2.1) was used to gather responses from participants for the following questions:

1. What types of mitigation/adaptation work does your department do?
2. What is your top hazard of concern?
3. Please share mitigation project ideas.

Figure 2-1: Google Jam Board Exercise from TAC Kickoff Meeting

The meeting concluded with an overview of the project schedule, key milestones, and a list of next steps. The committee was requested to complete and distribute the survey, and to use Social Pinpoint to share hazard experiences, mitigation ideas, and input on critical facilities. A demo of Social Pinpoint was led before the meeting concluded.

Stakeholder Interviews

A series of six supplemental engagement calls were held across six different sectors to collect mitigation ideas and a greater understanding of local risk.

- IT / Cyber Security – May 10, 2022
- University of Michigan / Emergency Management – May 10, 2022
- Housing – May 16, 2022

- Sustainability – May 16, 2022
- Wastewater Treatment Plant / Dams – May 17, 2022
- Stormwater – May 20, 2022
- CRS / Flooding – May 20, 2022

TAC Meeting #2 Risk Assessment & Mitigation Strategy Review – June 9, 2022

The virtual TAC Risk Assessment & Mitigation Strategy Review meeting was held on June 9, 2022, at 1:00pm. The purpose of the meeting was to provide an update of the project progress including schedule, public survey results, risk assessment, capability assessment findings, and to review and gather additional information on the mitigation actions.

The public survey reached a large audience with 301 responding participants, and key takeaways were shared at the meeting including participant knowledge of hazards and prevention methods, mitigation priorities, and favored methods to receive information. Key findings from the risk assessment were also provided, addressing climate change impacts on vulnerability. The risk assessment results aligned with responses from the public survey. The overview of the mitigation strategy began with a review of the updated goals and actions from 2017 plan, then led into an explanation of how mitigation actions would be revised and supplemented by integrating public input, and through incorporating risk assessment and capability results. The capability assessment results were described as identified ongoing opportunities, and participants were made aware that the plan will also document the work already successfully implemented by the city for FEMA's review and accolades. Following the capability assessment discussion, there was a question about the Comprehensive Stormwater Master Plan and the need to revisit that action for future consideration. The Action Prioritization methodology that will be used to rank mitigation actions was shared with the request for feedback.

The meeting concluded with an explanation of the expected review timeline for sections of the draft plan: TAC would be sent for their review the first draft plan chapters in mid-June and remaining chapters in late July.

Public Meeting #2 Mitigation Strategy Review – June 22, 2022

The virtual Public Meeting #2 focused on the Risk Assessment Results and a Mitigation Strategy Review. The meeting was held via Zoom at 5:30pm on June 22, 2022.

Following administrative items, Ms. Cunningham began meeting by reviewing the definition of mitigation. This was followed by an explanation of the need for a hazard mitigation plan, including an overview of local risk, state and federal hazard mitigation funding, and the city's completed mitigation projects. She described the changes to this plan update including expanded integration of climate change, a focus on equity, and a more actionable path forward to reduce risk.

DRAFT

Ms. Cunningham then described the generalized hazard mitigation planning process. She explained each step of the planning process. The planning process included organizing resources, collecting data, documentation the plan, engaging the public, assessing capability and risks, developing a mitigation strategy, and implementing the plan. Next, the results from the public survey were reviewed. This was followed by an overview of the risk assessment results. At the conclusion of the risk assessment results, attendees were asked if there were questions. None were reviewed.

The next portion of the meeting focused on the mitigation strategy. It began with an overview of the process, a review of the goals, and a description of the seven projects categories (e.g., social cohesion, structural measures). From here, to actions were presented and feedback from attendees was requested. No comments were made.

The last section of the meeting focused on next steps including when the full plan would be available for review and where it would be posted. The floor was opened for any questions or comments. A comment was received to consider a Community Emergency Response Team (CERT) as an action. The meeting was then adjourned.

A recording of the plan was posted to A2 Open City Hall (https://www.opentownhall.com/p/116) and the Social Pinpoint website.

Involving the Public

44 CFR Requirement
44 CFR Part 201.6(b)(1): The planning process shall include an opportunity for the public to comment on the plan during the drafting stage and prior to plan approval.

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An important component of the mitigation planning process involved public participation. Individual citizen and community-based input provides the entire planning team with a greater understanding of local concerns and increases the likelihood of successfully implementing mitigation actions by developing community "buy-in" from those directly affected by the decisions of public officials. As citizens become more involved in decisions that affect their safety, they are more likely to gain a greater appreciation of the hazards present in their community and take the steps necessary to reduce their impact. Public awareness is a key component of any community's overall mitigation strategy aimed at making a home, neighborhood, school, business, or entire city more resilient to the potential effects of hazards.

Public involvement during the *Ann Arbor Hazard Mitigation Plan* Update was sought using three methods: (1) Two public meetings were held during the planning process (Public Kickoff Meeting; Public Mitigation Strategy and Plan Review Meeting, as described above); (2) promotion through information tables at key community events, social media, and traditional media; (3) a public survey was conducted (described below) which permitted open comment; and (4) copies of the draft Plan deliverables were made available and advertised for public review and comment on the city's website and in hard copy form in City Hall. The public was provided two opportunities to be involved in the development of the plan at two distinct periods during the planning process: (1) during the drafting stage of the Plan – two onsite public meetings; and (2) upon completion of a final draft Plan – draft plan review, but prior to official plan approval and adoption. A link to an electronic version of the draft plan was posted and advertised via the city's social media channels, the city's website, and a Gov Delivery email. Appendix C documents each of these advertisements. The final plan was reviewed and approved by City Council on October xxth, 2022 during a public meeting. (The adoption resolution can be found in Appendix A).

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Ann Arbor staff and committee members promoted participation in the planning process through use of the City's social media platforms and at several public events including the Public Safety Open House (150 visitors), Green Fair, Earth Day, A^{2}Zero week, Huron River Day (250 visitors), and the Farmers Market. Sydney Parmenter participated in an interview with radio station 89.1 WEMU, discussing the Hazard Mitigation Plan and the second public meeting.

Throughout the planning process, interested individuals were routed to the project website (Figure 2-2) where they could learn about upcoming meetings, place markers on a map showing areas where hazards occur and where they have ideas for risk reduction activities, and a forum for providing feedback on risk reduction activities.

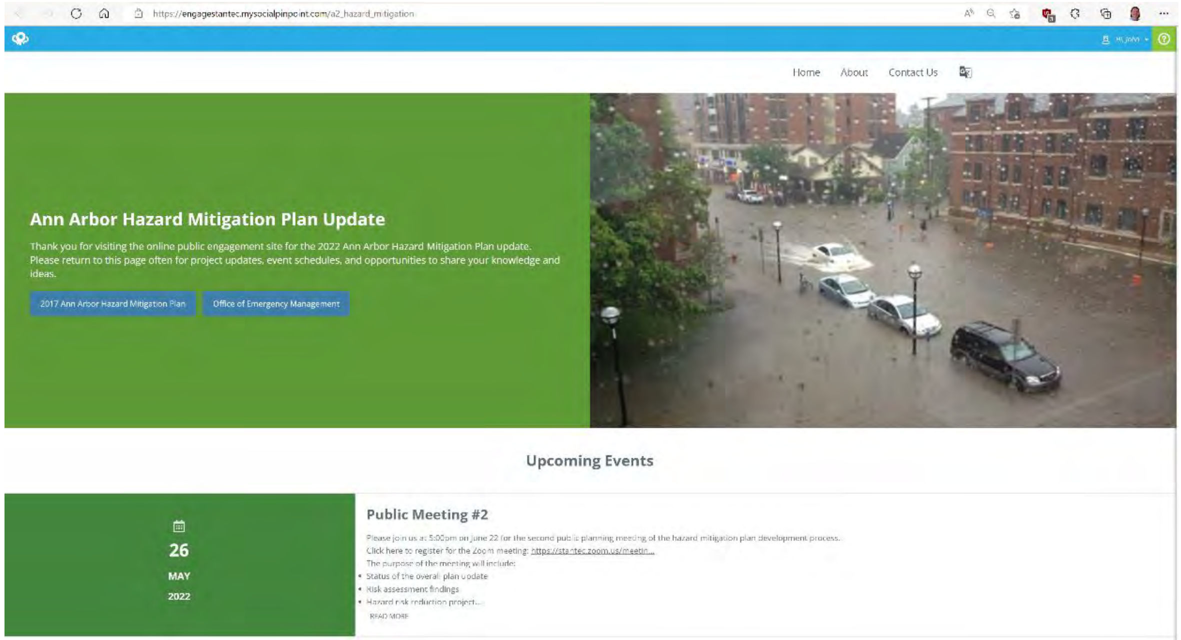

Figure 2-2: Project Website

Public Participation Survey

The Technical Advisory Committee was successful in getting citizens to provide input to the mitigation planning process through the use of the *Public Participation Survey*. The *Public Participation Survey* was designed to capture data and information from residents of the City of Ann Arbor might not be able to attend public meetings or participate through other means in the mitigation planning process.

A link to the electronic version of the survey was posted and advertised via the city's social media channels, the city's website, a Gov Delivery email, and the project website. Appendix C documents each of these advertisements.

A total of 301 survey responses were received, including 197 responses suggesting the two most important actions the city can take to increase resilience to hazards, including climate-related hazards. The survey responses provided valuable input for the TAC to consider in the development of the plan update and helped prioritize mitigation actions. Selected survey results are presented below. A copy of the survey is provided in Appendix B and a detailed summary of the survey results are provided in Appendix D.

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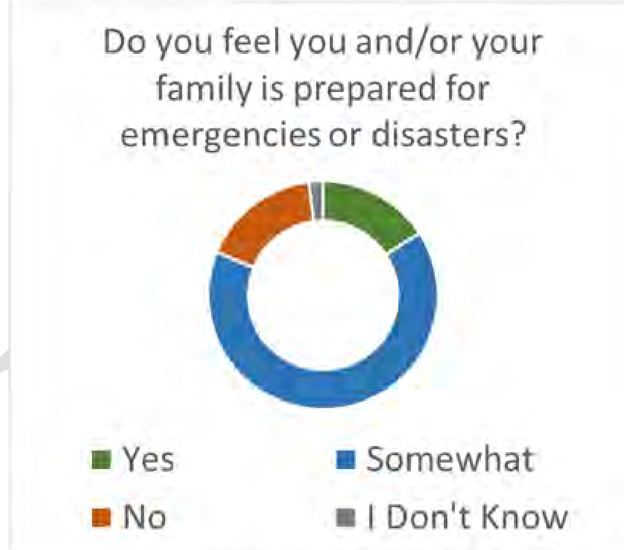
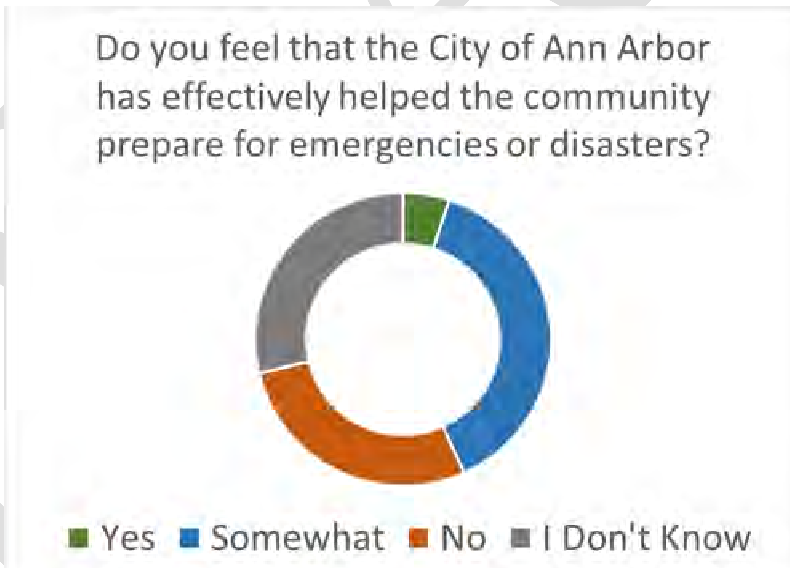
Is your home or business located in a floodplain?
Yes
No
I Don't Know


Do you feel you and/or your family is prepared for emergencies or disasters?
Yes
Somewhat
No
I Don't Know


Do you feel that the City of Ann Arbor has effectively helped the community prepare for emergencies or disasters?
Yes
Somewhat
No
I Don't Know

Hazards most concerned about:
1. Power outages
2. Public health emergencies
3. Drinking water contamination
4. Severe wind

Climate threats most concerned about:
1. More extreme and more frequent rainfall events (more frequent flooding)
2. Increased heat wave intensity and frequency
3. More extreme and more frequent thunderstorm storm events (including tornadoes)
4. More extreme and more frequent winter storm events (including ice storms)

Preferred method to receive preparedness information:
1. Internet (website, email, etc.)
2. Mailer (e.g., in water or tax bill)
3. Fact sheet/brochure

Preferred method(s) to receive ongoing emergency/disaster information:
1. Internet (website, email, etc.)
2. Notification services (A2 Emergency Alerts)
3. Radio

What two actions do you think are the most important for the city to take to increase resilience to hazards, including climate-related hazards (197 responses)?

Type of Action	Count
Protection - infrastructure improvements	65
Power grid – hardening, greening, backup power	45
Education and outreach	43
Prevention - zoning/development control/building codes	31
Plant/keep trees, invasive species removal	20
Resilience hubs/shelters	16
Gelman plume/pollution mitigation	14
Emergency Services/preparedness	11
Social cohesion (vulnerable pops)	9

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Neighborhood emergency response teams/CERT	8

Involving the Stakeholders

44 CFR Requirement
44 CFR Part 201.6(b)(2): The planning process shall include an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia, and other non-profit interests to be involved in the planning process.

The TAC worked to provide an opportunity for a wide range of stakeholders, including opportunity for neighboring communities, agencies involved in hazard mitigation activities, agencies that have the authority to regulate development, private entities, and others to be involved in the planning process.

In order to involve a wide range of stakeholders, the city made a significant effort to broadly distribute the public survey, advertise public meetings, and solicit comments on the draft plan. These opportunities to be involved and offer input were provided for local officials, residents, businesses, academia, and other private interests in the city and surrounding areas throughout the local mitigation planning process.

Furthermore, the following activities demonstrate broad stakeholder involvement:

- The TAC included representation from the Huron River Watershed Council and the University of Michigan.
- Risk assessment data was leveraged from these sources, the state, and FEMA.
- Members of the planning team (including the Planning Manager and Floodplain Administrator) have the authority to regulate development through planning or code enforcement.
- The final draft plan was publicized on websites for stakeholder comment and review.

Incorporation of Plans, Studies, and Technical Information

44 CFR Requirement
***44 CFR Part 201.6(b)(3):** Does the Plan describe the review and incorporation of existing plans, studies, reports, and technical information?*

Several plans and studies have been leveraged during the development of this plan. Each section references these sources at the end of the section, which are primarily found in Section 3 through Section 5. Types of sources leveraged included:

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- Local planning documents (e.g., floodplain management ordinances, land use plans).
- Local inundation studies for High Hazard Potential Dams (HHPDs)(e.g., dam failure analysis reports, maps, and data).
- Local, state, federal hazard technical information (e.g., USGS Earthquake data, FEMA Flood Insurance Rate Maps).
- FEMA hazard mitigation plans and planning guidance.

Local plans were also queried via a Local Capability Review Form which is discussed further in Section 5.

Documentation of Plan Progress

Progress in hazard mitigation planning is documented in this plan update. Since hazard mitigation planning efforts officially began with the development of the initial Hazard Mitigation Plans in the late 1990's/early 2000s, many mitigation actions have been completed and implemented by the city. These actions will help reduce the overall risk to natural hazards for the people and property in the City of Ann Arbor. The actions that have been completed are documented in the Mitigation Action Plan found in Section 6 and Appendix C.

In addition, community capability continues to improve with the implementation of new plans, policies and programs that help to promote hazard mitigation at the local level. The current state of local capabilities is captured in Section 5: *Capability Assessment*. The city continues to demonstrate their commitment to hazard mitigation and hazard mitigation planning and have proven this through NFIP compliance, joining the CRS in May 2017, and an ongoing commitment to obtaining and implementing mitigation funding and projects, such as the Rail Road berm. For this plan update, the team focused on the mitigation strategy, including revamping the existing action plan to focus on actionability and implementation. Also, the city took a much bolder on plan integration, particularly through its alignment to A²Zero and One Community equitable outreach efforts.

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Notes

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i Multihazard Mitigation Council (2017) Natural Hazard Mitigation Saves 2017 Interim Report: An Independent Study – Summary of Findings. Retrieved July 8, 2022 from https://www.fema.gov/sites/default/files/2020-07/fema_ms2_interim_report_2017.pdf

ii Copies of agendas, sign-in sheets, minutes, and handout materials for all meetings and workshops can be found in Appendix C.

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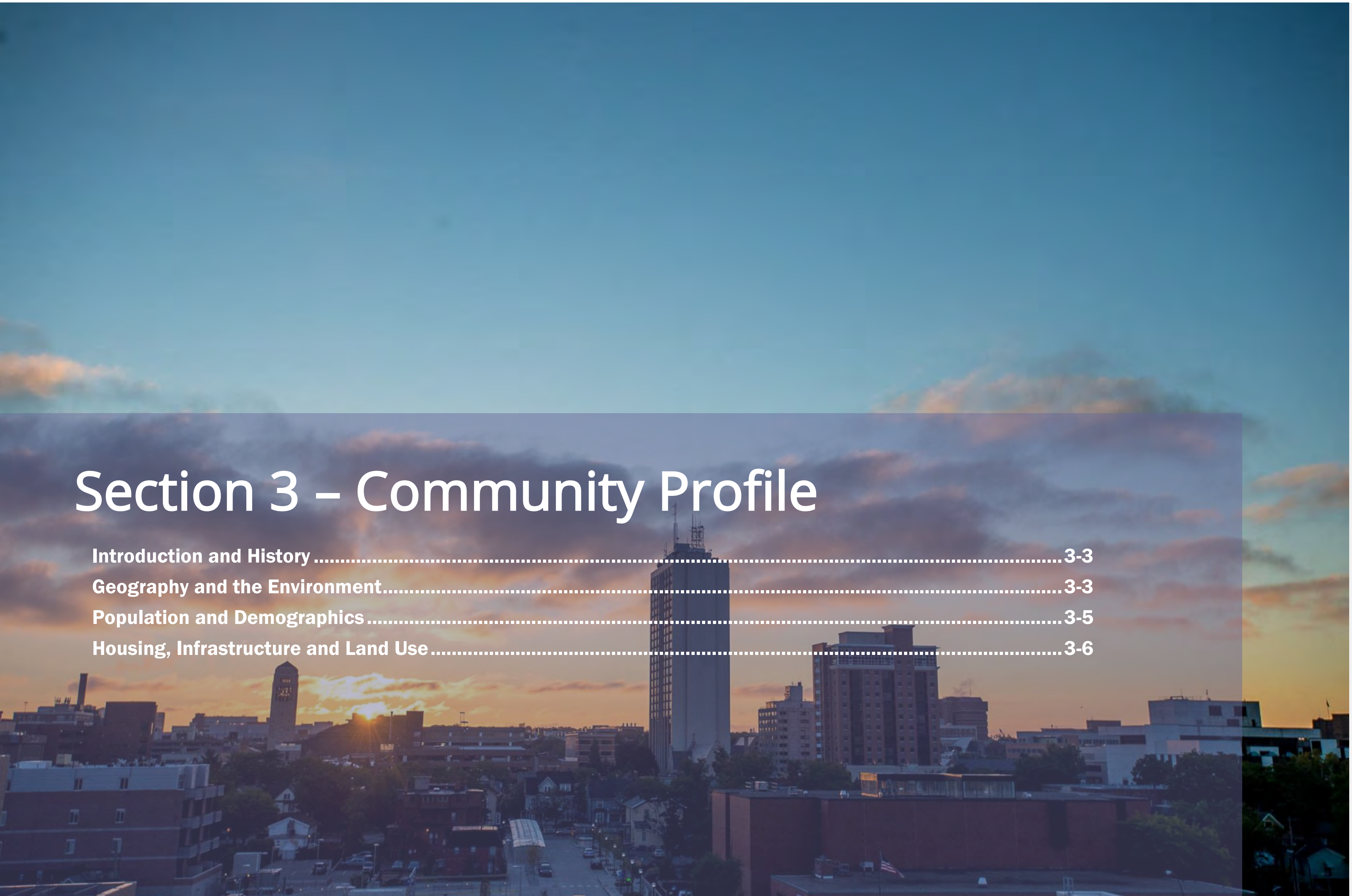

Section 3 – Community Profile

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Introduction and History

John Allen and Elisha Rumsey founded Ann Arbor in 1824 when they claimed 650 acres of land west of Detroit. Local lore is that the name Ann Arbor came from seeing their wives, Ann Allen and Mary Ann Rumsey, sitting under an arbor built by their husbands. In 1833 the first charter of Ann Arbor was created. The charter allowed for a Township President and Council, the first Township President being John Allen. The city was made the Washtenaw County seat in 1827. When Michigan became a state in 1937, the State Legislature agreed to move the University of Michigan to Ann Arbor from Detroit. Ann Arbor became a city in 1851.[i] One of the nation's first zoning ordinances was developed for the city by Frederick Law Olmstead in 1923 as a result of growth (proceeding the nation's first ordinance in New York City, 1916).[ii]

Geography and the Environment

The City of Ann Arbor is in the lower Great Lakes Region of southeastern portion of Michigan. It is located on the Huron River approximately 40 miles west of Detroit. The county seat of Washtenaw County, the city is home to the University of Michigan. An orientation map is provided as Figure 3-1~~Figure 3-1~~. The total land area of the city is approximately 28 square miles.[iii]

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The city's gentle rolling river valley topography ranges from approximately 750 feet above sea level downriver at Gallop Park to approximately 1,050 feet near Pauline Boulevard and Maple Road.

The city is a popular tourist destination well known for: its walkable downtown; many outdoor activities such as canoeing, tubing, biking, walking, and golfing; a variety of cultural opportunities at festivals, music venues, museums, and galleries; and dining and nightlife at a wide range of restaurants, brewpubs, and bars.

Ann Arbor enjoys a full four seasons climate with an average annual temperature of 50.1° Fahrenheit, average annual rainfall of 32.83 inches and average annual snowfall of 41.19 inches.[iv,v,vi] The city enjoys a climate that is characterized by moderate winters normal for the lower Great Lakes Region with few hot, humid summer days. Summer temperatures average in the 80s and only occasionally rise above 90°.

The city averages 178 sunny days with the clearest part of the year being June-October. Spring average temperatures range from 37° to 57°, summer temperatures 60° to 81°, fall temperatures 43° to 61°, winter temperatures 19° to 33°.[vii] The coldest recorded temperature was -23° (February 1885) while the warmest temperature was 105° (July 1934).[viii,ix]

Snowfall can occur October through April although greater snow averages occur in December, January, and February. Most snowfall events in Ann Arbor result in less than an inch of fresh snow. On average, less than 19 days a year result in new snow over an inch. Snowfall over 10 inches in one day are rare (and usually occur in January), while storms over 5 inches in a day occur a couple times a year. Given the cold temperature, fallen snow tends to linger. In fact, it is typical that over half of the winter days have at least one inch of snow on the ground.[x]

In recent decades, the climate has been gradually changing. Annual average temperatures in Ann Arbor warmed by 0.3°F-when comparing the 1951-1980 mean temperature to 1981-2010. When comparing precipitation from these same timeframes, total precipitation increased by 25 percent. Similarly, heavy precipitations days (in the top 1 percent of daily precipitation totals) increased by 42 percent from 1981-2010 when compared to 1951-1980.[xi]

Figure 3-1: City of Ann Arbor Base Map

Population and Demographics

The City of Ann Arbor is the largest jurisdiction in Washtenaw County and the fifth largest city by population in the State of Michigan. Between 2000 and 2010, the city experienced slight population decline; however, the population increased by almost 9 percent from 2010 to 2020. Population counts from the U.S. Census Bureau for 1990, 2000, 2010, and 2020 for the city are presented in Table 3-1~~Table 3-1~~. Population projections for 2030-2045 are presented in Table 3-2~~Table 3-2~~.

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Table 3-1: Population Counts

	1990 Census Population	2000 Census Population	2010 Census Population	2020 Census Population	% Change 1990-2020
City of Ann Arbor	109,592	114,024	113,934	123,851	13%

Source: U.S. Census Bureau

Table 3-2: Population Projections

	2030 Population Estimate	2035 Population Estimate	2040 Population Estimate	2045 Population Estimate	% Change 2030-2045
City of Ann Arbor	129,144	130,493	131,572	132,325	2.5%

Source: SEMCOG[xii]

Based on the 2020 American Community Survey, the median age of residents is 27.5 years. The racial characteristics of the city are presented in Table 3-3~~Table 3-3~~. Generally, whites make up the majority of the population, accounting for over 69 percent of the population. Asian Indian, Chinese, Filipino, Japanese, Vietnamese, and other Asian persons make up over 17 percent of the population.

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Table 3-3: Demographics

	White Persons, Percent (2020)	Asian Persons, Percent (2020)	Black Persons, Percent (2020)	Other Race, Percent (2020)	Multiracial, Percent (2020)	Persons of Hispanic Origin, Percent (2020)*
City of Ann Arbor	69.5%	17.4%	7.0%	0.4%	4.7%	4.6%

*Hispanics may be of any race, so also are included in applicable race categories.

Source: U.S. Census Bureau[xiii]

Housing, Infrastructure and Land Use

Housing

According to the 2020 U.S. Census, there were 53,213 housing units in the City of Ann Arbor, the majority of which are single family homes or townhomes. Housing information for the city is presented in Table 3-4~~Table 3-4~~ Owner-occupied housing is less than 50 percent. Median gross rent is $1,299, while the median value of owner-occupied housing units is $346,800 (2016-2020).

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Table 3-4: Housing Characteristics

	Housing Units (2000)	Housing Units (2010)	Housing Units (2020)	Owner-Occupied Units (2016-2020)	Median Home Value (2016-2020)
City of Ann Arbor	47,218	49,789	53,213	45.4%	$346,800

Source: U.S. Census Bureau

Infrastructure

Infrastructure is the fundamental facilities and systems serving the city. These include the transportation network, utilities, and community facilities that provide essential services to the city and residents.

Transportation

As illustrated in Figure 3-1~~Figure 3-1~~, there are several major highways that ring the City of Ann Arbor, two interstates and one U.S. highway. Interstate 94 (I-94) is part of the interstate highway system which runs primarily east-west from Montana to the eastern edge of Michigan leading to the international crossing at the Blue Water Bridge to Ontario, Canada. Locally, I-94 connects Ann Arbor to Jackson to the west and Ypsilanti to Detroit to the east. The highway passes along the southwestern extent of the city.

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M-14 splits northerly from I-94 on the western side of Ann Arbor and crosses the Huron River to join with US-23. US-23 runs north-south along the eastern edge of the city until it joins with M-14 in Ann Arbor Township. The joint stretch of M-14/US-23 runs east-west along the northern edge of the city. M-14 continues to the east to connect Ann Arbor to Detroit and the northern suburbs of Wayne and Oakland County.

These highways- I-94, M-14, and US-23 - are four-lane divided highways in the Ann Arbor area. There are also several surface state trunkline highways under the jurisdiction of the Michigan Department of Transportation (MDOT), these include Huron Street, Washtenaw Avenue, and Main Street north of Huron Street.[xiv] The city's Engineering Department is responsible for the network of city streets including public alleys, local, collector and arterial roads.

Three active rail lines run through Ann Arbor. Amtrak passenger service and Norfolk Southern freight traverse east-west on the Norfolk Southern rail lines. This rail line connects to Detroit to the east and Jackson, Battle Creek, Kalamazoo, and Chicago, Illinois to the west. The Great Lakes Central rail line runs north through Howell to Durand and continues to the northern portion of the lower peninsula. The Ann Arbor Railroad runs south to Toledo, Ohio. Both provide freight service.[xv]

The Detroit Metropolitan Airport is the largest airport serving southeastern Michigan including Ann Arbor. The airport currently offers non-stop commercial flights on twelve airlines to numerous destinations across the eastern U.S. and Midwest, most major U.S. cities, and to several international destinations.[xvi] This airport is approximately 25 miles from Ann Arbor. Other major nearby airports include the Bishop International Airport in Flint and the Oakland County International Airport in Pontiac. Willow Run Airport in Van Buren Charter Township provides freight, corporate, and general aviation, but no large airlines fly out of this airport. Ann Arbor Municipal Airport is located in Pittsfield Township just outside of the city. The airport is owned and operated by the City of Ann Arbor and maintains a 3,500-foot concrete runway and a 2,750-foot turf runway to serve public and business flights, medical flights, flight instruction and charter service.[xvii]

Utilities

Electrical power in the City of Ann Arbor is provided by one public utility, DTE Energy. DTE and Consumers Energy Company have a shared territory for natural gas, although Ann Arbor is predominately served by DTE Energy.[xviii]

Water and sewer service is provided by the City of Ann Arbor through the Utilities Department. Water is sourced from the Huron River north of the city and municipal wells south of Ann Arbor at the Ann Arbor Municipal Airport. Approximately 85 percent of the water comes from the river. The water is treated at the water treatment plant (WTP) and distributed throughout the City of Ann Arbor. The city supplies approximately 5 billion gallons of water a year. The city also supplies water to portions of Ann Arbor and Scio Townships.[xix] Wastewater (sewer) is collected and treated by the city at the wastewater treatment plant in Ann Arbor Township west of the city. The plant also provides services for portions of Ann Abor, Pittsfield, and Scio Townships.[xx]

Community Facilities

There are a number of public buildings and community facilities located throughout the City of Ann Arbor. According to the data collected for the vulnerability assessment (Section 4), there are five fire stations, one police station (the Justice Center), and 31 public schools (many of which also function as emergency shelters) located within the city limits. The community utilizes four community centers and five libraries as resilience hubs. The City of Ann Arbor Housing Commission, along with its partner Avalon Housing, provide affordable, long-term housing to low-income individuals and families in the community. Collectively, there are over 40 affordable housing properties, ranging from single family homes to entire apartment complexes. Additionally, the Shelter Association of Washtenaw County provides temporary shelter and services to out of the Delonis Center, and the Food Gatherers program serves as a food bank and food rescue program for Washtenaw County.

There are two major hospital complexes in the City of Ann Arbor. The University of Michigan Health System complex, U-M Medical Center – Ann Arbor (East Medical Center Drive), consists of multiple hospitals and centers including the University Hospital, University

Commented [ma1]: Should the 32 public schools be listed here as community facilities since they can be used as shelter locations and are used for community events?

Commented [CC2R1]: Yep! They are referenced in this paragraph

Hospital – South, A. Alfred Taubman Health Care Center, C.S. Mott Children's Hospital, Von Voigtlander Women's Hospital, Rogel Cancer Center, Frankel Cardiovascular Center, as well as several learning and research facilities. Across the Huron River on Wall Street, the University of Michigan Health System operates the Kellogg Eye Center.[xxi]

East of the Medical Center on Fuller Road is the LTC Charles S. Kettles VA Medical Center operated by the U.S. Department of Veterans Affairs. The VA Ann Arbor Healthcare System consists of the LTC Charles S. Kettles VA Medical Center, as well as six outpatient clinics throughout the region. Collectively, the VA Ann Arbor Healthcare System services nearly 70,000 Veterans from Michigan and northwestern Ohio.[xxii] Trinity Health operates a 537-bed hospital and medical complex, Trinity Health Ann Arbor Hospital, approximately 2 miles east of Ann Arbor in Superior Township.[xxiii] In addition to the hospitals, there are numerous health centers and clinics spread throughout the city and adjacent townships operated by the University of Michigan and Trinity Health.

There are numerous city and local parks in the Ann Arbor vicinity. Combined, these facilities offer recreational opportunities to area residents and millions of visitors each year. City of Ann Arbor Parks and Recreation operates over 160 parks and park facilities including the Ann Arbor Farmers Market, Ann Arbor Senior Center, two community centers, two canoe liveries, over 90 playgrounds, two golf courses, one indoor and one outdoor ice arenas, one indoor and three outdoor pools, Leslie Science and Nature Center, and Cobblestone Farm.[xxiv]

The Border to Border Trail (B2B) is an ongoing collaboration within Washtenaw County to construct a shared-use pathway linking Huron River Greenways. The City of Ann Arbor Parks and Recreation is an active part of this system having completed several legs within the city. The B2B Trail consists of 35 miles of ADA accessible, paved pathway. The B2B Trail is part of the State of Michigan's Iron Belle Trail - a network of over 2,000 miles of trails that connect Detroit to Ironwood in the western upper peninsula[xxv].

Washtenaw County Parks operates two parks within the city: County Farm Park and Swift Run Dog Park. There are also numerous County parks and preserves in the surrounding communities including Parker Mill Park, as well as Freeman, Goodrich, and Dominican Meadows Preserves. These are all just east of the city in Ann Arbor Township.[xxvi]

Huron-Clinton Metroparks, a regional park system operated by the Huron-Clinton Metropolitan Authority, consists of 13 parks along the Huron and Clinton Rivers in southeastern Michigan. The closest park is Delhi Metropark just northwest of the city along the Huron River.[xxvii] Nearby State of Michigan Parks and Wildlife Lands are Pinckney and Waterloo Recreation Areas and Chelsea State Game Area.

The University of Michigan also has numerous recreation and open space facilities within the city and surrounding areas. Some are open to the public, such as the Nichols Arboretum located along the Huron River on the eastern edge of the central campus.

Land Use

In general, the City of Ann Arbor is developed throughout the city limits and is where the bulk of the county's population is concentrated. Based on the city's land use data, by area, the largest land use in the city is residential. Approximately 35 percent of the land area is devoted to single family residential use, while approximately 13 percent is multiple family. Government and institutional uses account for approximately 15 percent; transportation, communication and utilities occupy approximately 3 percent; while open space including parks, recreation, natural and undeveloped area account for 18 percent.[xxviii] In the downtown area, many of the uses are mixed.

The State Street/South Main Street area south of downtown consists of a large share of city's commercial and office uses. Other commercial and office land uses are scattered throughout the city concentrated along major thoroughfares and freeway interchanges. The State Street/I-94 interchange area has a large concentration of commercial transportation including several hotels.

There is minimal heavy manufacturing in the city. Some light industry exists along North Main Street and the railroad tracks that run north to south through the city. Research uses are found in the State Street/I-94 area on the south side of town and the Plymouth Road area in the northeast side of town. A few small township islands exist within the city boundaries as shown in Figure 3-1~~Figure 3-1~~. Under a boundary agreement with the adjacent Townships (Ann Arbor, Scio, and Pittsfield Townships) eventually these islands will be annexed into the city.[xxix]

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The University of Michigan is a major landowner within the city, and includes 19 schools and colleges, many of which rank among the top programs in the nation. Student enrollment for fall 2020 of undergraduate, graduate, and professional students was 47,907.[xxx] The university provides housing to 11,000 students in 18 residence halls and 1,480 campus apartment buildings.[xxxi] Other higher education facilities in Ann Arbor include Concordia University and Cleary College (satellite campus).

Development trends are also a notable topic when considering future hazard risk. Ann Arbor was built out in the 1970s, before floodplain and drainage regulations; most of the current development in the city is infill and redevelopment rather than new or greenfield development. Green space within Ann Arbor typically consists of parks, school grounds, and detention basins. City officials noted several locations within the city where new development is occurring:

- State Street / Eisenhower Corridor (bounded by the railroad to east, I-94 to the south, Briarwood/Main Street to the west, and Oakbrook to the north);
- North Maple/West Stadium Corridors (roughly Pauline to Miller);
- Downtown district and areas near downtown; and,
- Pontiac Trail/Dhu Varren/Leslie Park area.

A future land use map can be found in *Section 4: Risk Assessment*.

Employment and Industry

Ann Arbor's economy developed around the Huron River and its tributaries. Co-settler, John Allen, located a gristmill along Allen's Creek and soon after following settlers developed other mills, a tannery and general store. In 1827 the city became the county seat and the University of Michigan relocated here from Detroit in 1837.[xxxii] The completion of the Michigan Central Railroad's Detroit-Ann Arbor connection in 1839 symbolized the beginning of a new era of immigration, economic accessibility and growth for Ann Arbor and Washtenaw County.[xxxiii]

In general, the City of Ann Arbor has a diverse technology industry, although somewhat more heavily reliant on the University of Michigan than the automotive industry in the surrounding region. The western extent of a high-technology corridor extending from Detroit along I-94 and M-14, the regions key industries include life sciences and health care, technology, data and information, and automotive and mobility. An increase in research, development, or testing firms is also likely due to the proximity of the University of Michigan, which provides technical resources and an educated workforce.[xxxiv] According to SPARK Ann Arbor, the top regional employers are the University of Michigan, Trinity Health, General Motors Proving Grounds, VA Ann Arbor Healthcare System, and the Ann Arbor Public Schools.[xxxv]

According to the U.S. Bureau of Labor Statistics, the Ann Arbor metropolitan region had a nonfarm employment of 227,200 persons and a total labor force of 198,800 persons (as of March 2022).[xxxvi] Government employed 87,200 persons (44%), professional and business services 31,400 (16%), education and health services 29,400 (15%), trade, transportation, and utilities 27,100 (14%), leisure and hospitality 14,600 (8.5%), and manufacturing 13,500 (7%). In 2021, the annual mean wages in the Ann Arbor metropolitan region for all occupations was $61,010, compared to $55,160 for the State of Michigan.[xxxvii,xxxviii]

Notes

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xiv MDOT Roads and Travel. (2017). Michigan Department of Transportation. Retrieved June 2, 2022 from http://www.michigan.gov/mdot.
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Section 4 – Risk Assessment

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Introduction

This chapter provides a risk assessment of natural, technological, and human-related hazards that could impact the City of Ann Arbor. All hazards include a profile and a vulnerability assessment. All hazards include a qualitative analysis of the city's vulnerability and, when data permitted, a quantitative analysis was performed (including potential dollar losses).

The hazard profile includes a description of the nature of the hazard, past occurrences and damages, extent (or magnitude) of the hazard, and likelihood or probability of the hazard occurring in the future. Ann Arbor's assets have been examined to estimate the potential health, safety, and property damages attributable to hazards in the vulnerability assessment. In addition, beginning with the 2017 update of the plan, each hazard includes climate change considerations.

Following the hazard profiles, a summary of Ann Arbor's overall vulnerability is provided. This includes hazard ranking based on the Priority Risk Index (PRI), and a summary of key points on risk. The PRI is a tool used to measure the degree of risk for identified hazards in a planning area with consideration to probability, impact, spatial extent, warning time, and duration.

Hazard Identification

Hazards were identified by reviewing the 2017 Ann Arbor Hazard Mitigation Plan, the latest Michigan State Hazard Mitigation Plan, and previous disaster declarations. Input from the Technical Advisory Committee (TAC) was also solicited and used to identify hazards.

Disaster Declarations

Since 1965, five hazard events have resulted in damage severe enough to warrant a federal Presidential Disaster Declaration in the planning area. Presidential Disaster Declarations are declared at the county-level; therefore, declarations made for Washtenaw County were considered as relevant to Ann Arbor. Details for these declarations are presented in Table 4-1.

DRAFT

Table 4-1: Historic Presidential Disaster Declarations for Washtenaw County

Date	Disaster Number	Description
04/14/1965	190	Tornadoes and Severe Thunderstorms
09/08/1980	631	Severe Storms and Flooding
06/30/2004	1527	Severe Storms, Tornadoes, and Flooding
03/27/2020	4494	COVID-19 Pandemic
07/15/2021	4607	Severe Storms, Flooding, and Tornadoes

Hazard List

Hazard identification is the process of identifying the types of hazards that can affect the mitigation plan study area – The City of Ann Arbor. As this is a plan update to the city-wide plan that was adopted in 2017, hazards from that plan were reviewed along with hazards listed in the state plan. Input was gathered from the Technical Advisory Committee (TAC) to discern hazards that should remain, be added, or be removed from those included in the last plan iteration and the State of Michigan Hazard Mitigation Plan. Hazards were reviewed at the TAC Kickoff Meeting and finalized on a subsequent call. Table 4-2 presents the final hazards list for this plan update and whether each hazard was recognized in the State of Michigan Hazard Mitigation Plan and the 2017 Ann Arbor Hazard Mitigation Plan. Table 4-3 indicates the hazards from the State of Michigan Hazard Mitigation Plan that were excluded from this plan update and provides a justification for exclusion. New hazards for the 2022 plan update include power outages, water contamination, cyber-attacks, public health emergencies, and the addition of extreme precipitation to the flood hazard.

DRAFT

Table 4-2: Hazards Identified for the 2022 Ann Arbor Plan Update

2022 Ann Arbor Plan Update Identified Hazards	Michigan SHMP Identified Hazard (YES/NO)	Included in 2017 Ann Arbor Plan (YES/NO)
NATURAL HAZARDS – WEATHER HAZARDS		
Extreme Cold/Wind Chill	YES (as Extreme Cold)	YES
Extreme Heat	YES	YES
Fog	YES	YES
Hail	YES	YES
Lightning	YES	YES
Severe Winter Weather	YES	YES
Severe Winds	YES	YES
Tornadoes	YES	YES
NATURAL HAZARDS – HYDROLOGICAL HAZARDS		
Dam Failure	YES	YES
Drought	YES	YES
Flood and Extreme Precipitation	YES	YES (Extreme Precipitation new to 2022 plan)
NATURAL HAZARDS – ECOLOGICAL HAZARDS		
Invasive Species	YES	YES
NATURAL HAZARDS – GEOLOGICAL HAZARDS		
Earthquakes	YES	YES
TECHNOLOGICAL HAZARDS – INDUSTRIAL HAZARDS		
HAZMAT – fixed and transportation	YES	YES
Nuclear Power Plant Incidents	YES	YES
Petroleum and Natural Gas Pipeline Accidents	YES	YES
Power Outages	YES (as Energy Emergencies and Infrastructure Failure)	NO
Structural and Industrial Fires	YES	YES
Water Contamination	YES (under Infrastructure Failure)	NO
HUMAN-CAUSED HAZARDS		
Civil Disturbances	YES	YES
Cyber-Attacks	YES	NO (previously addressed under Terrorism and Similar Criminal Activities)
Public Health Emergencies	YES	NO

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2022 Ann Arbor Plan Update Identified Hazards	Michigan SHMP Identified Hazard (YES/NO)	Included in 2017 Ann Arbor Plan (YES/NO)
Terrorism and Similar Criminal Activities	YES	YES

Table 4-3: Justification for Excluded Hazards

Michigan SHMP Identified Hazards (Excluded from 2022 Ann Arbor Plan Update)	Justification
NATURAL HAZARDS – WEATHER HAZARDS	
Ice and Sleet Storms	Covered under the Severe Winter Weather hazard profile.
Snowstorms	Covered under the Severe Winter Weather hazard profile.
NATURAL HAZARDS – HYDROLOGICAL HAZARDS	
Great Lakes Shoreline Hazards	Ann Arbor does not have shoreline on the Great Lakes; hazard was not included in 2017 plan.
NATURAL HAZARDS – ECOLOGICAL HAZARDS	
Wildfire	According to the USDA Wildfire Risk to Communities Project, which integrates Wildfire Hazard Potential data, populated areas of Ann Arbor are not likely to be impacted directly or indirectly by wildfires.[i] No census blocks within the city are designated as wildland-urban-interface areas, and only three census blocks are indicated as medium density wildland-urban-intermix areas (with no high or low density intermix areas). In addition, the Technical Advisory Committee indicated that wildfires are not a hazard of concern. The 2017 Ann Arbor hazard mitigation plan indicated that wildfires do not have a great history of substantial local impacts, despite occurring in Washtenaw County.
NATURAL HAZARDS – GEOLOGICAL HAZARDS	
Subsidence	TAC members agreed that subsidence is not an issue faced by the community and noted that future subsidence is not anticipated. In the State of Michigan hazard mitigation plan, Washtenaw County was not identified for potential subsidence hazards related to mining. In addition, the state plan designated Ann Arbor as being in an area where sinkholes are "absent or likely absent."
Space Weather / Meteorites	The TAC agreed that celestial impacts are not of great concern to the community during the 2017 plan update and noted a lack of historical impacts. The Emergency Manager described one historic occurrence of solar weather interfering with communications equipment but noted that impacts were not substantial or widespread. When revisited, it was decided to continue to exclude this hazard in the 2022 plan update.
TECHNOLOGICAL HAZARDS – INFRASTRUCTURE PROBLEMS	

Michigan SHMP Identified Hazards (Excluded from 2022 Ann Arbor Plan Update)	Justification
Infrastructure Failures	This hazard will be considered for all applicable hazards as a potential vulnerability. Water main breaks are addressed under the Water Contamination hazard profile.
Energy Emergencies	This hazard will be considered for all applicable hazards as a potential vulnerability and predominantly addressed under the Power Outage hazard profile.
Major Transportation Accidents	This hazard will be considered for all applicable hazards as a potential vulnerability.
HUMAN RELATED HAZARDS	
Catastrophic Incidents (National Emergencies)	National emergencies are not within the scope of this plan.
Nuclear Attack	This hazard is addressed under terrorism. In addition, mitigation of a nuclear attack would likely occur at the national level. Nuclear Power Plant Incidents are addressed under the Nuclear Power Plant Incidents hazard profile.

Sources of Information

Hazard information and data was collected for all hazards using hazard studies, geospatial data, and descriptions of previous events. This information is cited throughout the plan. In addition to the local, state, and Federal data sources described below, a climate analysis was performed for this plan using ERA5 reanalysis and CORDEX data.

Local Sources

Local sources used in the risk and vulnerability assessment include:

- City reports and studies
- City geospatial data
- Washtenaw County studies and reports applicable to the planning area
- Washtenaw County geospatial data
- Washtenaw County Opportunity Index
- Information gathered from Technical Advisory Committee (TAC) meetings and calls
- Information gathered from interviews with local officials
- Information, data, and reports from the Huron River Watershed Council

DRAFT

- Reports, studies and memos from the University of Michigan and Michigan State University (Great Lakes Integrated Sciences and Assessments (GLISA) program)
- Ann Arbor 2017 Hazard Mitigation Plan
- Local news sources (e.g., M Live, Ann Arbor News)

State Sources

State sources used in the risk and vulnerability assessment include:

- The State of Michigan hazard mitigation plan
- Michigan state agency maps, data, reports, and webpages applicable to the planning area, including but not limited to those from the Michigan Department of Natural Resources, Michigan Department of Environmental Quality, and Michigan Emergency Management & Homeland Security

Federal Sources

Federal sources used in the risk and vulnerability assessment include agency studies, maps, geospatial data, and reports applicable to the planning area, including but not limited to the following:

- Federal Emergency Management Agency (FEMA) mapped flood hazards areas and NFIP statistics
- U.S. Department of Agriculture (USDA) Forest Service wildfire hazard potential and wildland-urban interface data
- National Oceanic and Atmospheric Association (NOAA) National Centers for Environmental Information (NCEI) Storm Events Database
- National Risk Index
- U.S. Climate Resilience Toolkit
- U.S. Drought Monitor data
- Environmental Protection Agency (EPA) information
- U.S. Geological Survey (USGS) data and information
- U.S. DOT Pipeline Hazard Safety Administration data
- U.S. Transportation Safety Administration information
- U.S. Centers for Disease Control information
- U.S. Global Change Research Program information and data

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Data Limitations

Although Ann Arbor has a wealth of available data, data limitations do constrict the risk analysis at certain points. Data limitations include:

- Previous occurrences for many hazards were gathered from the NOAA National Centers for Environmental Information (NCEI) Storm Events Database, which is not all-inclusive. Therefore, the occurrence of certain hazards is likely under-reported. In addition, data for certain hazards was only available at the county-level, and events specific to Ann Arbor could not be identified (noted in the hazard's profile). Additional sources for previous occurrences were considered when available.
- Building footprints obtained from the city are not linked to parcel data; therefore, building value exposure could only be analyzed in terms of the parcel. This reduces accuracy of the analysis as the entire parcel is considered rather than the more precise location of a building footprint.
- Not all hazards have identified geographic boundaries therefore, a GIS Intersection analysis could not be performed to identify vulnerable parcels, buildings, infrastructure, and populations. In this case, it was assumed that all current and future buildings and populations are at risk.
- Several different sources of climate change data were used to analyze future risk. Different sources use different scenarios, geographic regions, and timelines therefore, projections are not always consistent. In addition, future conditions (e.g., emissions, radiative forcing, effects) are difficult to predict, and there is a known uncertainty associated with climate projections and models. Uncertainty differs for hazards; for instance, temperature models are considered more certain than precipitation models. For certain hazards, climate impacts were not available or were inconclusive.

Risk Assessment Tools

Hazard information was collected for all hazards under consideration using hazard studies, geographic information system (GIS) data, and descriptions of previous events. This information is cited throughout the plan.

GIS

GIS tools provide a mechanism to perform quantitative analysis. Hazards that have specified geographic boundaries permit analysis using GIS. These hazards include:

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- Dam Failure
- Flood
- Hazardous Materials Incidents

The objective of the GIS-based analysis was to determine the estimated vulnerability of structures for the identified hazards in Ann Arbor using best available geospatial data. ESRI® ArcGIS™ 10.5 was used to assess hazard vulnerability utilizing digital hazard data, such as FEMA FIRMs, building footprints, and tax assessor data. Using these data layers, hazard vulnerability can be assessed by estimating the number and of type of structures determined to be in identified geographic hazard area boundaries.

Social Vulnerability

For this plan, social vulnerability is considered to be the susceptibility of certain social groups to adverse impacts from hazards, including disproportionate death, injury, loss, or disruption of livelihood relative to the general population. Two sources of data were used to assess areas of social vulnerability within Ann Arbor: the FEMA National Risk Index and the Washtenaw County Opportunity Index.

The National Risk Index (NRI) is an online mapping tool that aids communities in visualizing risk to natural hazards. The NRI includes social vulnerability scores by census tract using the University of South Carolina's social vulnerability index (SoVI). The SoVI uses 29 socioeconomic variables to assign a social vulnerability score to each census tract. Variables include those that are indicators that consider wealth, race, Hispanic ethnicity, age, job sector, special needs individuals, and residents without health insurance.[ii] The NRI further categorizes SoVI scores into five categories from "very low" to "very high" social vulnerability.

The Washtenaw County Opportunity Index was developed by the county in 2020 to benchmark opportunity within the community. The purpose of the index is to:

- Illustrate where there is and is not access to opportunity across Washtenaw County;
- Inform policymakers, community partners, businesses, and the general public;
- Collect and communicate data through an "opportunity lens" – and complement that lens with strategies and tactics that foster human potential; and

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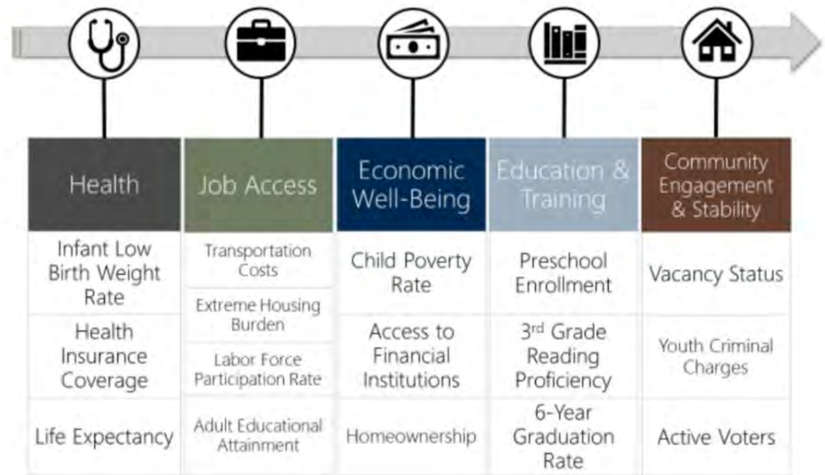
- Provide the community with a common, understandable framework by which to make policy and resources allocation decisions that can create more equitable opportunity across the county.[iii]

The Opportunity Index scores opportunity by census tract within the county and classifies tracts ranging from "very low access to opportunity" to "very high access to opportunity." Scores are based on 16 factors that fall under broad categories such as health, job access, economic well-being, education, and community engagement.

Headwaters Economics' Neighborhoods at Risk tool was also explored for climate projections and social vulnerability.[iv]



Annualized Loss Estimation

Many of the hazards listed above have the potential to affect all current and future buildings and all populations. For many of the hazards listed above, no additional analysis was performed. When possible, annualized loss estimates were determined using the best available data on historical losses. Annualized loss is the estimated long-term weighted average value of losses to property in any single year in a specified geographic area. Annualized loss estimates were generated by totaling the amount of property damage over the period for which records were available and calculating the average annual loss. Given the standard weighting analysis, losses can be readily compared across hazards providing an objective approach for evaluating mitigation alternatives.

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Priority Risk Index

The prioritization and categorization of identified hazards for Ann Arbor is based principally on the Priority Risk Index (PRI), a tool used to measure the degree of risk for identified hazards in a particular planning area. The PRI was used to assist the Ann Arbor Technical Advisory Committee in identifying hazards that pose the most significant threat to the city.

The PRI results provide a numerical value for each hazard, allowing hazards to be ranked against one another (i.e., the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard: probability, impact, spatial extent, warning time and duration. Each degree of risk has been assigned a value (1 to 4) and a weighting factor.

To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

PRI VALUE = [(PROBABILITY x .30) + (IMPACT x .30) + (SPATIAL EXTENT x .20) + (WARNING TIME x .10) + (DURATION x .10)]

According to the weighting scheme applied, the highest possible PRI value is 4.0. Table 4-4 shows the weighting schemes for each category. By determining a value for each hazard that can be compared to other hazards threatening the planning area, hazards can be ranked with greater ease.

Many of the PRI categories are described within the hazard profiles. The final PRI results, including the calculated values for each hazard in Ann Arbor, are found at the end of this section in the "Summary of Overall Vulnerability," beginning on page 4-228.

Table 4-4: Priority Risk Index Scoring Criteria

PRI Category	DEGREE OF RISK Level	Criteria	Index Value	Assigned Weighing Factor
Probability	Unlikely	Less than 1percent annual probability	1	30 percent
	Possible	Between 1 and 10 percent annual probability	2	
	Likely	Between 10 and 90 percent annual probability	3	
	Highly likely	90 percent+ annual probability	4	
Impact	Minor	Only minor property damage and minimal disruption to government functions and services.	1	30 percent
	Limited	Minor injuries are possible. More than 10 percent of buildings damaged or destroyed.	2	
	Critical	Multiple deaths/injuries possible. More than 25 percent of buildings damaged or destroyed.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50 percent of buildings damaged or destroyed.	4	
Spatial Extent	Negligible	Limited to one specific area.	1	20 percent
	Small	Small areas affected.	2	
	Moderate	Large areas affected.	3	
	Large	All areas affected.	4	
	More than 24	self-explanatory	1	10

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PRI Category	DEGREE OF RISK Level	Criteria	Index	Assigned Weighing Factor
Warning Time	hours			percent
	12 to 24 hours	self-explanatory	2	
	6 to 12 hours	self-explanatory	3	
	less than 6 hours	self-explanatory	4	
Duration	less than 6 hours	self-explanatory	1	10 percent
	6 to 12 hours	self-explanatory	2	
	12 to 24 hours	self-explanatory	3	
	More than 24 hours	self-explanatory	4	

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Summary of Data Analyzed

The risk assessment relies on a range of data sources to provide accurate hazard impact data for the city. Data was collected from city, county, regional, state, and federal agencies and organizations. Parcel data, including improvement value, as well as building footprints were obtained from the city. Infrastructure data was also obtained from the city.

Descriptions of the data used in the vulnerability assessment is described below. Social vulnerability data was obtained from the NRI and Washtenaw County.

Parcel and Building Data

Table 4-5 shows the City of Ann Arbor provided GIS-based tax assessor parcel data, which contains building improvement values. The improved value is the assessed value of the structure and does not include land values. This data may not include improvement values for tax-exempt properties. GIS-based building footprints, including building use, were also obtained from the city, as summarized in Table 4-6. Where possible, a GIS intersection analysis will be performed using parcel data and hazard data to determine the number and value of properties at risk and to estimate losses. However, data limitations hinder the ability to conduct this analysis on all hazards (and many hazards impact the entire planning area). The following table indicates the number and value of total parcels in the planning area.

Table 4-5: Ann Arbor Parcel and Building Data

Number of Parcels	Number of Improvements	Total Value of Improvements (2022 dollars)	Number of Building Footprints
31,781	30,441	$6,741,252,592	34,741

Table 4-6: Building Data by Use

Building Use	Number of Building Footprints
Commercial	978
Office	415
Public	948
Residential	32,400
Total	34,741

Areas of New Development

Ann Arbor city officials and members of the TAC provided areas in the city where development and redevelopment has been concentrated in recent years. It should be noted that most of the city is built-out, and most development in redevelopment or infill development rather than greenfield development. Identified areas of new development include:

- The State Street/Eisenhower Corridor (bounded by the railroad to the east, I-94 to the south, Briarwood/Main Street to the west, and Oakbrook to the north);
- The North Maple Road and West Stadium Boulevard corridors (roughly Pauline Boulevard to Miller Avenue);
- Downtown and surrounding areas (Districts 1 and 2); and,
- The Pontiac Trail/Dhu Varren Court/Leslie Park area

These areas are shown in Figure 4-1 below.

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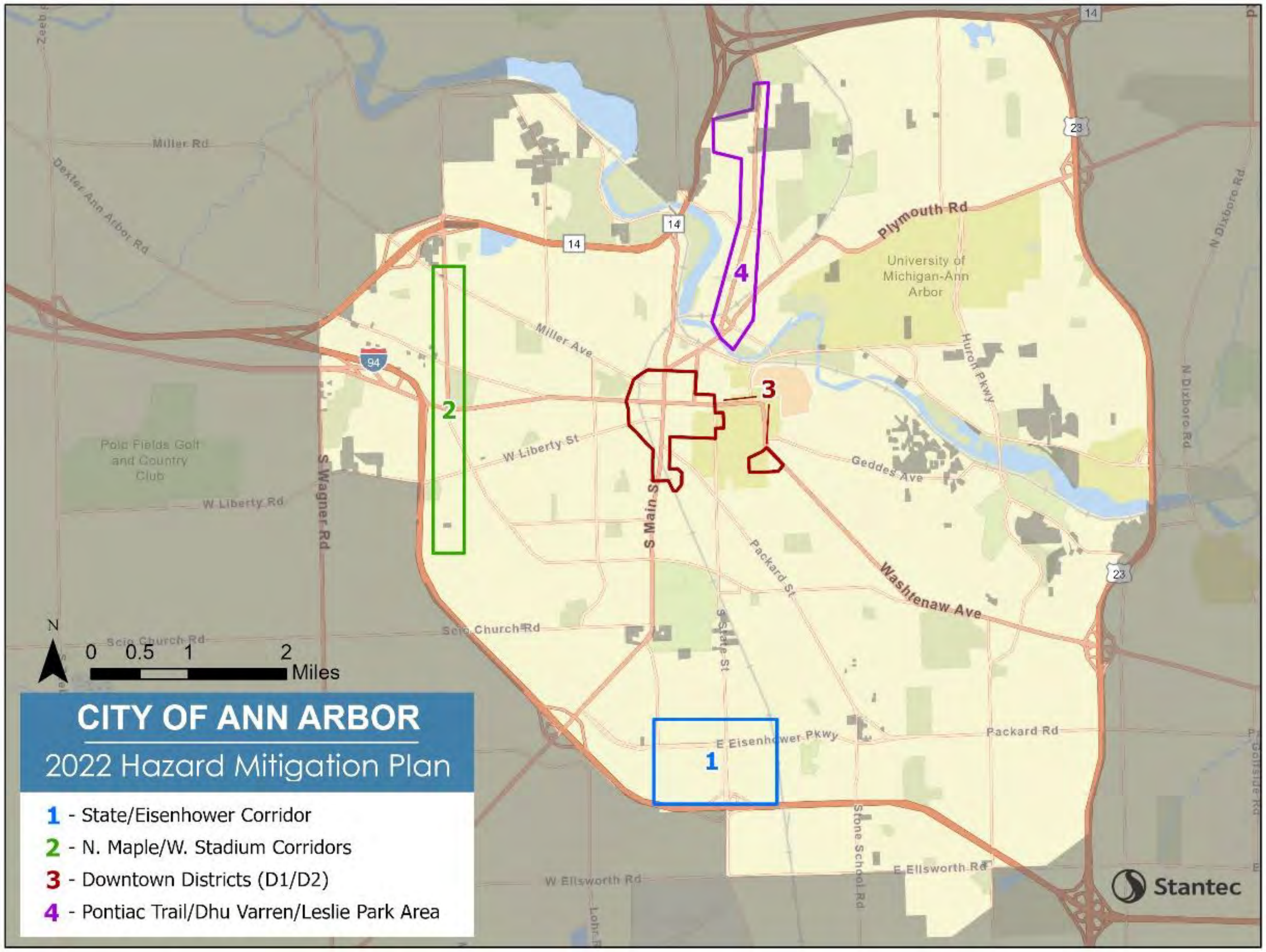

Figure 4-1: Areas of New Development

Infrastructure Data

The city provided GIS data for roads, bridges, and railroads. Value data was not provided for infrastructure. When possible, the location of critical infrastructure was mapped in relation to hazard boundaries.

Social Vulnerability Data

The NRI's social vulnerability rankings and the Washtenaw County Opportunity Index were used to assess at-risk areas where socially vulnerable populations may reside. Both of these sources report at the census tract level. Using NRI social vulnerability rankings, Ann Arbor has one census tract categorized within the highest ranked area for social vulnerability ("relatively high"), and six census tracts categorized under the next highest rank ("relatively moderate"). When considering the Washtenaw County Opportunity Index, Ann Arbor does not have any tracts within the lowest access category ("very low access to opportunity") but does have six tracts within the second lowest category ("low access to opportunity"). These tracts are shown in Figure 4-2Figure 4-2 and Figure 4-3 Figure 4-3below. The Headwaters Economics Neighborhoods at Risk tool was utilized to explore census tracts that exceed thresholds for certain indicators of social vulnerability. Ann Arbor does not have a city-specific social vulnerability index, thus regional and national sources were relied upon.

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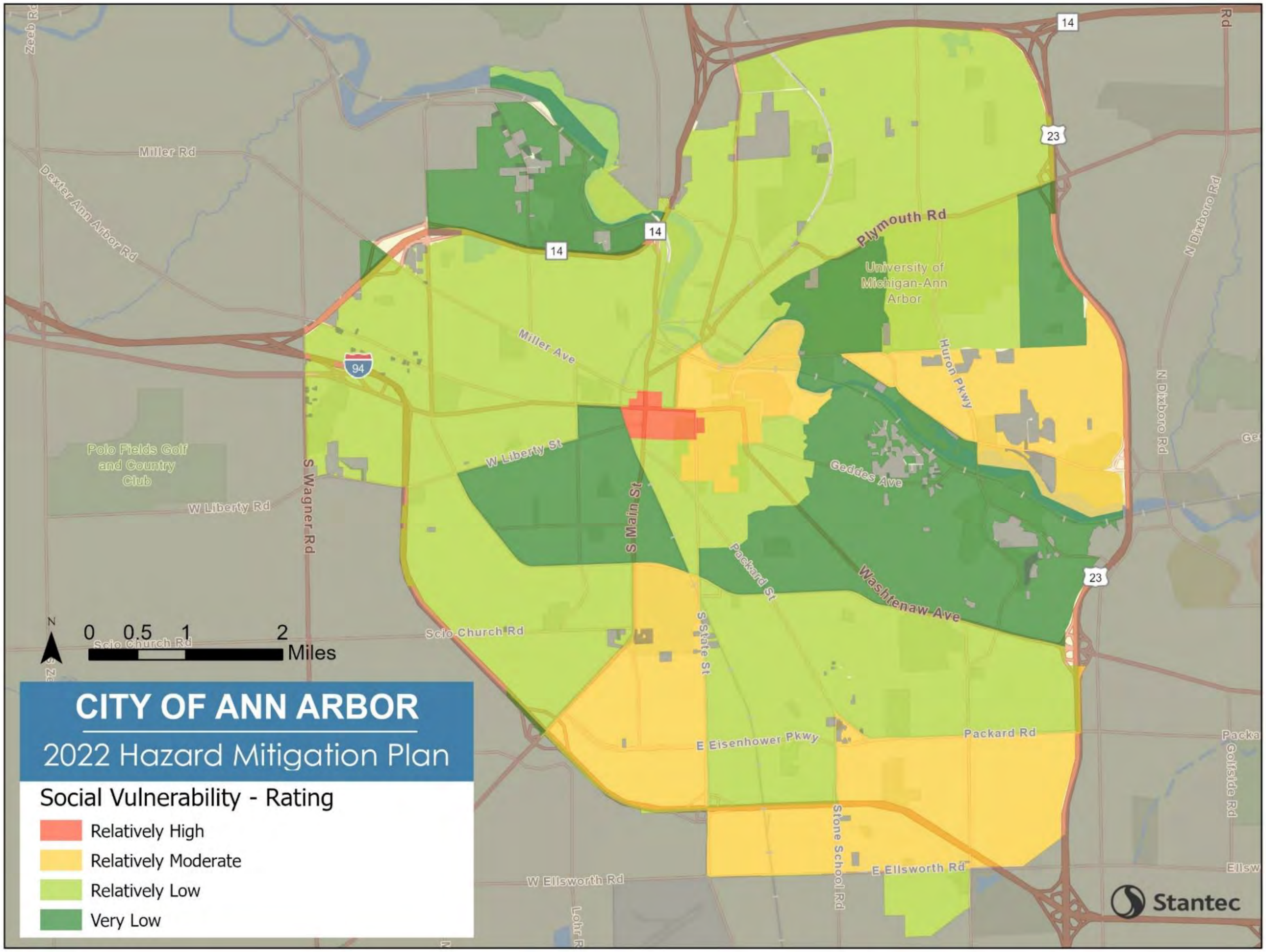

Figure 4-2: NRI Social Vulnerability by Census Tract in Ann Arbor

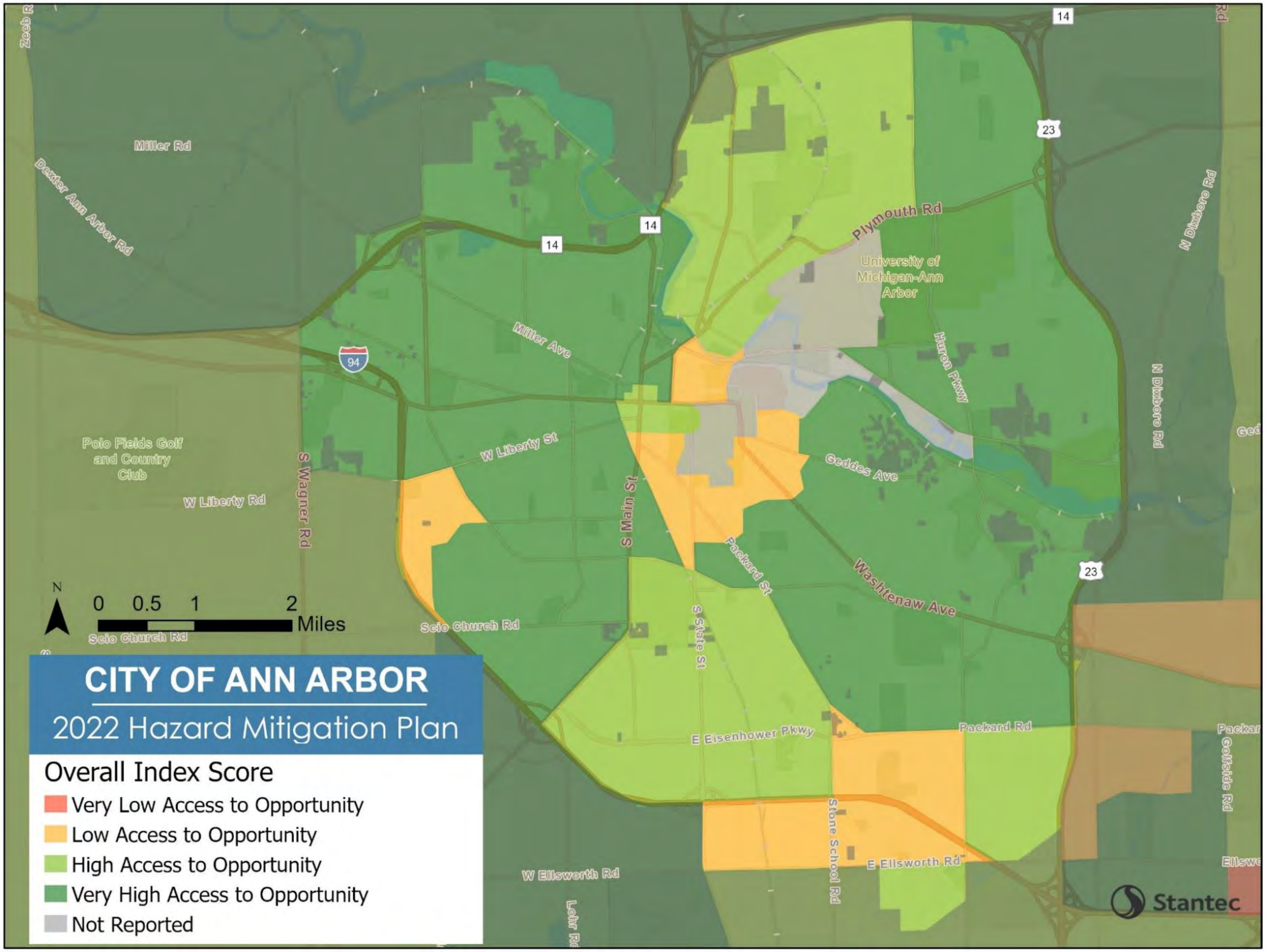

Figure 4-3: Washtenaw County Opportunity Index Values by Census Tract in Ann Arbor

Hazard Profiles

The hazards profiles are presented in alphabetical order by category: Natural (weather, hydrological, ecological, geological); Technological; and Human-Caused Hazards.

Natural Hazards – Weather Hazards
- Extreme Cold/Wind Chill
- Extreme Heat
- Fog
- Hail
- Lightning
- Severe Winter Weather

Natural Hazards – Weather Hazards
- Severe Winds
- Tornadoes

Natural Hazards – Hydrological Hazards
- Dam Failures
- Drought
- Flood and Extreme Precipitation

Natural Hazards – Ecological Hazards
- Invasive Species

Natural Hazards – Geological Hazards
- Earthquakes

Technological Hazards – Industrial Hazards
- HAZMAT – fixed and transportation
- Nuclear Power Plants
- Petroleum and Natural Gas Accidents
- Power Outages
- Structural and Industrial Fires
- Water Contamination

Human-Caused Hazards
- Civil Disturbances
- Cyber-attacks
- Public Health Emergencies
- Terrorism and Similar Criminal Activities

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44 CFR Requirement
44 CFR 201.6(c)(2)(i) and 44 CFR 201.6(c)(2)(iii): Does the Plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction? *44 CFR 201.6(c)(2)(i): Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction?* *44 CFR 201.6(c)(2)(ii): Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction?*

As noted above, each hazard is profiled separately to describe the hazard and potential impacts to the city. Where data exists, specific information on location will also be included. When applicable, impacts from climate change are integrated throughout each hazard profile, including observed climate trends, projected impacts on hazard extent and future probability, and expected impacts on vulnerability. The profile for each hazard includes:

- Description: A scientific explanation of the hazard including potential magnitude (or severity) and impacts (including climate change considerations);
- Location: Geographical extent of the hazard;
- Previous occurrences: The number of previous impacts from the hazard in Ann Arbor in the past;
- Extent (or magnitude): The severity of the hazard in the past and potential severity in the future (including climate change considerations). Measures may include wind speed, wave height, or property damage, for example;
- Probability of future events: The likelihood of future events impacting the city (including climate change considerations). Given that an exact probability is often difficult to quantify, this characteristic is categorized into ranges to be used in hazard profiles (per the PRI criteria):
    - Unlikely: Less than 1 percent annual probability
    - Possible: Between 1 percent and 10 percent annual probability
    - Likely: Greater than 10 percent and less than 90 percent annual probability
    - Highly Likely: Greater than 90 percent annual probability
- Vulnerability assessment: The vulnerability assessment investigates the potential number of and type of structures at risk, potential dollar loss, and potential impacts resulting from each hazard based on available data and information.
    - Impact on Buildings: The vulnerability of structural damage to buildings or other property damage.
    - Impact of Infrastructure: The vulnerability of damage to infrastructure is described.
    - Impact on Life Safety, Health, Evacuation and Warning Procedures: This category relates to health and life safety hazards. Waring systems and evacuations prompted by hazards are described.
    - Impact of Public Health: Impacts to public health caused by hazards is described here.
    - Economic Impact: Typical impacts on businesses, utilities, and the city's tax base are described here.
    - Climate Change Considerations: A description of potential future conditions and how they may affect the hazard impacts.

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Extreme Cold/Wind Chill

Description

The term "extreme cold" can have varying definitions. It may or may not be associated with a winter storm. Generally, extreme cold events refer to a prolonged period of time (days) with extremely cold temperatures. An extreme cold event to the National Weather Service refers to a single day of extreme or record-breaking day of sub-zero temperatures. Extended or single day extreme cold events can be hazardous to people and animals, and cause problems with buildings and transportation.

The Wind Chill Index (Figure 4-4)[v] is a measure of the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As the wind increases, heat is carried away from the body at a faster rate, driving down both the skin temperature and eventually the internal body temperature. Exposure to extreme wind chills can be life threatening. The NOAA chart shows the Wind Chill Index as it corresponds to various temperatures and wind speeds. As an example, if the air temperature is 5°F and the wind speed is 10 miles per hour, then the wind chill would be -10°F. As wind chills decline towards -19°F and below, there is an increased likelihood that continued exposure will lead to individuals developing cold-related health impacts.

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WIND SPEED (mph)	AIR TEMPERATURE (F)																		
	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40
5	48	42	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57
10	46	40	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66
15	45	38	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71
20	44	37	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74
25	43	36	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78
30	42	35	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80
35	41	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82
40	41	34	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84
45	40	33	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86
50	40	33	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88
55	40	32	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89
60	39	32	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91
65	39	32	24	17	10	2	-5	-12	-19	-27	-34	-41	-49	-56	-63	-70	-78	-85	-92
70	38	31	24	16	9	2	-6	-13	-20	-27	-35	-42	-49	-57	-64	-71	-79	-86	-93
75	38	31	23	16	9	1	-6	-13	-21	-28	-36	-43	-50	-58	-65	-72	-80	-87	-95
80	38	30	23	16	8	1	-7	-14	-21	-29	-36	-44	-51	-59	-66	-73	-81	-88	-96
85	38	30	23	15	8	0	-7	-15	-22	-30	-37	-44	-52	-59	-67	-74	-82	-89	-97
90	37	30	22	15	7	0	-8	-15	-23	-30	-38	-45	-53	-60	-68	-75	-83	-90	-98
95	37	29	22	14	7	-1	-8	-16	-23	-31	-38	-46	-53	-61	-68	-76	-84	-91	-99
100	37	29	22	14	6	-1	-9	-16	-24	-31	-39	-47	-54	-62	-69	-77	-84	-92	-100

Approx frostbite times: 30 min | 10 min | 5 min

Figure 4-4: National Weather Service Wind Chill Index Chart

NOAA's Warnings and Advisories for Extreme Cold/Wind Chill

The Detroit/Pontiac NWS Weather Forecast Station has the following thresholds for wind chill:
A Wind Chill Advisory is issued if wind chill values drop between -15 and -24°F. A Wind Chill Warning is issued if wind chill values fall to -25°F or below.

Frostbite and hypothermia are both extreme cold-related impacts that result when individuals are exposed to extreme temperatures and wind chills. The following text describes the symptoms associated with each.

During exposure to extremely cold weather, the body reduces circulation to the extremities (e.g., feet, hands, nose, cheeks, ears, etc.) in order to maintain its core temperature. If the extremities are exposed, then this reduction in circulation coupled with the cold temperatures can cause the skin tissue to freeze resulting in frostbite. Frostbite is characterized by a loss of feeling and a white or pale appearance. At a wind chill of -19°F, exposed skin can freeze in as little as 30 minutes. Seek medical attention immediately if frostbite is suspected. It can permanently damage tissue and in severe cases can lead to amputation.

Hypothermia occurs when the body begins to lose heat faster than it can produce it. As a result, the body's temperature begins to fall. If an individual's body temperature falls below 95°F, then hypothermia has set in, and immediate medical attention should be sought. Hypothermia is characterized by uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness, and exhaustion. Left untreated, hypothermia will lead to death. Hypothermia occurs most commonly at very cold temperatures but can occur at cool temperatures (above 40°F) if an individual isn't properly clothed or becomes chilled.

Nationally, climate change is expected to result in increasing temperatures for all parts of the country. Climate scientists expect that warming temperatures will result in the coldest days being less cold which would reduce the impact of extreme cold/wind chill hazard. Trends show temperature increases on cold days growing larger farther north across the United States.

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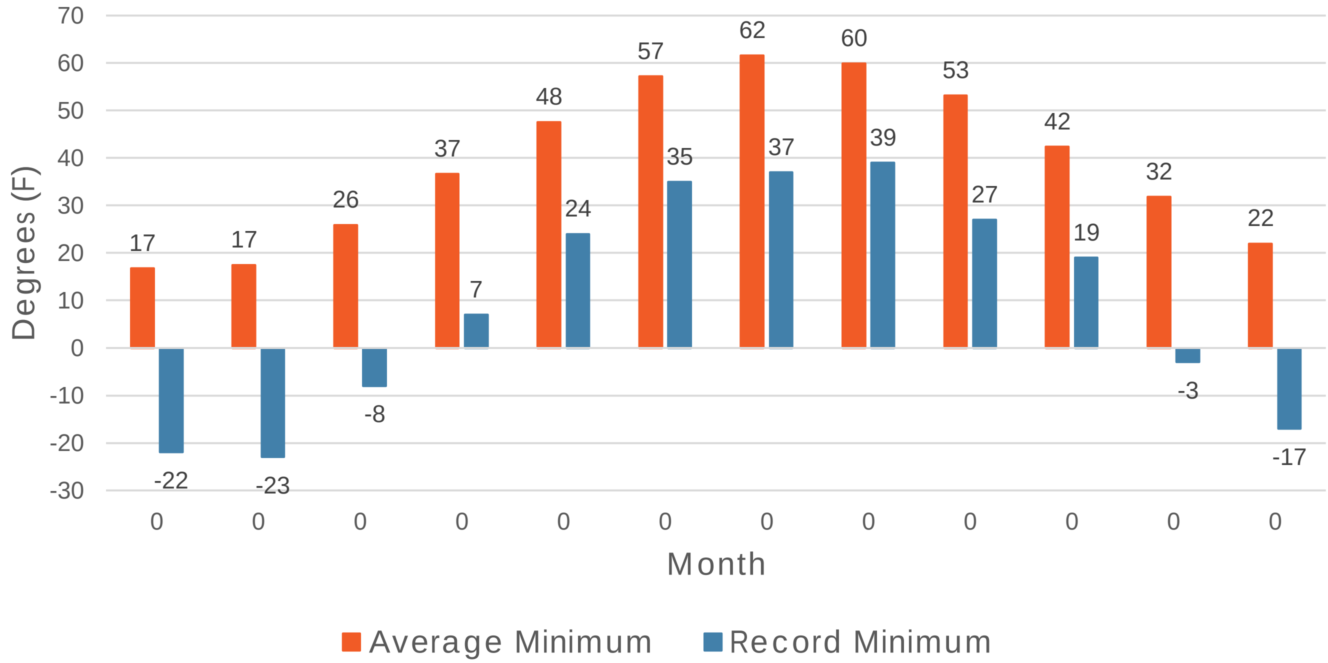
Location

It is assumed that all of Ann Arbor is uniformly exposed to the Extreme Cold/Wind Chill hazard.

Previous Occurrences

To understand extremes, it is beneficial to understand typical temperatures. Figure 4-5 shows average minimum temperatures and record minimum temperatures for Ann Arbor, as observed from a weather station at the University of Michigan. Average temperatures are freezing or below from November through March.



Source: Western Regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2022

Figure 4-5: Average and Record Minimum Temperatures in Ann Arbor

The NOAA NCEI Storm Events Database records extreme cold events by county; city-specific data is not available. Therefore, all extreme cold events reported for Washtenaw County are included. According to NCEI, there has been a total of three extreme cold events in Washtenaw County since 2000; as cold temperatures are a regular occurrence during winter months in Ann Arbor, events have likely gone unrecorded. These events resulted in no reported deaths or injuries in Ann Arbor but did result in over $900,000 worth of property damage (one event, inflated to current dollars). Details for these events are included in Table 4-7.

Table 4-7: Previous Extreme Cold/Wind Chill Occurrences in Ann Arbor

Date	Deaths/ Injuries	Property Damage (2022 dollars)	Details
12/21/2000	0/0	$910,149	Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of -3 degrees. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The cold also hampered shipping interests. Ice formation was extremely rapid on the Great Lakes and the connecting waterways. Average temperatures for the month were 19.3 degrees in Detroit, which was the 4th coldest December on record.
1/14/2009	0/0	$0	An arctic airmass become firmly established over the Great Lakes region on January 14th and persisted through the 18th. Temperatures fell below zero all four days, with wind chill values in the 5 to -30 degrees range during the majority of the time.
2/14/2015	0/0	$0	Arctic airmass ushered in by northwest winds produced wind chills around -30 degrees across most of Southeast Michigan the early morning of February 15th. Temperatures of -5 to 5 above zero in the evening hours of February 14th coupled with northwest winds of 15 to 20 mph produced wind chills around 25 below zero. Although winds diminished to around 10 mph during the early morning hours of February 15th, temperatures bottomed between 5 to 15 below zero. Temperatures slowly rose during the morning hours with corresponding wind chills climbing above -20 degrees during the afternoon hours.

No new extreme cold/wind chill events have been reported to the NCEI Storm events database for Ann Arbor in NCEI since 2015. In addition to the events reported by NCEI, the 2017 Ann Arbor hazard mitigation plan listed the following historic extreme cold/wind chill events:

December 9, 1995. This date was especially severe as winds averaged 20 to 25 mph and resulted in Wind Chill Temperatures of -30 to -35 degrees.

Cold Wave of 1997. From January 17 to 19, 1997 the coldest weather of the winter occurred in southeast Michigan. Low temperatures reached -6 at Detroit Metro Airport.

Cold Wave of 2000. In late December 2000 after heavy snow had ended extreme cold temperatures invaded southeast Michigan, including the Ann Arbor area. Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of -3. The arctic weather would take a toll on pipes. Ypsilanti High School in Washtenaw County had pipes burst over Christmas weekend, damaging classrooms. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The end result was the 4th coldest December of all time in southeast Michigan. No other December on record comes close to its combination of heavy snow and brutal cold.

Cold Wave of 2007. The worst cold wave event since the 1990s struck the southeast Michigan region on February 3, 2007, and did not let up until February 6, 2007. Wind chill ranged from -15 to -25 degrees throughout almost the entire event, causing nearly every school district to cancel classes for one to two days. Hospitals reported numerous cold-related illnesses and frostbite cases. Area homeless shelters were filled to capacity. Frozen pipes and water main breaks occurred throughout the area, and flooding occurred in cases where these involved sprinkler system pipes. According to AAA, there were more than 20,000 vehicle service calls from Michigan due to the cold weather—more than had been seen for nearly 10 years.

Cold Wave of 2009. An arctic air mass become firmly established over the Great Lakes region on January 14, 2009, and persisted through the 18th producing the winter season's coldest temperatures. Temperatures fell below zero all four days, with wind chill values in the 5 to 30 below range during the majority of the time. Detroit's low temperatures for January 14-18th were as follows: -3, -3, -15, and -11.

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Extent

Extreme cold/wind chill extent can be defined with record lows and the NWS Wind Chill Index. The record temperature at the University of Michigan monitoring station is -22°F, occurring in January 1950. This correlates to frostbite exposure times of 10-30 minutes (Figure 4-2). According to the historic events from the previous plan, the most severe cold/wind chill event was a day on which the wind chill reached -35°F. This correlates to frostbite exposure times of 5-30 minutes. However, colder events are possible.

Climate change projections indicate extreme cold/wind chill events in Ann Arbor may become less severe as temperatures warm. However, it is likely Ann Arbor will continue to experience temperatures capable of causing frostbite according to the NWS Wind Chill Index. A summary of climate projections related to Extreme Cold for Ann Arbor is shown in Table 4-8.

Table 4-8: Summary of Climate Change Projections for Extreme Cold in Ann Arbor

Source	Climate Projection

Fourth National Climate Assessment (National Projections)[vi]	Projections for annual average mean temperature relative to 1986-2015:
	▸ Mid-century increase of about 2.2°F (all scenarios)
	▸ Late century (i.e., 2100):
	    ▸ Lower emission scenario (RCP4.5): increase of 2.3°–6.7°F
	    ▸ Higher emissions scenario (RCP 8.5): increase of 5.4°–11.0°F

Source	Climate Projection
Headwaters Economics	Observed average annual mean temperature: 51.8°F Projected average annual mean temperature: • 2020s: 52.2°F • 2050s: 55.0°F • 2080s: 59.0°F
GLISA (Ann Arbor Projections)	Observed changes in average annual mean temperature from 1951-1980 to 1981-2010: 0.3°F Projected late century (i.e., 2070-2099) mean winter temperature (relative to 1961-1990): • Lower emission scenario (RCP4.5): increase of ~5°F in the winter • Higher emission scenario (RCP8.5): increase or ~9°F in the winter
ERA5/CORDEX Analysis (Ann Arbor Projections	Observed average annual mean temperature from 1981-2010: 48.7°F Projected annual mean temperature: • 2020s: 50.8°F • 2050s: 53.2°F • 2080s: 56.3°F Observed average annual record minimum temperature from 1981-2010: -8.2°F Projected annual record minimum temperature: • 2020s: -3.7°F • 2050s: 0.8°F • 2080s: 7.6°F

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Probability of Future Occurrences

With only six recorded events since 1995, data indicates that Ann Arbor experiences less than one recorded extreme cold/wind chill event every three years. However, it is likely events have gone unreported, as cold temperatures are a regular occurrence during Ann Arbor's winter months.

In addition, projected temperature increases in Ann Arbor, as noted above, indicate an increase in average annual minimum temperature. Projected temperature increases could reduce the frequency of extreme cold/wind chill events in the future.

Considering the minimal number of historic events, the likelihood of unreported or underreported events, and climate projections for increasing winter temperatures, the probability assigned the extreme cold/wind chill hazard is highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

All of Ann Arbor, including current and future buildings, populations, infrastructure, and other assets, is vulnerable to severe winter storms hazards. Potential annualized loss from extreme cold/wind chill is estimated at $30,338 based on six events from 1995 to 2022. This figure is for Washtenaw County, as events were only reported at the county-level. Potential impacts are described below. Climate-related impacts from winter weather events are also described.

Damage to Buildings. Extreme cold can result in damage to buildings, typically from internal pipes freezing and bursting. For example, during one extreme cold event in Washtenaw County, damage from burst pipes caused over $900,000 worth of damage to high school and university buildings, including the University of Michigan's School of Dentistry and Wolverine Tower. All current and future buildings in Ann Arbor are considered at risk to extreme cold/wind chill.

Damage to Infrastructure. Extreme cold/wind chill can result in damage to infrastructure, including broken water mains and stress to concrete and asphalt. However, such events are not typical. All infrastructure in Ann Arbor is considered at risk to extreme cold.

Life Safety, Health, and Warning and Evacuation Procedures. All populations in Ann Arbor are considered at risk to extreme cold/wind chill. Extreme cold/wind chill can result in frostbite or hypothermia, even after only a few minutes of exposure. Certain populations, such as the elderly, young children, and those without access to an adequate heat source are considered at a higher risk to the impacts of extreme cold, which could include death. Some extreme cold/wind chill events may result in advisories for people to remain indoors to limit exposure. Evacuations are not likely for extreme cold events; however, people may be advised to remain indoors.

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Public Health. Wide-scale impacts to public health from extreme cold/wind chill events are limited. Carbon Monoxide-related deaths are highest during extreme cold events, due to the increased use of gas-powered furnaces and alternative heating sources (e.g., generators, grills, and camp stoves) inside homes and buildings. Risk for fire and electric shock also increases when using alternative heating and power sources, such as space heaters.[vii]

Impacts to Socially Vulnerable Populations. Socially vulnerable populations have high risk to extreme cold events. Economically constrained households are more likely to live in homes with inadequate heat (e.g., substandard or aging housing) and less able to find or even seek out a warm place. Further, such populations may have little to no financial buffers that would facilitate preparedness or mitigation actions such as repair or insulation of homes, purchase and installation of safe heating options, or the ability to afford a heating bill surge resulting from an extreme hold event. This often results in use of improper heat sources (such as use of a stove) which creates further dangers like carbon monoxide poisoning. The homeless population also faces increased risk risks and may struggle finding or traveling to a heating location.

Economic Impact. Economic impacts from extreme cold/wind chill include repairs to burst pipes or degraded roads, for example. In some cases, extreme cold may result in business disruptions if cannot get to work, to school, or to the store.

Climate Change Impacts. Climate change has the potential to decrease the severity and frequency of extreme cold/wind chill events in Ann Arbor. Annual average temperatures are expected to increase, as are average winter temperatures and average minimum winter temperatures. Projected temperature increases in Ann Arbor are presented in Table 4-8 under the Extent subsection of this profile.

Projected temperature increases will likely reduce the frequency and severity of extreme cold/wind chill events in the future, which will potentially lessen future impacts. However, Ann Arbor is likely to continue to experience temperatures below freezing and those capable of causing frostbite in future.

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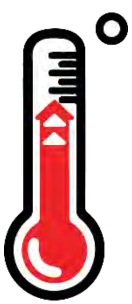
Extreme Heat

Description



Extreme heat is characterized by temperatures that hover 10 degrees or more above the average high temperature of a region for several days to several weeks. In comparison, a heat wave may occur when temperatures hover 10 degrees or more above the average high temperature for the region and last for an extended period. The actual temperature threshold depends on norms for the region.[viii]

Extreme heat events are usually a result of both high temperatures and high relative humidity. (Relative humidity refers to the amount of moisture in the air.) The higher the relative humidity, or the more moisture in the air, the less likely that evaporation will take place. This becomes significant when high relative humidity is coupled with soaring temperatures. On hot days, the human body relies on the evaporation of perspiration (or sweat) to cool and regulate the body's internal temperature. Sweating does nothing to cool the body unless the water is removed by evaporation. When the relative humidity is high, then the evaporation process is hindered, robbing the body of its ability to cool itself.

NOAA's Warnings and Advisories for Extreme Heat

The Detroit/Pontiac NWS Weather Forecast Station has the following thresholds for heat waves:
A heat wave is a prolonged period of excessive heat and humidity. An Excessive Heat Warning is issued if the heat index equals or exceeds 105° for at least three consecutive hours. Heat Advisories are posted when the heat index is expected to exceed 100° for three consecutive hour and can be extended into the night if low temperatures are in the 70s or higher. Excessive Heat Warnings and Heat Advisories can be issued below these thresholds with additional guidance, or if a prolonged event is occurring or forecasted.

The National Weather Service Weather Fatalities Database has records of heat-related fatalities beginning in 1986. Since1986, there has been an approximate annual average of 127 heat fatalities nationally.[ix] In an effort to raise the public's awareness of the hazards of extreme heat, the National Weather Service has devised the "Heat Index." The Heat Index Chart, shown in Figure 4-6, uses air temperature and humidity to determine the heat index or apparent temperature.[x] In addition, information regarding the health dangers by temperature range is presented.

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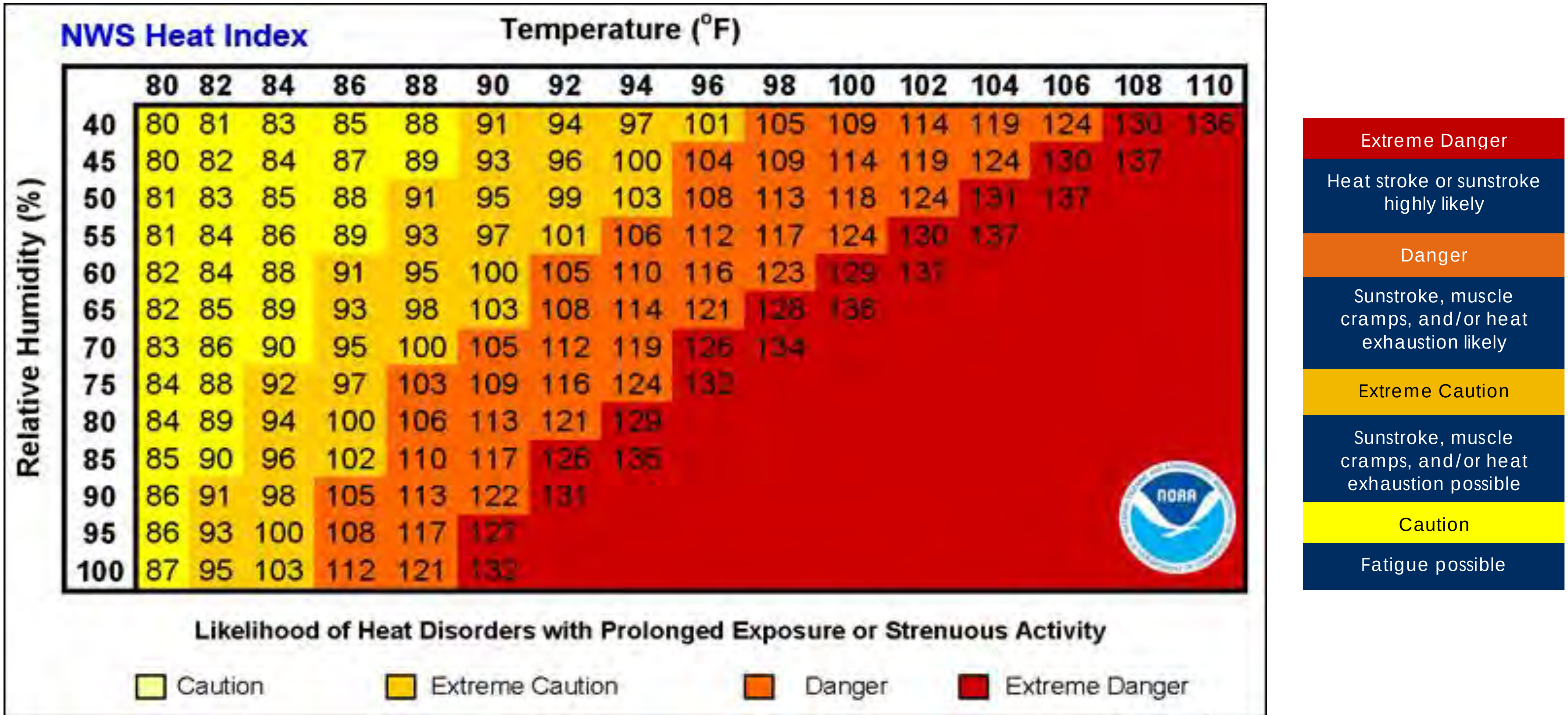

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	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										

Figure 4-6: National Weather Service Heat Index Chart

Some of the heat dangers associated with extreme heat are described below. Some populations, such as the elderly and young children, are more susceptible to heat danger than other segments of the population.

Heat Disorders. Heat disorders are illnesses caused by prolonged exposure to hot temperatures and are characterized by the body's inability to shed excess heat. These disorders develop when the heat gain exceeds the level the body can remove or if the body cannot compensate for fluids and salt lost through perspiration. In either case, the body loses its ability to regulate its internal temperature. All heat disorders share one common feature: the individual has been overexposed to heat, or over exercised for their age and physical condition on a hot day. The following describes the symptoms associated with the different heat disorders.

Sunburn. Sunburn is characterized by redness and pain of skin exposed too long to the sun without proper protection. In severe cases it can cause swelling, blisters, fever, and headaches. It can significantly retard the skin's ability to shed excess heat.

Heat Cramps. Heat cramps are characterized by heavy sweating and painful spasms, usually in the muscles of the legs and possibly the abdomen. The loss of fluid through perspiration leaves the body dehydrated resulting in muscle cramps. This is usually the first sign that the body is experiencing trouble dealing with heat.

Heat Exhaustion. Heat exhaustion is characterized by heavy sweating, weakness, nausea, exhaustion, dizziness, and faintness. Breathing may become rapid and shallow and the pulse weak. The skin may appear cool, moist, and pale. Blood flow to the skin increases, causing blood flow to decrease to the vital organs. This results in a mild form of shock. If not treated, the victim's condition will worsen.

Heat Stroke (Sunstroke). Heat stroke is a life-threatening condition characterized by a high body temperature (106°F or higher). The skin appears to be dry and flushed with very little perspiration present. The individual may become mentally confused and aggressive. The pulse is rapid and strong. There is a possibility that the individual will faint or slip into unconsciousness. If the body is not cooled quickly, brain damage and death may result.

Studies indicate that, all things being equal, the severity of heat disorders tend to increase with age. Heat cramps in a 17-year-old may be heat exhaustion in someone 40 and heat stroke in a person over 60. Elderly persons, small children, chronic invalids, those on certain medications and persons with weight or alcohol problems are particularly susceptible to heat reactions.

Nationally, climate change is expected to result in increasing temperatures for all parts of the country. According to the Fourth National Climate Assessment, annual average U.S. temperatures have increased by 1.8°F since 1895, when recordkeeping began (using a linear trend). Since 1970, temperature increases have occurred rapidly. Figure 4-7 shows changes in temperatures across the United States from 1986-2016, compared to the 1901-1960 average. Warming is projected for all parts of the country over the next several decades. In general, the contiguous United States is projected to increase by about 2.2°F relative to 1986-2015 in the immediate future. The degree of warming that occurs by the late 21st century will ultimately depend on greenhouse gas emissions. Under a lower scenario (RCP4.5) temperatures are projected to increase by 2.3-6.7°F, and under a higher scenario (RCP8.5) temperatures are projected to increase by 5.4-11.0°F relative to 1986-2015. Warming temperatures have already had an impact on heat waves. In 2011 and 2012, the number of intense heat waves were almost triple the long-term average, and analyses from the National Climate Assessment show that climate change has increased the probability of heat waves.

Warming will also vary by location; generally, the farthest north regions are projected to experience the greatest amount of warming, with the southeast experiencing the least. According to the Fourth National Climate Assessment, the Midwest region is projected to have 2,000 additional premature deaths as a result of extreme temperatures by 2090, the largest increase of any region. An Arbor is projected to experience an increase in both the frequency and severity of extreme heat, including increases heat waves, as detailed throughout this profile.

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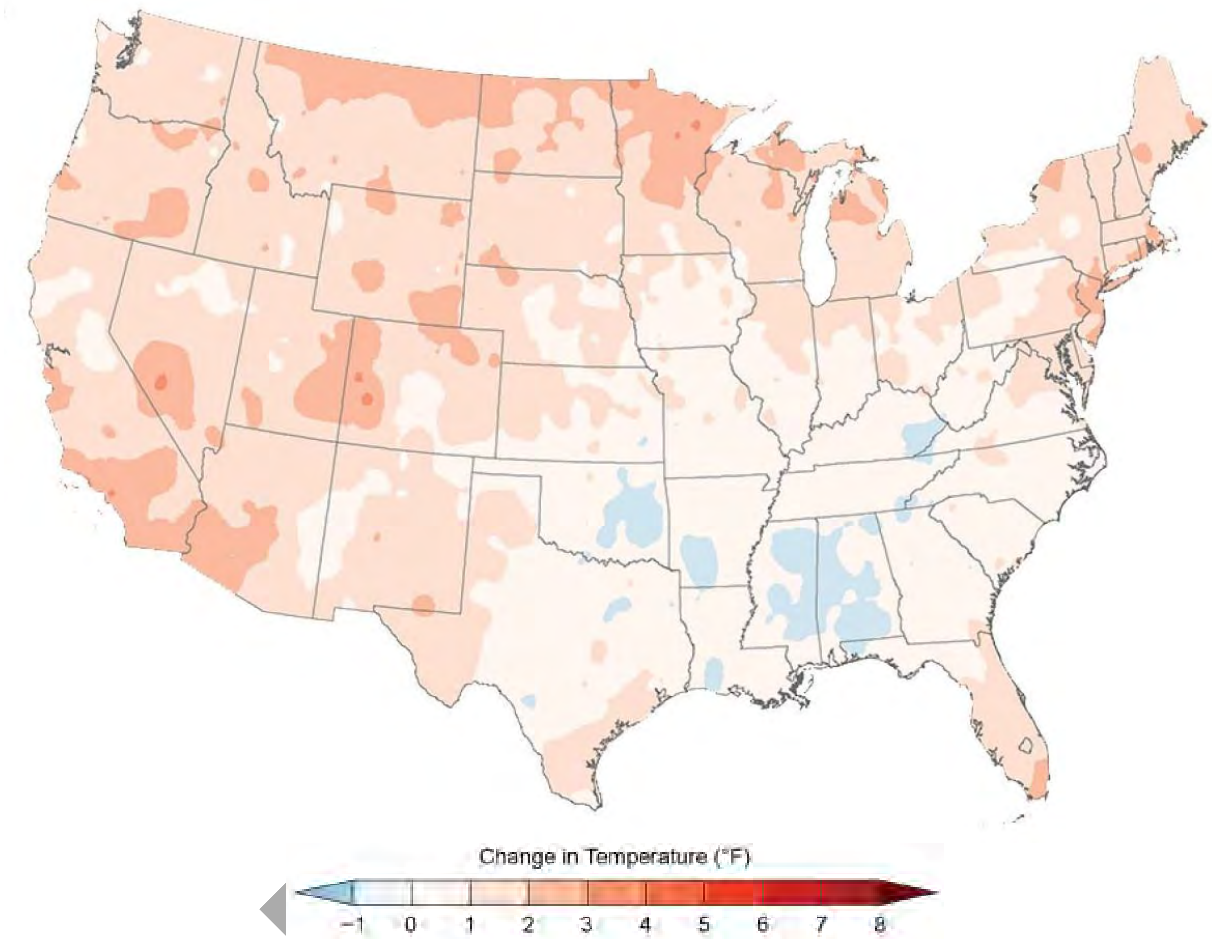


*Compared to the 1901-1960 average
Source: The Fourth National Climate Assessment

Figure 4-7: U.S. Temperature Observed Changes (1986-2016)

Extreme heat events can be exacerbated in localized places by what are known as "heat islands." Heat islands form when open land and vegetation are replaced with impermeable surfaces, such as concrete, asphalt, and building rooftops. On hot, sunny days exposed surfaces can absorb and radiate heat, sometimes to temperatures 50 to 90°F hotter than the air temperature.[xi] In contrast, vegetated areas tend to remain close to air temperatures, and trees can provide shade for people, buildings, and automobiles. Figure 4-8 demonstrates the temperature variations that can occur due to different types of land cover, resulting in heat islands in developed locations.[xii]

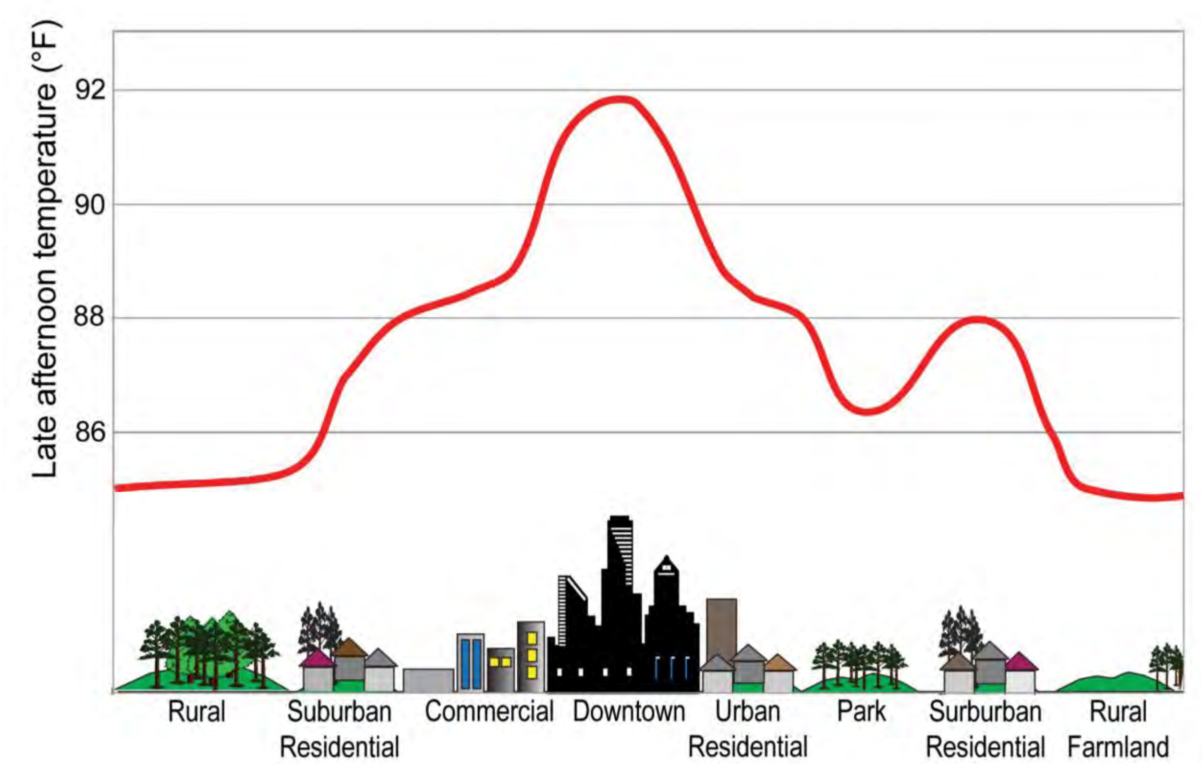


Figure 4-8: The Urban Heat Island Effect

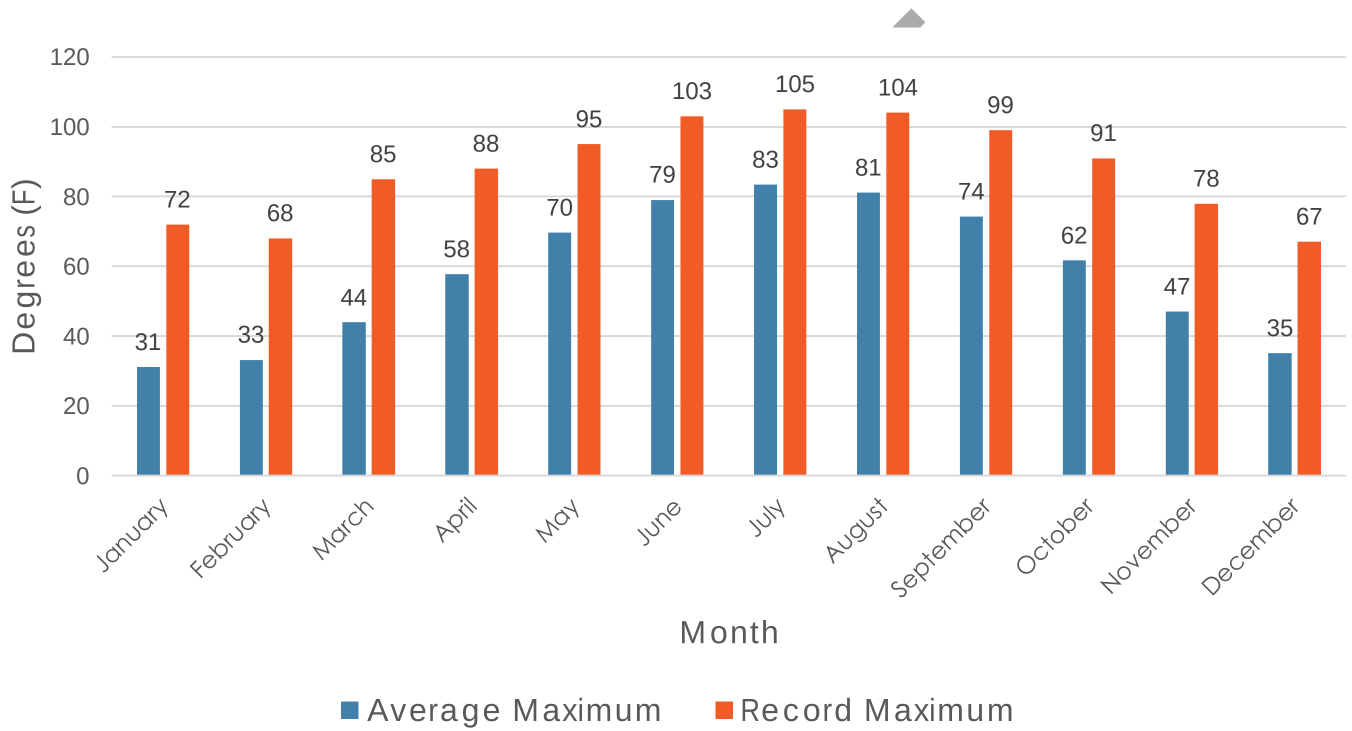
Location

The entire city is impacted by extreme heat events, and more developed areas (i.e., those without vegetation and/or tree cover) experience even higher temperatures.

Previous Occurrences

To understand extremes, it is beneficial to understand typical temperatures. Table 4-9 shows average maximum temperatures and record maximum temperatures for Ann Arbor, as observed from a weather station at the University of Michigan. Summer months, or June through August, are generally the warmest months with average maximum temperatures of 79ºF to 83ºF.

Table 4-9: Average and Record Maximum Temperatures in Ann Arbor



Source: Western regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2022

The NCEI Storm Events Database records extreme-heat events by county; city-specific data is not available. Therefore, all extreme heat events reported for Washtenaw County were assessed. According to NCEI, there has been a total of 14 extreme heat or heat events in Washtenaw County since 1999. These events resulted in at least 17 reported injuries within Washtenaw County, though this number is likely higher as indicated by event descriptions. Details for these events are included in Table 4-10. Descriptions are included for events resulting in injuries.

Table 4-10: Previous Extreme Heat Occurrences in Ann Arbor

Date	Deaths/ Injuries	Details
2/11/1999	0/0	--
7/4/1999	0/0	--
3/8/2000	0/0	--
8/6/2001	0/2	A large high-pressure ridge settled across the Great Lakes region during the first week of August and temperatures soared into the 90s across southeast Michigan. In addition to the heat, humidity levels rose significantly during the same time period. The high heat and humidity allowed daytime heat indices to exceed 100 degrees four days in a row. Heat advisories were in effect for all southeast Michigan for the afternoons and evenings of the 7th, 8th, and 9th. The heat caused several people to seek emergency care for heat stroke and heat exhaustion. One fatality also occurred due to the heat when an Oak Park man was found suffering from severe heat exhaustion while locked in his car. Thousands of power outages also occurred throughout the region as demand surpassed supply.
5/29/2006	0/4	An early season heat wave, leading to an unusually hot Memorial Day, resulted in dozens of people in the region suffering from heat related illnesses. Near record-to-record setting high temperatures, in the low to mid 90's, sent some people to the hospital. The official high temperatures for the day ranged from 88 to 93 degrees. Conditions were further exacerbated by the combination of high humidity, light winds, and mostly clear skies. Heat indices were in the mid 90's throughout most of the day. According to local newspapers, at least 20 people, from across the entire region, were admitted to area hospitals for heat illnesses. This number was likely much larger.
7/29/2006	0/0	--
8/1/2006	0/0	--
7/4/2010	0/0	--
7/17/2011	0/0	--
6/28/2012	0/0	High temperatures climbed to around 100 degrees across much of southeast Michigan during the afternoon hours of June 28th, with heat indices climbing between 100 and 110 degrees. This led to an increase in heat related hospitalizations. Friday June 29th ended up being hot as well, with high temperatures in the low to mid 90s. Dry air helped to keep heat indices short of 100 degrees on the 29th.
7/1/2012	0/5	An extended heat wave gripped southeast Michigan during the first week of July, with temperatures topping out around 100 degrees on multiple days. Heat indices peaked our around 110 degrees on July 4th and July 6th. Although no known heat deaths were reported, over 700 heat related emergency room visits were reported statewide.

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Date	Deaths/ Injuries	Details
7/14/2013	0/6	A six-day heat impacted Southeast Michigan July 14th through the 19th with high temperatures ranging from the upper 80s to mid-90s. Heat Indices were in the 90s for the most part, but area hospitals reported an increase of 173 heat related illnesses during this stretch.
6/30/2018	0/0	--
7/1/2018	0/0	--

In addition to the events reported by NCEI, the 2017 Ann Arbor hazard mitigation plan listed the following historic extreme heat events:

Heat Wave of 1936. During the second week of July 1936, a terrible heat wave struck Michigan, with temperatures exceeding 100 degrees for several days in a row including in the Ann Arbor area. The temperature peaked at 112 degrees in Mio in the northern Lower Peninsula, setting a state record that still stands today. The extreme heat was an “equal opportunity” killer, causing many healthy adults to succumb to the heat at work or in the streets. Also, because most people relied on iceboxes to keep their food fresh, many heat-related deaths and illnesses occurred when the ice melted, causing the food to spoil. Statewide, 570 people died from heat-related causes, including some in the Ann Arbor area. Nationally, the heat wave caused 5,000 deaths.

Heat Wave / Drought of 1988. The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan, including the Ann Arbor area. Nationwide, the drought caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the “dust bowl” days of 1934. During that 39-day stretch, the temperature in the Ann Arbor area topped the 100-degree mark on 5 occasions.

Heat Wave of 1995. During the period from July 11-27, 1995, the Central United States and many East Coast cities experienced a devastating heat wave. According to the National Oceanic and Atmospheric Administration, that heat wave caused 1,021 deaths - 465 of those occurring in the Chicago metropolitan area alone. Many of the deaths were low-income elderly persons living in residential units not equipped with air conditioning. Local utilities in Chicago were forced to impose controlled power outages because of excessive energy demands, and water suppliers reported very low levels of water in storage. Michigan experienced 28 heat-related fatalities in 1995, most of them occurring during the intense heat period in July. In addition to this tremendous human toll, the intense heat also caused the loss of tens of millions of cattle and poultry throughout the Midwest. This was the hottest summer on record for Southeast Michigan, in terms of having the highest average temperature in Detroit (74.5 degrees). The average August temperature was even higher, at 77 degrees, which set a new record.

DRAFT

Heat Wave of 2001. Extreme heat and humidity in the Midwest and Central Plains during parts of June, July and August sent heat stress index readings soaring well above 100 degrees Fahrenheit on many days. Communities across the region were forced to open "cooling centers" and take other steps in an attempt to avoid heat-related deaths among vulnerable segments of the population. Despite those efforts, heat-related deaths occurred in many areas – and unfortunately, Michigan was no exception. On August 1 and August 8, heat advisories were issued in many areas in the southern Lower Peninsula, including the Ann Arbor region.

Heat Wave of 2006. A summer 2006 heat wave delivered the hottest weather the Ann Arbor region had experienced in at least 4 years. A 5 day stretch of temperatures at or above 90 degrees began on July 29th. A blanket of especially high heat and oppressive humidity settled over the area on July 31st and remained relentless through August 2nd. Temperatures, on the 31st, soared above 90 by noon with heat indices over 100 degrees. Heat indices averaged between 105 and 110 degrees through the entire afternoon. Most significantly, Detroit Metro tied the all-time record for the warmest minimum temperature, for any date, when it failed to record a temperature below 80 degrees on July 31st. This had happened only 3 other times in the previous 136 years of record keeping, and this was the first time in 64 years that it had happened again. The major power companies in the area reported an all-time record customer demand for power on the 31st. remarkably, very few heat related illnesses occurred during the event. Newspaper articles revealed an extremely high level of awareness and preparedness from the communities across southeastern Lower Michigan. A large number of cooling centers were made available to those in need as folks reportedly heeded the warnings and took extra precaution.

Heat Wave of 2012. During June and July of 2012, Ann Arbor experienced periods of extreme heat prompting Heat Advisories on June 26 and 27 with heat indices in the 100-105 degrees Fahrenheit, and actual temperatures of 99-100 degrees. A similar event occurred during the July 2 through July 7 time period with actual temperatures reaching the upper 90's to 102 degrees. Several area agencies and libraries opened their doors for cooling stations. A widespread power outage occurred in Ann Arbor in the South and Southwest portion of the city caused by severe thunderstorms. The American Red Cross provided ice and water to a functional needs apartment community and Emergency Services was prepared to shelter larger numbers of the population, however restoration of power was relatively quick.

In addition to the above, several extreme heat events were described within local news sources, as detailed below:

August 2020. Extreme heat caused the pavement on I-94 to buckle east of Detroit, causing one lane of traffic to close for repairs *(source: MLive)*.

June 2022. Washtenaw County, including Ann Arbor, experienced temperatures above 105°F when accounting for the heat index. Cooling centers were opened in Washtenaw County *(Source: MLive)*.

DRAFT

Extent

Extreme heat extent can be defined with record highs and the NWS Heat Index. The record temperature at the University of Michigan monitoring station is 105°F, occurring in July 1934, which was likely into the extreme danger level (Figure 4-8).

Hotter events are possible in the future, especially with expected temperature increases due to climate change. Climate change projections indicate extreme heat events in Ann Arbor will become more severe as temperatures warm. A summary of climate projections related to Extreme Heat for Ann Arbor is shown in Table 4-11.

DRAFT

Table 4-11: Summary of Climate Change Projections for Extreme Heat in Ann Arbor

Source	Climate Projection

Fourth National Climate Assessment (National Projections)[xiii]	Projections for annual average mean temperature relative to 1986-2015:
	- Mid-century increase of about 2.2°F (all scenarios)
	- Late century (i.e., 2100):
	  - Lower emission scenario (RCP4.5): increase of 2.3°–6.7°F
	  - Higher emissions scenario (RCP 8.5): increase of 5.4°–11.0°F

Headwaters Economics (Ann Arbor Projections)	<u>Temperature Increases:</u> Observed average annual mean temperature: 51.8°F Projected annual mean temperature: - 2020s: 52.2°F - 2050s: 55.0°F - 2080s: 59.0°F <u>Extreme Heat Days</u> Projected annual occurrence of maximum daily temperature of 90°F or more: - 2020s: 22 days - 2050s: 41 days - 2080s: 67 days Projected annual occurrence of maximum daily temperature of 95°F or more: - 2020s: 5 days - 2050s: 15 days - 2080s: 34 days
GLISA (Ann Arbor Projections)	Observed changes in mean temperature from 1951-1980 to 1981-2010: 0.3°F Projected late century (i.e., 2070-2099) mean summer temperature (relative to 1961-1990): - Lower emission scenario (RCP4.5): increase of ~6°F in the summer - Higher emission scenario (RCP8.5): increase or ~12°F in the summer

DRAFT

Source	Climate Projection
ERA5 Analysis/CORDEX (Ann Arbor Projections	Temperature Increases Observed average annual mean temperature from 1981-2010: 48.7°F Projected average annual mean temperature: - 2020s: 50.8°F - 2050s: 53.2°F - 2080s: 56.3°F Observed average annual record maximum temperature from 1981-2010: 94°F Projected average annual record maximum temperature: - 2020s: 97.6°F - 2050s: 101.3°F - 2080s: 105.0°F Extreme Heat Days Observed annual occurrence of maximum daily temperature of 90°F or more from 1981-2010: 6 days Projected annual occurrence of maximum daily temperature of 90°F or more: - 2020s: 13 days - 2050s: 24 days - 2080s: 40 days Observed annual occurrence of maximum daily temperature of 95°F or more from 1981-2010: 2 days Projected annual occurrence of maximum daily temperature of 95°F or more: - 2020s: 6 days - 2050s: 13 days - 2080s: 25 days Heatwaves (3+ consecutive days reaching 86°F or more) Observed annual occurrence of heatwaves from 1981-2010: 2.6 Projected annual occurrence of heatwaves: - 2020s: 4.0 - 2050s: 6.0 - 2080s: 7.8

DRAFT

Probability of Future Occurrences

Summer temperatures in Ann Arbor regularly reach into 80s and above. With 16 reported extreme heat events in 23 years, Ann Arbor experiences a reported extreme heat event every one to two years. However, when determining future probability, the historic frequency must be considered along with projected future conditions. Several sources were consulted to determine the projected increase in future extreme heat occurrences, as presented in the table above. Generally, Ann Arbor will experience more extreme heat days and more heatwaves in the future. By the 2080s, Ann Arbor may experience days with temperatures above 90°F for 20 percent of the year. Projections also indicate that Ann Arbor will experience approximately four additional heatwaves per year by 2080 (from 4 to 8). Based on historic events and projected conditions, the probability assigned to the extreme heat hazard is highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

All of Ann Arbor is vulnerable to extreme heat, including all current and future buildings, infrastructure, and populations. There are no reported associated dollar losses with the extreme heat hazard in the planning area. Future damages are expected to be negligible but are possible through power outages or road buckling, for example. Despite limited potential for damages, there are serious health risks to the population. Potential impacts are described below. Climate-related impacts to extreme heat events are also described.

Damage to Buildings. Extreme heat events generally have limited impact on buildings. However, in some rare cases extreme heat can cause structures to collapse or buckle.

Damage to Infrastructure. Extreme heat events generally have minimal impact on infrastructure. Power consumption for air-conditioned environments could increase, and thus stress utility infrastructure, resulting in blackouts (see *Power Outage* profile). Ann Arbor currently experiences issues with electrical capacity during high-demand periods, and members of the TAC noted power outages during extreme heat events. In severe cases, heat can cause railroad tracks to expand. This is referred to as a heat kink in the rail line and can result in disruptions or derailments. Heat can also cause pavement to expand and buckle, as noted in August 2020 when heat caused the pavement on I-94 to buckle.

Life Safety, Health, and Warning and Evacuation Procedures. Ann Arbor, like most areas of the Midwest, is vulnerable to extreme heat, particularly in the summer months. Urban areas are exposed more acutely to the dangers of extreme heat due to the urban heat island effect. People are at risk for heat stroke or sun stroke, heat exhaustion, fatigue, and dehydration. Preparedness reduces the risks associated with this hazard. In cases of extreme heat:

- Stay indoors as much as possible to limit exposure (consider public buildings such as libraries, schools, movie theaters, or cooling centers);
- Limit alcoholic intake;

DRAFT

- Drink plenty of water, even if you do not feel thirsty;
- Do not leave children or pets in vehicles;
- Check on vulnerable populations;
- Arrange your day to avoid strenuous work during the warmest part of the day, if possible;
- Use an electric fan to vent hot air out or bring cool air in; and
- Wear loose-fitting clothing.

In addition to preparedness, Ann Arbor works to mitigate the impacts of extreme heat by increasing tree cover to reduce heat island impacts to the community. When considering health, street trees are especially useful for providing shade to pedestrians. During extreme heat events, heat advisories are issued and the city and/or Washtenaw County opens cooling centers.

Public Health. Aside from the heat-induced health impacts described above, extreme heat negatively impacts air quality by increasing the amount of ground-level ozone (or smog). Worsened air quality can aggravate existing respiratory illnesses, and long-term exposure can result in decreased lung function[xiv]. Extreme heat can also degrade water quality by heating water bodies directly or heating runoff that drains into them which may result in algae blooms and ecosystem disruption, for example.

Impacts to Socially Vulnerable Populations. Socially vulnerable populations are considered at higher risk to extreme heat events relative to the general population. Groups particularly vulnerable to extreme heat include:[xv]

- Older adults who do not adjust as quickly to changes in temperature. Older adults are also more likely to be on medications or have chronic illnesses that affect the body's ability to regulate its temperature.
- Infants and children, who rely on others to keep them cool and hydrated and sensitive to do a smaller size.
- Athletes, who may be more likely to exercise and become dehydrated during extreme heat events.
- Outdoor workers, who have more exposure to extreme heat and are more likely to become dehydrated.
- Low-income populations and those experiencing homelessness, who may not have access to air conditioning.

Economic Impact. Generally, direct economic impacts due to extreme heat are minimal. Indirect losses due to business interruption in the case of a power outage or road buckling during an extreme heat event. Increasing temperatures will increase the demand for electricity, increasing electricity costs.

DRAFT

Climate Change Impacts. Climate change will impact the frequency and intensity of extreme heat events. According to the Fourth National Climate Assessment, the Midwest is projected to have the largest increase in extreme temperature-related premature deaths under the higher emissions scenario by 2090.[xvi] This is a product of several factors, such as increased daytime and nighttime temperatures. In addition, midwestern cities, such as Ann Arbor, may be less equipped to deal with extreme heat relative to southern cities (e.g., less likely to have air conditioning, less public awareness). Furthermore, extreme heat in urban areas, like Ann Arbor, can lead to dangerous conditions as these temperatures are exacerbated by urban heat island effects. Those without resources to use or install air-conditioning will be most impacted. This could be further impacted by potential increases in the cost of electricity.

Several sources were consulted to determine the projected increase in future extreme heat occurrences and severity. A summary of these various projections is provided in Table 4-11. Based on the climate analysis and other sources, increases in the extent and frequency of extreme heat events are inevitable. This will result in warmer weather and shifting habitat extents for local flora and fauna. GLISA research indicates that by the end of the 21st century summers in Michigan will feel more like current summers in Arkansas. Their research also indicates that forest in the area will transition from being comprised of elm, ash, and cottonwood to being comprised of oak and hickory, along with other species more well-suited for the increased temperatures.

Increases in the intensity and frequency of extreme heat events will exacerbate the life safety, health, and public health impacts described above. Ann Arbor should not only prepare for the current extent experienced for extreme high temperatures, but also for those projected due to climate change. In addition, impacts from urban heat islands could increase due to increased development and densification in Ann Arbor. Such impacts from urban heat islands could be reduced with through the increased use of mechanisms such as tree canopies and green roofs.

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Fog

Description

Fog forms near the ground when water vapor condenses into tiny liquid water droplets that remain suspended in the air. While many different processes can lead to fog formation, all fog is formed by saturated air. Air can become saturated when it is cooled to its dew point, or when evaporated moisture increases the air's water vapor content. Fog can form at a varying speed; it may form in a matter of minutes or more slowly, over several hours. Fog is considered a hazard when it results in reduced visibility and, consequently, dangerous transportation conditions for air and ground travel. Localized fog is especially dangerous, as drivers can be caught by surprise. Fog is particularly hazardous at airports, where aircraft are attempting to land and take-off.

In addition, freezing fog (a hazard for which the National Weather Service issues special statements) can become hazardous by causing slickness on roadways in addition to low visibility, resulting in especially dangerous road conditions.

Location

It is assumed that all of Ann Arbor is uniformly exposed to fog hazards.

Previous Occurrences

Fog is a common occurrence in Ann Arbor, but typically dissipates by mid-morning. While fog has been noted as a regular occurrence, just two fog events have been reported to the NCEI Storm Events database since 1996 (Table 4-12). Of note, freezing fog events were not reported to NCEI until 2006. No injuries, deaths, or damages were associated with these events. No new fog incidents were reported since the 2017 plan update. However, it is assumed that many fog events go unreported; therefore, it is likely that a much greater number of fog occurrences has occurred since 1996.

Table 4-12: Previous Fog Events in Ann Arbor

Date	Event Type	Event Details
10/26/2000	Dense Fog	On this morning, the dense fog was found in metro Detroit. The fog caused significant headaches for morning commuters, and delayed dozens of flights at Detroit Metropolitan Airport.
11/24/2006	Freezing Fog	A high-pressure system set up a favorable situation for fog formation. Light winds off Lake Erie and Lake St Clair carried a marine layer of low clouds and dense fog inland across the Detroit area, mainly along and south of I-94. Visibility was near zero at times during rush hour traffic. Visibilities were near zero at times during the rush hour traffic. Temperatures in the 20's allowed the dense fog to freeze on area roadways, creating slippery conditions and numerous accidents. By 10:00 EST, temperatures had climbed above freezing and visibility visibilities had begun to improve.

Extent

The extent of fog is difficult to measure. It could be measured in terms of thickness or visibility. However, such measurements are not consistently applied to fog events. The details for the fog event occurring on 11/24/2006 indicate that visibility was "near zero."

Probability of Future Occurrences

Although only two fog events for Ann Arbor were recorded in the NCEI database, fog is a regular occurrence for Ann Arbor. Therefore, the probability assigned for future fog events is highly likely (greater than 90 percent annual chance).

DRAFT

Vulnerability Assessment

Fog itself does not have a significant impact on buildings, infrastructure, health, and the economy. Fog becomes damaging when it results in reduced visibility. All current and future buildings, infrastructure, and populations are considered at-risk to fog. No dollar losses are associated with fog events in Ann Arbor; future losses from fog events are expected to be negligible.

Damage to Buildings. Direct building damages are not typically attributable to fog. The primary risks from fog are the dangers of traveling under conditions of limited visibility. Fog resulting in vehicular crashes may result in damages to buildings.

Damage to Infrastructure. Fog resulting in vehicular crashes may result in damages to infrastructure such as roads, guardrails, and utility poles.

Life Safety, Health, and Warning and Evacuation Procedures. During fog events, it is recommended that motorists delay travel until fog has dissipated. If travel is necessary, driving at reduced speeds, keeping safe distances, and use of fog lights is recommended. Fog also creates dangerous conditions for aircraft. The Federal Aviation Administration issues weather-related delays for commercial aircraft. The National Weather Service issues advisories for freezing fog events.

Public Health. Fog on its own does not directly impact public health. However, fog may reduce visibility and can create dangerous traveling conditions. Transportation accidents as a result of limited visibility could involve a chemical release posing risk to the public and the environment. (Please refer to the *Hazardous Materials* profile in this Section for additional information on this hazard).

Impacts to Socially Vulnerable Populations. Socially vulnerable populations may lack flexibility to refrain from travel during unsafe conditions and may be more impacted by disruptions or delays to public transportation.

Economic Impact. Fog can impact air, marine, and land transportation, including travel on rail and roadways. Lingering dense fog can the result in minor business disruptions, especially those reliant on deliveries and transportation.

Climate Change Impacts. Because fog can form from several different conditions, it is difficult to determine the impact that a changing climate will have on fog frequency and intensity. One way fog develops is when rain cools and moistens the air near the ground surface to the point that fog forms. Increases in precipitation are expected for Ann Arbor due to climate change. Therefore, it is possible that the frequency of fog events will increase as well.

DRAFT

Hail

Description

Hailstorms are a potentially damaging outgrowth of severe thunderstorms. Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until they develop to a sufficient weight and fall as precipitation. Hail typically takes the form of spheres or irregularly shaped masses greater than 0.75 inches in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size.[xvii]

Hailstone size can range in size from just under a fifth of an inch (approximately pea-sized) to almost four inches (approximately melon-sized). Hailstones are categorized using the TORRO Hailstorm Intensity Scale (Table 4-13). Hailstone size descriptions are located in Table 4-14.

Hail-related insured losses averaged between $8 billion to $14 billion per year from 2000 to 2019.[xviii] It damages buildings and homes by perforating holes in roofs and shingles, breaking windows and denting siding, and damages automobiles by denting panels and breaking windows. Hail rarely causes any deaths; however, several dozen people are injured each year in the United States.

Table 4-13: TORRO Hailstorm Intensity Scale (in millimeters)

	Intensity Category	Typical Hail Diameter (in)	Probable Kinetic Energy, J-m^2	Typical Damage Impacts	Size Code
H0	Hard Hail	0.20	0-20	No damage	1
H1	Potentially Damaging	0.20 - 0.59	>20	Slight general damage to plants, crops	1-3
H2	Significant	0.39-0.79	>100	Significant damage to fruit, crops, vegetation	1-4
H3	Severe	0.79-1.18	>300	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored	2-5
H4	Severe	0.98-1.57	>500	Widespread glass damage, vehicle bodywork damage	3-6
H5	Destructive	1.18-1.97	>800	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries	4-7

DRAFT

	Intensity Category	Typical Hail Diameter (in)	Probable Kinetic Energy, J-m²	Typical Damage Impacts	Size Code
H6	Destructive	1.57-2.36		Bodywork of grounded aircraft dented; brick walls pitted	5-8
H7	Destructive	1.97-2.95		Severe roof damage, risk of serious injuries	6-9
H8	Destructive	2.36-3.54		Severe damage to multiple roof types (including sheet and metal); damage aircraft bodywork	7-10
H9	Super Hailstorms	2.95-3.94		Extensive structural damage (including concrete and wooden walls). Risk of severe or even fatal injuries to persons caught in the open	8-10
H10	Super Hailstorms	>3.94		Extensive structural damage (including destruction of wooden houses and damage to brick-built homes). Risk of severe or even fatal injuries to persons caught in the open	9-10

Table 4-14: Hail Size Code Descriptions

Size Codes	Diameter (in)	Relational Size
0	0.2 - 0.4	Pea
1	0.4 - 0.6	Mothball
2	0.6 - 0.8	Marble, grape
3	0.8 - 1.2	Walnut
4	1.2 - 1.6	Pigeon's egg > squash ball
5	1.6 - 2.0	Golf ball > Pullet's egg
6	2.0 - 2.4	Hen's egg
7	2.4 - 3.0	Tennis ball > cricket ball
8	3.0 - 3.5	Large orange > Soft ball
9	3.5 - 3.9	Grapefruit
10	>3.9	Melon

DRAFT

Location

Hailstorms frequently accompany thunderstorms, so their locations and spatial extents coincide. It is assumed the city is uniformly exposed to severe thunderstorms; therefore, all areas of the city are equally exposed to hailstorms. According to the National Weather Service, Ann Arbor is located in an area of the United States that receives an average of six days per year with hail events (see Figure 4-9 below).[xix]

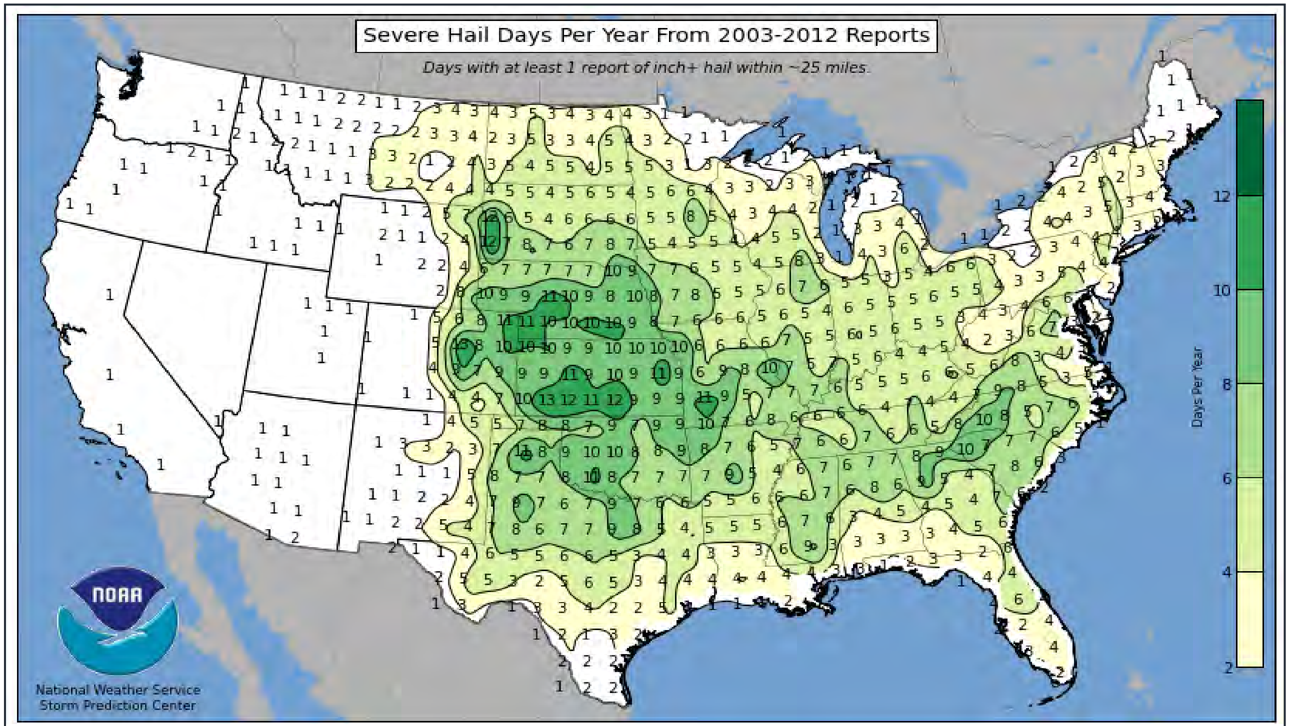

Figure 4-9: United States Average Number of Days per Year with Severe Hail Events

Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports hail information by county and, when the information is available, by town or by coordinate location. Of the 241 hail events reported for Washtenaw County between 1957 and 2021, 46 events occurred in Ann Arbor. None of these events resulted in reported deaths, injuries, or damages. However, it is likely that hail events and damages to private property were not reported to NCEI, especially during early years of reporting (only 4 of the 46 reported events occurred prior to 2000). Therefore, the number of events and resulting damages is likely higher than what is indicated. Detailed information on hail events reported in Ann Arbor are presented in Table 4-15.

Table 4-15: NCEI Historic Hail Events in Ann Arbor (1957-2022)

Date	Magnitude (inches)
4/27/1957	0.75
6/15/1974	0.75
9/22/1980	0.75
9/25/1994	0.75
5/11/2000	0.75
6/29/2000	0.75
7/14/2000	0.75
4/9/2001	1.75
7/22/2002	1.00
5/5/2003	0.88
5/5/2003	1.00
5/5/2003	1.75
5/20/2004	1.00
5/20/2004	0.75
5/21/2004	0.75
5/21/2004	0.75
5/13/2005	0.75
3/31/2006	0.75
3/31/2006	0.75
4/22/2006	0.75
5/25/2006	0.75
6/27/2006	1.75

DRAFT

Date	Magnitude (inches)
6/27/2006	0.75
6/27/2006	1.00
6/27/2006	1.00
6/27/2006	0.75
6/27/2006	0.75
9/13/2006	0.75
5/15/2007	1.00
5/15/2007	0.75
5/15/2007	0.75
5/15/2007	0.75
8/24/2011	0.75
3/15/2012	1.25
3/15/2012	0.75
3/15/2012	2.00
3/15/2012	1.00
3/15/2012	1.00
3/15/2012	1.00
3/15/2012	1.25
7/27/2014	1.00
7/7/2017	0.75
7/26/2018	1.00
4/7/2020	1.00
4/7/2020	1.50
6/12/2021	1.00

DRAFT

Extent

Hail extent can be measured in terms of size, typically by diameter. According to the events reported in NCEI, the greatest extent hail reported in Ann Arbor was 2 inches on March 15, 2012. On the TORRO scale, this size correlates to H6 or H7. According to the TORRO scale, hailstones of this size (about the size of a hen's egg) can cause serious injuries and damage to vehicles, grounded aircraft, glass, brick walls, and roofs. It should be noted that greater extent hail is possible in Ann Arbor. For example, in Washtenaw County, the greatest extent hail reported was 3 inches, which occurred in May of 2000. The effect of climate change on hail extent in Ann Arbor is uncertain, as detailed below in the *Probability* section.

Probability of Future Occurrences

With 46 reported events in 65 years, Ann Arbor experiences less than one reported hail event per year. As discussed above, it is likely that the number of events reported is lower than the number that occurred.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xx] Because hail is an outgrowth of severe thunderstorms, trends in hail frequency and intensity are directly related to trends in thunderstorm frequency and intensity. Although studies are ongoing, a 2013 study cited by the Fourth National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments.[xxi] While it is difficult to quantify these trends in terms of future hail occurrences, they can be considered when determining future probability.

Considering the rate of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, the probability assigned the hail hazard is likely (between 10 percent and 90 percent annual chance).

Vulnerability Assessment

Potential impacts to buildings, infrastructure, life safety, public heath, socially vulnerable populations, and the economy from the hail hazard are described below. Climate-related impacts to the hail hazard are also described. All current and future buildings, infrastructure, and populations are considered at risk to hail. No dollar losses are attributed to hail events in Ann Arbor, but future losses are possible. The NRI provides a hail risk index score, which indicates a county's hail risk relative to the rest of the United States. Figure 4-10 shows hail risk index results at a national level, as well as focusing on the lower peninsula. According to the index, Washtenaw County has "very low" risk to hail.

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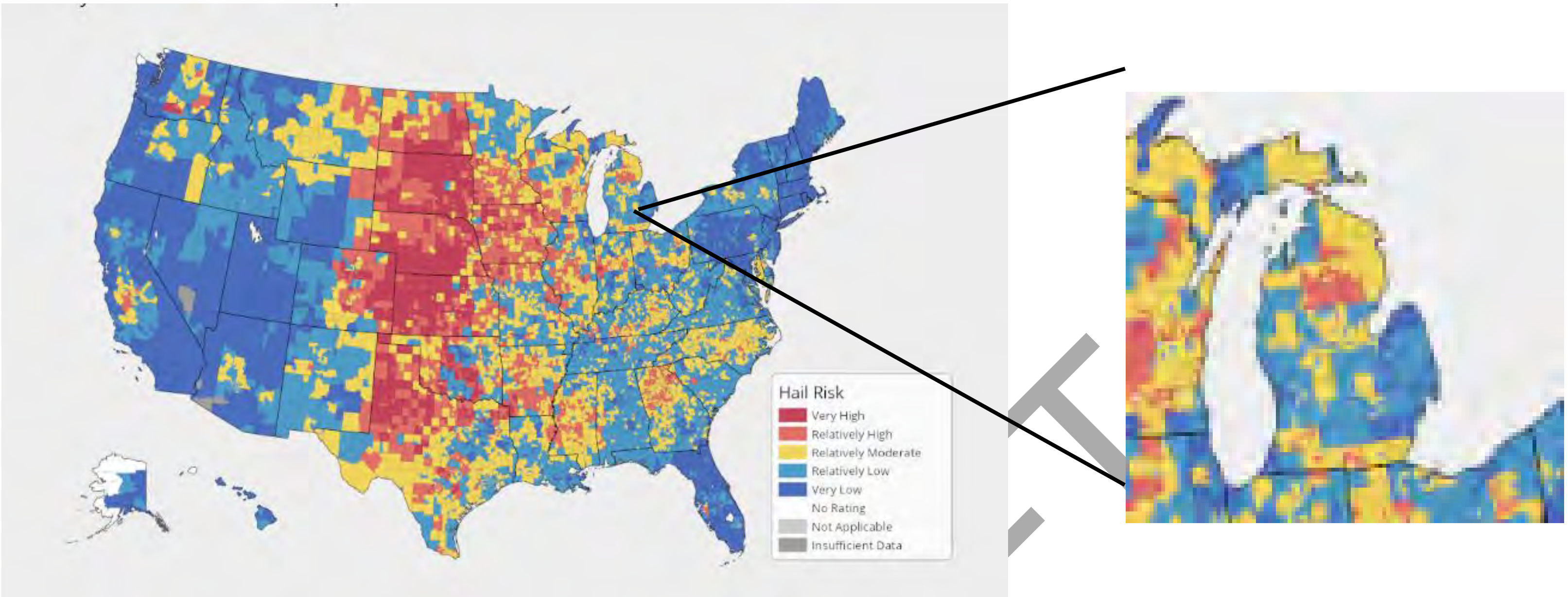

Figure 4-10: Hail Risk Index Results at a National Level

Damage to Buildings. All current and future buildings in Ann Arbor are considered at-risk to the hail hazard. Hail is capable of causing damages to roofs, brick walls, and exposed glass and metal.

Damage to Infrastructure. In severe cases, hail has the potential to damage exposed infrastructure, such as roads, sidewalks, bridges, and above-ground utilities. All exposed infrastructure in Ann Arbor is considered at-risk to hail.

Life Safety, Health, and Warning and Evacuation Procedures. In extreme cases, hail can result in injuries and loss of life to persons caught in the open. It is unlikely that hail would result in an evacuation; however, in some events, people may be advised to take shelter until the event has passed. All populations in Ann Arbor are considered at-risk to hail.

Public Health. No special public health issues are attributable to hail.

Impacts to Socially Vulnerable Populations. Unhoused populations and populations living in substandard housing are more vulnerable to the impacts of hail events. In addition, income constrained homeowners may be less able to repair property damages incurred from hail.

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Economic Impact. Hail can result in extensive property damages, including damage to cars, roofs, crops, and landscaping. Business interruptions are possible if people need to seek shelter until a hail event has passed.

Climate Change Impacts. Impacts on hail intensity (extent) due to climate change are uncertain. It is unknown if future climate conditions will result in different hailstone sizes on average. Research from the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments, which could lead to an increase in the number of hail occurrences in Ann Arbor. An increase in the frequency of events would increase the vulnerability of people, buildings, and infrastructure to the hail hazard.

Lightning

Description

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes the thunder, which often accompanies lightning strikes. While most often affiliated with thunderstorms, lightning may also strike outside of heavy rain and might occur as far as 10 miles away from any rainfall.

Lightning strikes occur in very small, localized areas. For example, they may strike a building, electrical transformer, or even a person. According to FEMA, lightning injures an average of 182 people and kills 33 people each year in the United States.[xxii] Direct lightning strikes can also cause significant damage to buildings and infrastructure largely by igniting a fire. Lightning is also responsible for igniting wildfires that can result in widespread damages to property.

Location

Lightning occurs randomly, therefore it is impossible to predict where and with what frequency it will strike. It is assumed the city is uniformly exposed to lightning. Lightning flash data compiled by Vaisala, Inc. with data from 2007 through 2016 shows the frequency of lightning flashes per square mile per year (see Figure 4-11). All of Washtenaw County receives an average of 3 to 12 flashes per square mile, with most areas in Ann Arbor receiving an average of 6 to 12 flashes per square mile per year.[xxiii]

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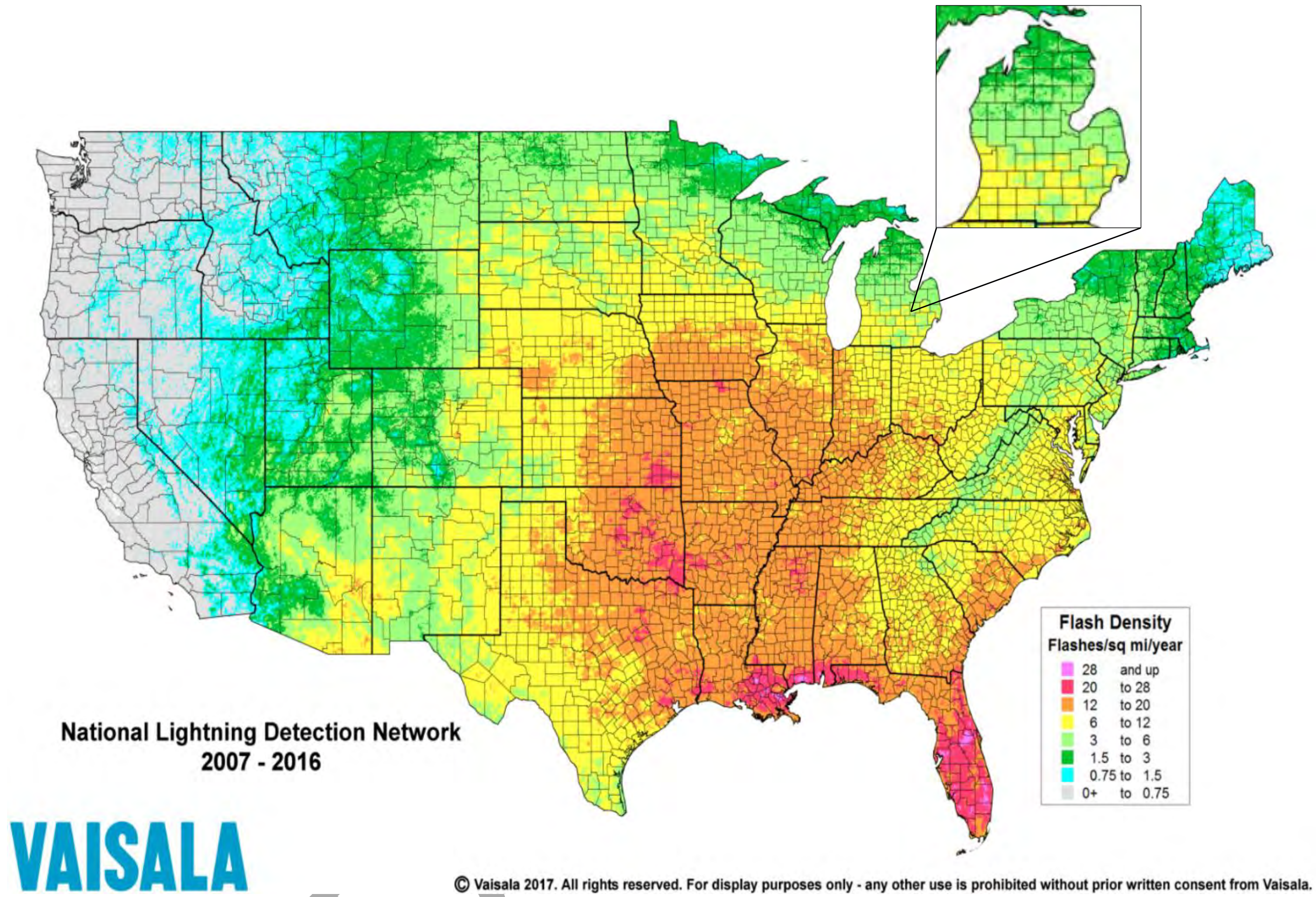

Figure 4-11: Vaisala, Inc. Average Lightning Flash per Square Mile (2007-2016)

Previous Occurrences

The NCEI Storm Events Database reports lightning information by county and, when the information is available, by town or by coordinate location. Of the 21 lightning events reported for Washtenaw County between 1996 and 2021, 5 events occurred in Ann Arbor. These 5 events resulted in 1 death, 4 injuries, and over $2.4 million (inflated to 2022 dollars) in property damages. It should be noted that additional lightning events have likely occurred that were not reported to NCEI; often only events with severe outcomes, such as injuries, deaths, or extensive damages, are reported. Therefore, the number of events and resulting damages are likely higher than what is indicated. Detailed information on lightning events reported in Ann Arbor are presented in Table 4-16.

Table 4-16: NCEI Historic Lightning Events in Ann Arbor

Date	Deaths/Injuries	Property Damage (2022 dollars)	Details
10/27/1997	0/0	$0	Lightning struck at transformer pole in Ann Arbor, knocking out power to about 500 Detroit Edison customers.
4/20/2000	0/2	$0	Two 18-year-old men were struck by lightning and briefly hospitalized.
12/11/2000	0/0	$2,107,714	A lightning strike ignited a large home just northwest of Ann Arbor. The home was destroyed by fire.
9/19/2002	1/2	$0	Three men were installing a roof at an apartment complex under construction when they were struck by lightning. Two of the men were injured, while the third was later pronounced dead.
6/21/2006	0/0	$320,941	A lightning strike tore a large hole in the roof of an upscale home, causing extensive damage. Much of the upstairs portion of the home was destroyed. Total Property damage was estimated at $200K based on pictures included in the newspaper.

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Extent

One method for measuring lightning extent is flash density, or the number of flashes per square mile per year. According to Figure 4-10, Ann Arbor is in a part of Michigan that receives approximately 6 to 12 lightning flashes per square mile per year (though not all flashes result in a lightning strike). Lightning can also be measured in terms of damages incurred from an event. The greatest amount of damage reported from a single lightning event in Ann Arbor was $2,107,714, when a lightning strike caused a house to catch fire. However, costlier events are possible.

Probability of Future Occurrences

With five reported lightning events in 21 years, the average historic rate of occurrence in for damaging lightning events in Ann Arbor is approximately one event every four years. However, county information suggests at least one event annually, and it is also assumed that data is not inclusive of all events in the city. Lightning flashes and strikes are a common occurrence, though all events may not result in damage.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xxiv] Because lightning is affiliated with severe thunderstorms, trends in lightning frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are ongoing, a 2013 study cited by the Fourth National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates an increase of 1.2 to 2.4 days per season with severe thunderstorm environments from 2070-2099.[xxv] While it is difficult to quantify these trends in terms of future lightning occurrences, they can be considered when determining future probability.

Considering the frequency of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, a probability of highly likely (greater than 90 percent annual chance) was assigned.

Vulnerability Assessment

All current and future buildings, infrastructure, and populations are considered at risk to lightning in Ann Arbor. Potential annualized loss from lightning is estimated at $80,955 (2022 dollars) based on five events occurring in 25 years. Specific impacts to buildings, infrastructure, life safety, public heath, socially vulnerable populations, and the economy from lightning are described below. Climate-related impacts to the lightning events are also described.

Damage to Buildings. All current and future buildings in Ann Arbor are considered at-risk to lightning. Lightning may result in structure fires and loss of electrical equipment. In addition, falling limbs caused by lightning strikes to trees may damage buildings or vehicles.

Damage to Infrastructure. All current and future infrastructure in Ann Arbor is considered at-risk to lightning. Electrical systems, telecommunications equipment, and infrastructure exposed in open areas are especially vulnerable to lightning.

Life Safety, Health, and Warning and Evacuation Procedures. Lightning is one of the leading causes of weather-related fatalities. From 2003 to 2012, lightning causes dozens of deaths per year in the U.S.[xxvi] Most lightning deaths and injuries in the United States occur in the summer months, when lightning frequency and outdoor activities reach a peak. All current and future populations in Ann Arbor are considered at risk to lightning. However, people who work outside or regularly engage in outdoor recreational activities are considered at a higher risk. People engaged in outdoor activities during a lightning event can reduce vulnerability by taking appropriate precautions. If thunder is heard, people outdoors should seek shelter and wait 30 minutes after the last clap of thunder before leaving the shelter. When possible, coaches, referees, camp counselors, or lifeguards should protect the safety of those outside by stopping activities in a prompt manner so that participants and spectators can get to a safe place.[xxvii]

Public Health. No special public health issues are attributable to lightning.

Impacts to Socially Vulnerable Populations. Certain socially vulnerable populations may be more vulnerable to lightning. The unhoused and those with jobs that require work outdoors may be more likely to be struck by lightning, especially for workers who

DRAFT

feel pressure to remain outdoors and continue working. In addition, those in substandard housing, housing not built to code, or older housing (i.e., without grounded electricity) may be more at risk to homes being struck by lightning. Income constrained households may also face difficulty repairing or replacing property damaged by lightning, such as electrical systems, electronics, and appliances.

Economic Impact. Lightning can cause costly fire damage due to hitting trees and causing wildfires as well as causing stress on electrical systems. Communications can be disrupted by lightning, and signal disruptions due to lightning are common. In addition, communication lines, antennas, and towers can suffer damage from lightning. Businesses can also be affected by power outages.

Climate Change Impacts. Changes to lightning intensity (extent) and frequency due to climate change are uncertain. Research cited by the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments in the Great Lakes Region (1.2 to 2.4 days per season from 2070-2099), which could lead to an increase in the frequency of lightning flashes in Ann Arbor. Similarly, another study found evidence linking warmer air temperatures to increased lightning strikes by about 12 percent per degree Celsius of warming (give or take 5 percent[xxviii]). According to data from Headwater Economics, by 2080 average temperatures in Ann Arbor are expected to increase by approximately 6°F under a high emissions scenario. An increase in the frequency of events would increase the vulnerability of populations, buildings, and infrastructure to the lightning hazard.

Severe Winter Weather

Description

A winter storm is an event in which varieties of precipitation are formed that only occur at low temperatures, such as snow, sleet, freezing rain or ice. Snowstorms generally occur with the clash of different types of air masses, with differences in temperature, moisture, and pressure; specifically, when warm moist air interacts with cold dry air. Snowstorms that produce a lot of snow require an outside source of moisture, such as the Great Lakes or the Atlantic Ocean.

Severe winter weather typically results in a winter weather watch, warning, and/or advisory. During a severe winter weather event, one or more of the following types of weather occur:

Winter Storm. A winter storm is generally defined as snow accumulation of at least 8+ inches in 12+ hours or 6+ inches in 6 to 9 hours, and can be in combination with rain, freezing rain, sleet, wind, blowing snow, or cold.

Heavy Snow. A heavy snowstorm is any winter storm that produces six inches or more of snow within a 48-hour period or less.

Blizzard. A blizzard is a severe snowstorm with winds in excess of 35 mph and visibility of less than a 1/4 mile for more than 3 hours.

Frost/Freeze. Frost forms during freezing temperatures when the ground surface cools to a temperature colder than the dewpoint of adjacent air. When water vapor in the air above the ground surface condenses, it freezes due to low temperatures. Sustained

DRAFT

temperatures below freezing are common during Ann Arbor's winter months, and the city is generally well prepared (see the *Extreme Cold/Wind Chill* profile for hazards relating to temperatures well below freezing). However, frost and freeze events can be detrimental when occurring outside of the expected winter season, such as early in the fall or late in the spring. These events can catch motorists off guard with slick road conditions, or damage crops and landscaping.

Ice Storm, Sleet, and Freezing Rain. An ice storm is defined as a storm with significant amounts of freezing rain and is a result of warm air in between two layers of cold air. With warmer air above, falling precipitation in the form of snow melts, then becomes either super-cooled (liquid below the melting point of water) or re-freezes. An ice storm typically has a coating of at least ¼ inch of ice but may be up to one-half inch if winds are less than 15 miles per hour.

In the former case, super-cooled droplets can freeze on impact (freezing rain), while in the latter case, the re-frozen water particles are ice pellets (or sleet). Sleet is defined as partially frozen raindrops or refrozen snowflakes that form into small ice pellets before reaching the ground. They typically bounce when they hit the ground and do not stick to the surface. However, it does accumulate like snow, posing similar problems and has the potential to accumulate into a layer of ice on surfaces. Freezing rain, conversely, usually sticks to the ground, creating a sheet of ice on the roadways and other surfaces. Generally, in Michigan, an ice storm is considered severe if there is an accumulation of ¼ inch or more of ice.

As the climate changes, winter precipitation is also expected to change. With warmer temperatures, it is more likely that rain will fall in place of snow, and mixed winter precipitation (such as freezing rain) will become more likely.[xxix]

Winter storms are defined differently in various parts of the country relevant to their standard weather. Two inches of snow may create serious disruptions to traffic in areas where snowfall is not expected; however, this may be considered a light dusting in regions where snowfall is typical. Therefore, there are multiple ways in which to measure a winter storm, based on snowfall, temperatures, wind speeds, societal impact, etc. Ann Arbor lies within the Detroit/Pontiac, MI NWS Forecast Office, which defines regional standards for severe winter weather events.

On the southern portion of Michigan's lower peninsula, the winter risk season starts in late November and runs through early April. However, it should be noted severe winter weather is possible outside of this window, and that mild snowfall and cold temperatures may also occur outside of the winter weather risk season.[xxx]

In addition to precipitation associated with severe winter storms, extreme cold events, especially those caused by the combined effects of wind and cold temperatures, can occur during a severe winter storm. However, extreme cold events have been included as a separate hazard as they are not always associated with winter storms.

Location

It is assumed that all of Ann Arbor is uniformly exposed to the severe winter weather hazard.

DRAFT

Previous Occurrences

The NCEI Storm Events Database records winter-related weather events by county; city-specific data is not available. Therefore, all winter weather events reported for Washtenaw County are included. According to NCEI, there has been a total of 63 severe winter weather events in Washtenaw County since 1996. In total, these events resulted in 1 injury, and 1 death, over $15,700,000 in property damages. Summary details for these events are included in Table 4-17, and details for each reported event can be found in Appendix C.

Table 4-17: Previous Winter Weather Occurrences in Ann Arbor

Event Type	Number of Occurrences	Deaths/Injuries	Property Damage (2022 dollars)
Blizzard	1	0/0	--
Frost/Freeze	2	0/0	$1,747,091
Heavy Snow	33	0/0	--
Ice Storm	3	0/1	$6,792,890
Winter Storm	19	0/0	$6,753,053
Winter Weather	5	1/0	$444,057

DRAFT

Severe winter weather events in Ann Arbor are frequent. The events described below are the more serious events that have occurred within the recent past, as described by NCEI, the 2017 Ann Arbor Hazard Mitigation Plan, or from descriptions provided by city officials.

The Blizzard of 1978. A Presidential Emergency Declaration was granted for the entire state following a blizzard from January 26-27, 1978, when a severe snowstorm struck the Midwest, and Michigan was at the center of the storm (including the City of Ann Arbor). Dubbed a "white hurricane" by some meteorologists, the storm measured 2,000 miles by 800 miles and produced winds with the same strength of a small hurricane and tremendous amounts of snow. In Michigan, up to 34 inches of snow fell in some areas, and winds of 50-70 miles per hour piled the snow into huge drifts. At the height of the storm, it was estimated that over 50,000 miles of roadway were blocked, 104,000 vehicles were abandoned on the highways, 15,000 people were being cared for in mass care shelters, and over 390,000 homes were without electric power. Two days after the storm, over 90 percent of the state's road system was still blocked with snow, 8,000 people were still being cared for in shelters, 70,000 vehicles were stranded, and 52,000 homes were still without electricity.

Ice Storm of 1997. Low pressure tracked from the central Plains northeast across southeast lower Michigan late on the 13th through the 14th of March. The storm brought widespread precipitation to southeast Michigan from late on the 13th through midday on the 14th. North of Detroit, nearly all the precipitation fell in the form of freezing rain, with small amounts of snow and sleet noted in a few spots. From Detroit and Ann Arbor south to the state-line, the freezing rain changed to rain, but not before heavy ice accumulations occurred. Total precipitation amounts ranged from 1.5 to nearly 2.5 inches from Detroit and Ann Arbor south to the Ohio state-line. From the northern suburbs of Detroit north to Flint and Port Huron, amounts ranged from 0.8 to 1.5 inches. North of that area, amounts ranged from 0.40 to 0.80 inches. In the Detroit Metropolitan area, the ice storm resulted in power outages to over 425,000 homes and businesses; the 3rd largest outage in history, and the worst ever for an ice storm. Several thousand residents were without power for as long as 4 days. In addition to powerlines, falling trees damaged dozens of cars and houses throughout the area. Most were closed, and there were numerous auto accidents.[xxxi]

The Blizzard of 1999. A Presidential Emergency Declaration was granted for Washtenaw County following a blizzard on January 2, 1999, that brought over ten inches of snow to the area along with wind gusts to 45 MPH and extremely low wind chills. To compound the problem, heavy snows continued through the month, totaling almost 30 inches. These storms were responsible for numerous motor vehicle accidents, extreme traffic congestion, and government expenditure of an additional one million dollars for road maintenance and response costs. Snowfall amounts in Ann Arbor were 15 inches.

Snowstorms of 1999. In addition to the big snowstorms of January 2nd and 12th-13th, several smaller snow events occurred in the first half of January. By the middle of the month, snowfall was nearing historic proportions, with January of 1999 already among one of the snowiest months ever in southeast Michigan. Compounding the problem was a sustained cold spell during the first half of the month, which prevented any of the snow from melting. Some roofs across the area gave way under the immense weight of the snow, including one vacant building in Ann Arbor. Ice dams on roofs were another widespread problem. Heat escaping from homes melted some of the snow on the roof; as the meltwater ran down to the eaves, it refroze, as the eaves were not heated from underneath. Ice buildup on the eaves of roofs created ice dams; further meltwater had nowhere to go and found its way through shingles and into ceilings. Tens of thousands of buildings suffered leaks, resulting in a barrage of calls to both roofers and insurance agents. Leakage got into the Clements Library of the University of Michigan in Ann Arbor, damaging or destroying several rare maps and atlases.

The Blizzard of 2000. A Presidential Emergency Declaration was granted for Washtenaw County following a blizzard in December 2000. The severe winter storm produced record or near-record 24-hour snowfall levels in Washtenaw County, paralyzing the entire Ann Arbor region. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on December 13. The storm produced great hardships for the area, resulting in many school closings for 2 to 4 days, including closing Eastern Michigan University for only the second time ever. Also, mail delivery the next day was spotty at best, and many businesses and government offices were closed. Another series of winter storms the following week dumped an additional foot or more of snow across southern Lower Michigan, increasing snow depths in the Ann Arbor area. The tremendous snow depths caused a host of public health and safety concerns across the region. The snow fell at such a steady rate in the area that public works crews worked at maximum capacity – often around the clock – for two weeks just to keep pace. The cumulative effects of the heavy snowfall, high winds, and severe cold temperatures that began on December 11 caused problems across the region for the next several weeks. The sheer volume of snow made it difficult to handle, and the process of clearing it out of the way became difficult and expensive, as there was almost no place to put it. The winter storms of December 2000 produced the worst winter conditions to hit the Ann Arbor area, and Michigan in general since the statewide blizzards that occurred in January 1978 and January 1999.

DRAFT

The Ice Storm of 2002. The heaviest freezing rain of this event fell along a line from Ann Arbor to Detroit. Snowfall totals were as much as 12 inches in the cities of Ann Arbor and Dearborn Heights. After the snow had changed over to freezing rain, one quarter to one half of an inch of ice had accumulated onto trees and power lines by the evening of January 31st. The weight of the snow and ice on trees caused hundreds of tree limbs to break and even uprooted a few large trees. This did damage to dozens of homes and automobiles. Several people were also treated for heart attacks after shoveling heavy snow. Falling tree branches and the weight of the ice downed hundreds of power lines and left an estimated 290 thousand residents and businesses in the region without power, some of which had to wait several days for power to be restored.

The Ice Storm of 2007. An ice storm ensued from I-69 south to I-94. Widespread ice accumulations of a quarter to a half inch brought down numerous trees, power poles and power lines. Over 150,000 customers were without power at one time during the ice storm. Many were without power for 2 days, and some for over 3 days. Several senior homes lost power and 200 residents had to be evacuated from one of them. Most of the damage and associated power outages occurred between M59 and I94. Although roads were just warm enough to remain mainly wet, patchy slick spots and downed tree debris made traveling very hazardous. Damages to vehicles, homes, businesses, and electrical poles and transformers were reported. Downed power lines also sparked several garage fires. In addition, many businesses in the hardest hit areas reported losses due to the extended power outages.

The Blizzard of 2011. From February 1-2, 2011, a major winter storm occurred throughout much of Michigan including the Ann Arbor region. The storm brought 10 to 15 inches of snow and blizzard conditions to much of the area with wind gusts in excess of 40 mph combined with heavy snow to produce whiteout conditions and snowdrifts of 3 to 5 feet. Thunder accompanied the snow with snowfall rates exceeding two inches per hour. Many businesses, schools, and some government offices were closed the next day. Most main roads were plowed by the next day, but some side streets were not cleared for a couple more days.

Based on NCEI reported events, a search of emergency declarations, and a search of local news sources, no additional historic severe winter weather events have occurred since the 2012 plan.

Freeze of 2012. A record warm March allowed many fruit blossoms to bloom early. Then temperatures dipping into the 20s in late April led to severe damage of fruit crops.

Snowstorm of 2014. A major winter storm impacted southeast Michigan with heavy snow. Generally, 6 to 18 inches of snow across the area in about 30 hours. The M-59 and I-69 corridors received the highest amounts, as Flint Bishop Airport recorded 17.1 inches, making it the 3rd highest snowstorm on record. A location in Washtenaw County (Chelsea) recorded 14.0 inches of snowfall.

Snowstorm of 2015. In early February of 2015, a strong and slowing moving low pressure system tracked through the Ohio Valley delivering eight to seventeen inches of snow along and south of the I-69 corridor, with four to eight inches north of I-69. The drier nature of the snow and strong winds lead to significant drifts. This was a long duration event, as snow fell over a 24-hour period, with some locations toward the Ohio Border seeing snow for close to 30 hours. Ann Arbor received: 14.1 inches of snowfall.

DRAFT

Snowstorm of 2016. A long-duration snowfall occurred on December 11, 2016. A low-pressure system over the Central Plains moved northeast over Lower Michigan, bringing good moisture to the region. Total snowfall accumulations ranged from 7-11 inches across most of Southeast Michigan, with the exception being over Huron County where accumulations came up short of 6 inches. Ann Arbor received 11.2 inches of snowfall.

Winter Storm of 2018. A large and complex low-pressure system impacted the Great Lakes region. Southeast Michigan saw heavy rain, snow, sleet, and freezing rain that began on Friday, April 13 and lasted through Sunday, April 15. Total rainfall of 1 to 2 inches was common in many locations in Southeast Michigan, with 2-3 of snow and sleet north of I-69, and about 1/4 to 1/2 of ice from freezing rain between the I-94 and I-96 corridors. Widespread tree damage and power outages from a combination of the snow, sleet, and freezing rain occurred. In total, DTE and Consumers Energy reported power outages for nearly 500,000 customers due to the event. There was a reported $6.7 million of damage from this event in Washtenaw County.

Snowstorm of 2019. A long duration heavy snow event impacted southeast Michigan on Veterans Day 2019. The storm peaked during the noon/early afternoon timeframe when 1 per hour snowfall occurred over the western and northern suburbs of Detroit. In general, most of southeast Michigan saw between 6-12 inches of snow. Ann Arbor reported a snowfall total of 11.0 inches.

February 2022 Winter Storm. A winter storm warning was issued for Washtenaw County for February 2nd and 3rd. Although the event produced less snow that originally predicted, Ann Arbor still received a total of 6.2 inches of snow and the city was able to utilize their virtual emergency operations center. The Public Works Department responded to 3 water main breaks during the storm and successfully had the roads cleared by Friday morning. The incident provided vital experience for the Office of Emergency Management, and city staff were able to successfully employ the virtual emergency operations center, the Washtenaw County Joint Information Center, Michigan Critical Incident Management System, and NWS Chat during the event.

Extent

Severe winter weather extent can be measured in several ways, including snowfall accumulations or damages. According to the Michigan state hazard mitigation plan, record snowfall in Ann Arbor was 15.8 inches, occurring on December 1, 1974. The most damages reported during a single winter-related weather event was during the winter storm of 2018, which reportedly caused over $6.7 million in property damages. It should be noted that more severe winter weather events are possible for Ann Arbor.

Probability of Future Occurrences

Some type of severe winter weather is expected to strike the city every year. It is only a matter of how severe and how many such events might occur in a particular year that is difficult to predict in advance. Based on a reported 63 events in 26 years, Washtenaw County has historically experienced between two and three severe winter weather events per year. In addition, historic climate

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data shows that winter precipitation (December-February) in Ann Arbor is increasing over time, and the frequency of heavy precipitation events is also increasing. According to data from GLISA, winter precipitation (of any kind) in Ann Arbor increased by 65.3 percent from 1951 to 2021.

When determining future probability, the historic frequency must be considered along with projected future conditions. It is difficult to quantify the impact climate change will have on the future occurrence of severe winter weather events. According to a report from the Graham Sustainability Institute at the University of Michigan, winter precipitation in Michigan will increase between 5 percent and 20 percent by 2030, and between 5 percent and 25 percent by 2100.[xxxii] In addition, the frequency of heavy precipitation events (24-hour and multi-day) will continue to increase, which could lead to an increase in the number of severe winter weather events. Although warmer temperatures may lead to more rainfall in place of snowfall, precipitation could be more likely to fall as freezing rain.

Based on historic occurrences and future projections, the probability assigned to the severe winter weather hazard is highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

All current and future buildings, infrastructure, and populations are considered at risk to severe winter weather. Potential annualized loss from severe winter weather events is estimated at $393,427 (2022 dollars) based on 63 events between 1996 and 2022. Specific impacts to buildings, infrastructure, life safety, public heath, and the economy from severe winter weather are described below. Climate-related impacts and impacts to socially vulnerable populations are also described.

Damage to Buildings. All current and future buildings are at-risk to severe winter weather. Downed trees and branches can cause damage to buildings and other structures. The weight of heavy snowfall accumulation can cause roofs to collapse. In addition, ice dams can cause leaks and water damage to buildings. Ice dams occur when the bottom layer of snow or ice accumulated on a roof melts due to heat from the building, and runs off into eaves, where it refreezes. The refrozen water causes an ice dam.

Damage to Infrastructure. Winter precipitation and subsequent salting cause significant damage to roads and sidewalks. Cold temperatures result in freezing pipes that can rupture and leak. Snow and ice accumulations damage communication infrastructure and power lines. Resulting power outages can last for several days.

Life Safety, Health, and Warning and Evacuation Procedures. Health hazards related to walking and snow removal are frequent and life-threatening. Falls, particularly to the elderly, can result in serious injury including fractures, broken bones, and shattered hips. Middle-aged and older adults are susceptible to heart attacks from shoveling snow.

Dangerous driving conditions frequently occur during and shortly after severe winter storms. While vehicular accidents are often caused by the driver's lapse in judgment, the weather and its impact on roads are also a major factor. Blowing snow, ice, and slush create slippery pavement making vehicle travel less safe during and immediately following winter storms. Blizzards can create

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whiteout conditions, resulting in low to no visibility of roadways. Icey road conditions cause automobile crashes, resulting in injuries and loss of life.

Severe winter weather can result in the need to close schools, airports, and employment centers. In extreme cases, sheltering and evacuations may be required, especially if prolonged power outages are expected.

Public Health. When severe winter weather strikes, cumulative impacts can impact public health. Power outages and road closures can result in limited access to food, basic supplies, and an adequate heat source. Young children and the elderly are especially at risk. Further, if hospitals, senior homes, or similar facilities housing vulnerable populations lose power, inhabitants may need to be evacuated to a different location to receive proper care.

Carbon monoxide-related deaths are highest during extreme cold events, due to the increased use of gas-powered furnaces and alternative heating sources (e.g., generators, grills, and camp stoves) inside homes and buildings. Risk for fire and electric shock is also increases when using alternative heating and power sources, such as space heaters.[xxxiii]

Exposure during winter weather, including stranded motorists or households without an adequate heat source, can result in hypothermia or frostbite.

Impacts to Socially Vulnerable Populations. Socially vulnerable populations may be most susceptible to negative consequences of severe winter weather. Households with inadequate heating sources, or those that cannot afford heating costs, may be more likely to use alternative heat sources, which presents increased fire and/or carbon monoxide threats. The unhoused may face exposure risks. Income-constrained individuals may feel pressure to report to work and commute in unsafe travel conditions. Individuals without paid leave who are unable to commute (e.g., unsafe, public transit not running) may experience income loss.

Economic Impact. Loss of power during a severe winter storm means businesses and/or public facilities must close down. Loss of access due to snow- or ice-covered roads has a similar effect. There are also impacts when people cannot get to work, to school, or to the store. Flights are often canceled. Expenses to local, state, and federal governments to repair roads, power outages, and other damages resulting from severe winter weather can balloon quickly. Overall reduced snow cover and warmer winters could impact winter recreation and tourism.

Climate Change Impacts. Climate change impact could have mixed impacts on winter weather in the city. Generally, more winter precipitation is expected in the future. Winter precipitation in Michigan will increase between 5 percent and 20 percent by 2030, and between 5 percent and 25 percent by 2100.[xxxiv] In addition, the frequency of heavy precipitation events (24-hour and multi-day) will continue to increase, which could lead to an increase in the number of severe winter weather events. The transition from snowfall to more freezing rain as temperatures warm could result in increased icy road conditions or refreezing of rain.

Climate projections indicate that winters in Ann Arbor will be warmer by the end of the century, as presented in Table 4-11 under the *Extreme Cold/Wind Chill* profile.

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Severe Winds

Description

There are several types of wind hazards that affect the planning area. These include high or strong wind events and thunderstorm wind events (including straight line winds). Tornadoes are also wind events that impact the city, which are listed as separate hazards due to their impacts and hazard potential.

High Wind definitions can vary by region. In general, high wind events are those events greater than normal averages and have damage potential. Wind events are common throughout the United States. However, the severity varies depending on location. Figure 4-12 below shows wind zones in the U.S. based on ASCE 7-98 criteria.[xxxv] These zones reflect the number and strength of extreme windstorms. According to the map, Ann Arbor is located in Wind Zone IV, which includes winds speeds up to 250 miles per hour.

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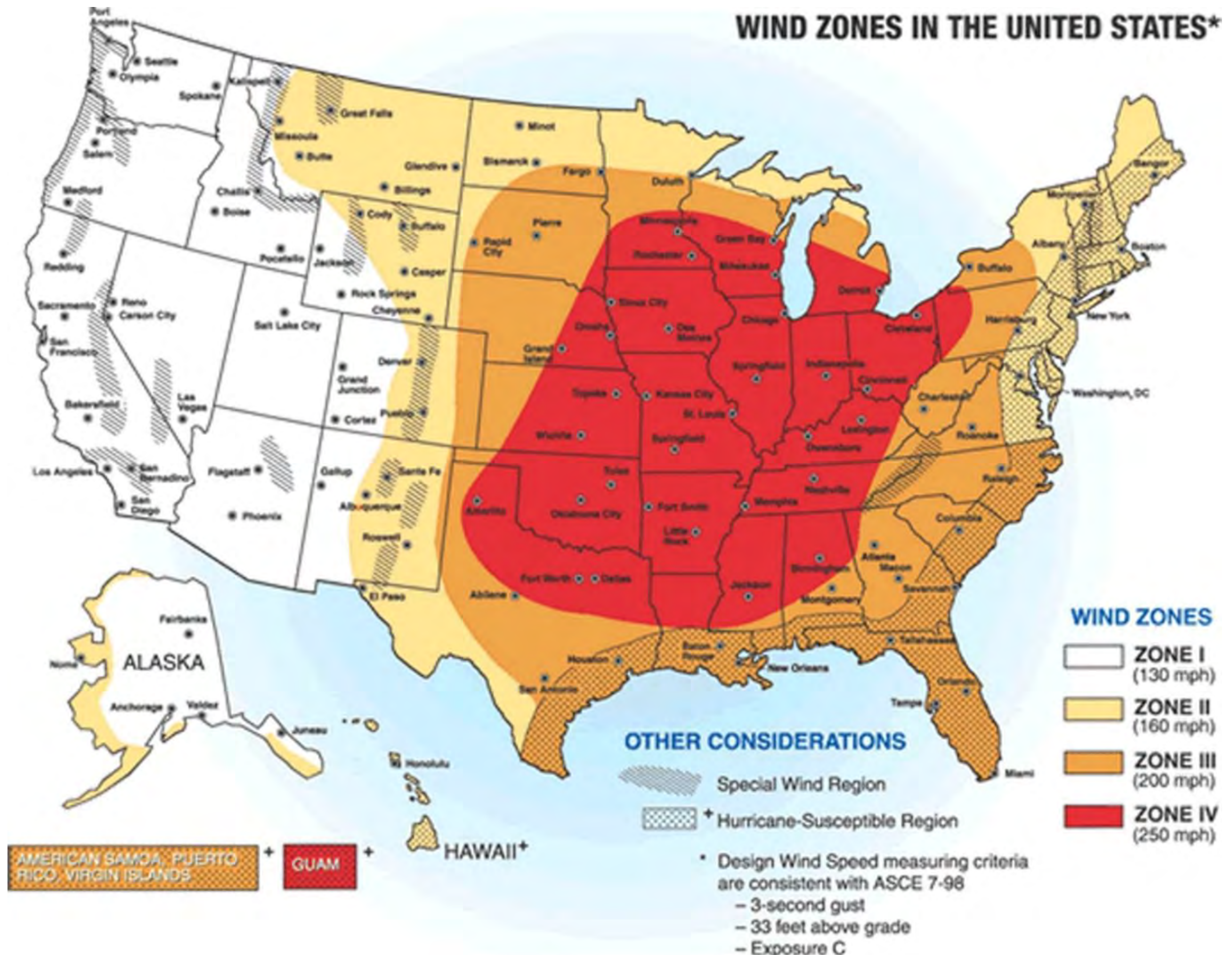

Figure 4-12: ASCE 7-98 U.S. Wind Zones

The National Weather Service Center can issue a high wind advisory or warning. A wind advisory is issued when conditions are favorable for the development of high winds over all or part of the forecast area, but the occurrence is still uncertain. The criteria of a wind advisory are sustained winds of 31 to 39 mph and/or gusts 46 to 57 mph for any duration. A high wind warning is issued when sustained winds from 40 mph or higher are expected for at least one hour or if any wind gusts are expected to reach 58 mph or more.[xxxvi] The definitions vary from state to state. Areas that frequently experience these high winds will not always issue the advisory or warning. A Beaufort Wind Scale may also be used to describe wind severity as shown in Table 4-18 below.

Table 4-18: The Beaufort Wind Scale[xxxvii]

Beaufort Number	Wind (MPH)	Description	On the Water	On Land
0	Less than 1.2	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1.2-3.5	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	3.6-6.9	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	7.0-11.5	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	11.6-18.4	Moderate Breeze	Small waves 1-4 ft. becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted; small tree branches move
5	18.5-24.2	Fresh Breeze	Moderate waves 4-8 ft. taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	24.3-31.1	Strong Breeze	Larger waves 8-13 ft., whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	31.2-38.0	Near Gale	Sea heaps up, waves 13-19 ft., white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	38.1-46.0	Gale	Moderately high (18-25 ft.) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Twigs breaking off trees, generally impedes progress
9	46.1-54.1	Strong Gale	High waves (23-32 ft.), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	54.2-63.3	Storm	Very high waves (29-41 ft.) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	63.4-72.5	Violent Storm	Exceptionally high (37-52 ft.) waves, foam patches cover sea, visibility more reduced	
12	72.6+	Hurricane	Air filled with foam, waves over 45 ft., sea completely white with driving spray, visibility greatly reduced	

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Thunderstorms are very dangerous because of their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and damaging lightning. While thunderstorms can occur in all regions of the United States, they are most common in the central and southern states because atmospheric conditions in those regions are ideal for generating these powerful storms. In Michigan, thunderstorms are most common in the summer months.

Three conditions need to occur for a thunderstorm to form. First, it needs moisture to form clouds and rain. Second, it needs unstable air, such as warm air that can rise rapidly (this often referred to as the "engine" of the storm). Third, thunderstorms need lift, which comes in the form of cold or warm fronts, sea breezes, mountains, or the sun's heat. When these conditions occur simultaneously, air masses of varying temperatures meet, and a thunderstorm is formed. These storm events can occur singularly, in lines, or in clusters. Further, they can move through an area very quickly or linger for several hours.

Straight-line winds, which in extreme cases have the potential to cause wind gusts that exceed 100 miles per hour, are responsible for most thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation.

According to the National Weather Service, more than 100,000 thunderstorms occur each year, though only about 10 percent of these storms are classified as "severe." A severe thunderstorm occurs when the storm produces either hail of inch or greater or has winds of at least 58 miles per hour.[xxxviii]

Figure 4-13 illustrates thunderstorm hazard severity based on the annual average number of days with a thunderstorm event. According to the map, Ann Arbor experiences between 27 and 45 thunderstorm days per year.

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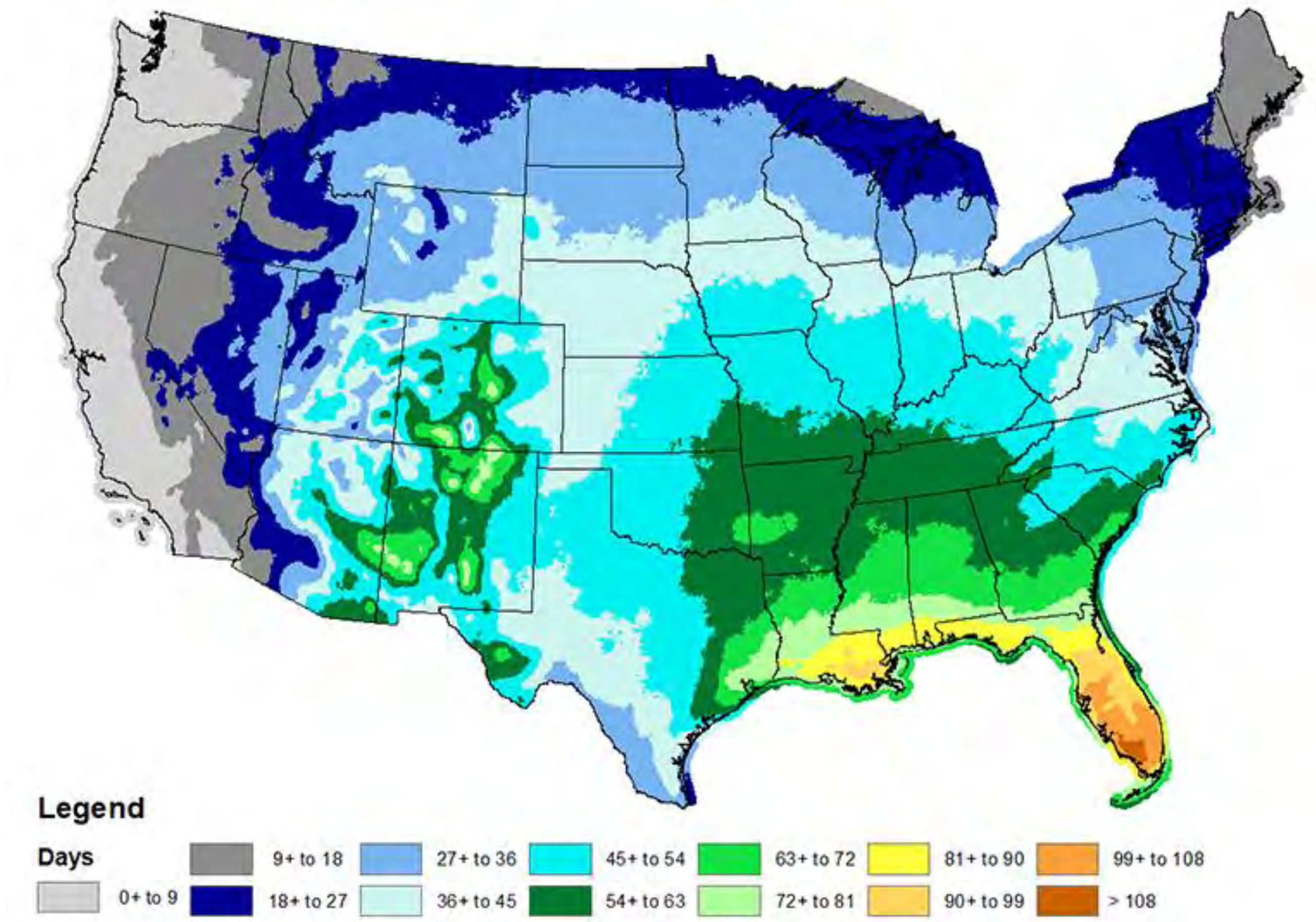

Figure 4-13: Annual Average Days with Thunderstorms (1993-2018)[xxxix]

Location

It is assumed that all of Ann Arbor is uniformly exposed to severe wind hazards.

Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports wind event information by county and, when the information is available, by city or by coordinate location. Of the 498 wind events reported for Washtenaw County between 1957 and 2021, 75 events noted impacts within Ann Arbor, including 63 thunderstorm wind events, 2 strong wind events, and 10 high wind events. These events resulted in no reported deaths and three reported injuries. Reported damages from these events totaled $44,299,359 (2022 dollars). It is likely that some wind events and damages to private property were not reported to NCEI. Therefore, the number of events and resulting damages is likely higher than what is indicated. Information on notable events in Ann Arbor are described below, as available. Details for each reported event can be found in Appendix C.

July 1998 Thunderstorms. On July 21, 1998, thunderstorms continued to intensify as they moved east into the densely populated Ann Arbor-Ypsilanti area. Ann Arbor Municipal Airport measured a 75-mph wind gust, which blew two hangars off their foundations, damaged the doors of three hangars, and damaged several planes. At least 75 trees were downed in Ann Arbor, most on the south side of town. Overall, more than a thousand trees and five thousand power lines were downed in southeast Michigan. Over 600,000 businesses and residences lost power at some point. For Detroit Edison, this was the fourth worst weather system of all time regarding power outages. The power was out for over a week in spots. Damage in Ann Arbor was reported at $9,094,287.

December 1998 Thunderstorm. A thin line of showers and thunderstorms moved east across the state at about 50 mph. Many of the storms along the line produced wind damage. The result was a December severe weather episode - a rather uncommon event for Michigan. Most of the wind damage occurred immediately behind the line of convection, and most of the damage involved the downing of trees, large limbs, and power lines. Damage was a little heavier across Washtenaw and Wayne Counties. A 64-mph gust was measured at the University of Michigan in Ann Arbor, while Detroit Metropolitan Airport had a 60mph gust. Damage in Ann Arbor was reported at $353,667.

July 1999 Thunderstorm. A trough of low pressure moved east into the western Great Lakes by late morning, and thunderstorms ignited along the trough. These storms moved southeast into Michigan, and many of them became severe. Several tents at the Ann Arbor Art Fair were demolished. The thunderstorm hazard resulted in over a hundred flights at Detroit Metropolitan Airport being either delayed or cancelled. Damage in Ann Arbor was reported at $69,076.

May 2000 Thunderstorm. Thunderstorms erupted in the region the night of May 9th. Most of the damage was in the form of trees, tree limbs, and power lines downed. The most substantial damage was in Washtenaw County. In Ann Arbor, falling trees crushed two cars. All told, over 40,000 people in southeast Michigan lost power at some point during the storms. Damage in Ann Arbor was reported at $57,483.

April 2001 Thunderstorm. Thunderstorms ignited ahead of a cold front, and several became severe, producing sporadic wind damage. A tree and several large limbs were downed onto State Street, landing on two cars. Damage in Ann Arbor was reported at $18,603.

DRAFT

June 2006 Thunderstorm. On Tuesday June 27th, an upper-level disturbance led to an environment with moderate instability and moderate windshear. The atmosphere was also susceptible to strong downbursts as evidenced by A severe storm with strong downbursts tracked across Washtenaw County and produced hail up to the size of golf balls. A wind gust measured 56 knots at the Ann Arbor airport. Law Enforcement reported a tree blown down on car and six utility poles downed. $25,675 in damages were reported.

July 2006 Thunderstorm. The July 17th severe weather event would eventually go down as the largest and most destructive of the 2006 severe weather season. Intense thunderstorms fired along and ahead of a cold front working down from the northern Great Lakes and eventually developed into a large MCS by mid evening. Reports indicate at least 13 downed trees in the area; $56,165 in damages were reported in Ann Arbor.

May 2014 Thunderstorm. On the afternoon of May 13, 2014, a line of thunderstorms raced across southeast Michigan, bringing winds, heavy rain, and frequent lightning with numerous reports of trees down, power outages, and local flooding. Wind gust measurements ranged from 50 to 60 mph. Several trees were downed, some of which fell onto homes which caused structural damage. Additionally, a large tree was uprooted and fell onto detached garage. Damage in Ann Arbor was reported at $133,011.

November 2014 Windstorm. High winds occurred across Southeast Michigan during the afternoon of November 24. Peak winds gusted at 50 knots. Numerous downed trees and power lines were reported, which lead to power outages reaching close to 200,000 at the peak of the wind event. Damage in Washtenaw County was reported at $63,338.

February 2016 Windstorm. Strong southwest winds of 50 to 60 mph brought down trees, tree limbs, and power lines, mainly along the M-59 corridor and I-94 corridors of Southeast Michigan. DTE reported 117,000 customers were affected during the peak early Friday evening, with 75,000 customers remaining without power into Saturday and the next day. Damage in Washtenaw County was reported at $4,776,209.

March 2017 Windstorm. On March 8, 2017, severe winds (not associated with a thunderstorm) with gusts of 60mph knocked down trees and power lines in Southeast Michigan, causing widespread damages, with numerous reports of structural damage to buildings. There were also reports of brush fires and tractor-trailers flipped over around the area. Due to the extensive damage, many areas were without power for several days. Approximately 800,000 DTE customers and approximately 300,000 Consumers Energy customers were affected. The University of Michigan alone reported over $695,564 (2022 dollars) in damages. Damage in Washtenaw County was reported at $28,981,852.

February 2019 Windstorm. A low-pressure system quickly intensified over the weekend of February 23-24th, as it crossed the Great Lakes region. This system brought blizzard warnings to western portions of the Great Lakes and high winds across the rest of the region, with gusts around 60 mph range. Widespread downed tree limbs with sporadic structural damage reported. Downed power lines led to close to 200,000 customers without power across southeast Michigan, with some of outages lasting into Monday. Ann Arbor reported wind gusts of 55 mph. Damage in Washtenaw County was reported at $500 (likely under-reported).

DRAFT

July 2019 Windstorm. A hot and humid air mass in place allowed a few severe thunderstorms to develop during the early evening hours which impacted areas between the M-59 and I-96 corridors. Tents were blown down at the Ann Arbor Art Fair which resulted in one injury.

Extent

Thunderstorm wind extent is measured in terms of wind speed. The greatest sustained wind reported in Washtenaw County was 80 knots, or 92 miles per hour. However, stronger gusts are possible. Extent can also be measured in terms of damage. The greatest amount of damage reported from a single wind event in Washtenaw County was $28 million. However, costlier events are possible.

Probability of Future Occurrences

According to NWS, Ann Arbor is located in an area of Michigan that experiences 27-45 thunderstorm days per year (Figure 4-13). Further, the State of Michigan hazard mitigation plan indicated that Ann Arbor is in an area that experiences an average of 34 thunderstorm days per year. NCEI data reported 111 wind events over 63 years, indicating that Ann Arbor experiences more than one wind event per year. However, it is likely NCEI data is not inclusive of all events that have occurred in the city during this time. Thunderstorms occur regularly in Ann Arbor, especially in the summer when weather is conducive to convective storms, although all events may not result in damage.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xl] Because wind events in Ann Arbor are often affiliated with severe thunderstorms, trends in wind event frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments.[xli] Additionally, the IPCC has indicated their predictive models show an increase in severe storms and a longer convective storm season in the US.[xlii] While it is difficult to quantify these trends in terms of future wind event occurrences, they can be considered when determining future probability.

Considering the frequency of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, a probability of highly likely (greater than 90 percent annual chance) was assigned to the severe wind hazard.

Vulnerability Assessment

All of Ann Arbor is vulnerable to severe storms due to the topography and movement of weather fronts through the area. Potential annualized loss from severe wind is estimated at $379,260 (2022 dollars) based on 111 events from 1960 to 2022, although this

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estimate included damages for several county-wide events. Specific impacts to buildings, infrastructure, life safety, public heath, and the economy from lightning are described below. All current and future buildings, infrastructure, and populations are considered at-risk to severe wind. Climate-related impacts to the severe wind events are also described.

Damage to Buildings. All current and future buildings in Ann Arbor are considered at-risk to severe winds. Severe wind has the potential to blow shingles, siding, awnings, and other features off buildings. Falling trees and tree limbs can damage structures. Objects picked up by wind can be hurled through the air, damaging structures and breaking windows when contact is made. In some cases, structures can be blown off foundations. This happened during the 1998 thunderstorm when two airport hangers were blown off their foundations at the Ann Arbor Municipal Airport. In addition, mobile homes are considered at a higher risk to severe wind. According to the TAC, Ann Arbor has one mobile home park. Proper anchoring can make mobile homes more resilient to severe wind.

Damage to Infrastructure. Severe winds can cause damage to critical infrastructure, including communications infrastructure, utility poles, and above ground power lines can be blown down.

Life Safety, Health, and Warning and Evacuation Procedures. Severe winds can result in serious life safety impacts. People outside during severe wind events may be struck by falling trees and limbs, or by objects falling off buildings or being hurled through the air.

In the event that winds of 75 miles per hour are confirmed anywhere in Washtenaw County, the city's siren warming system will deploy. The system has 22 sirens throughout Ann Arbor, which provide total coverage throughout the city, as demonstrated by Figure 4-14.

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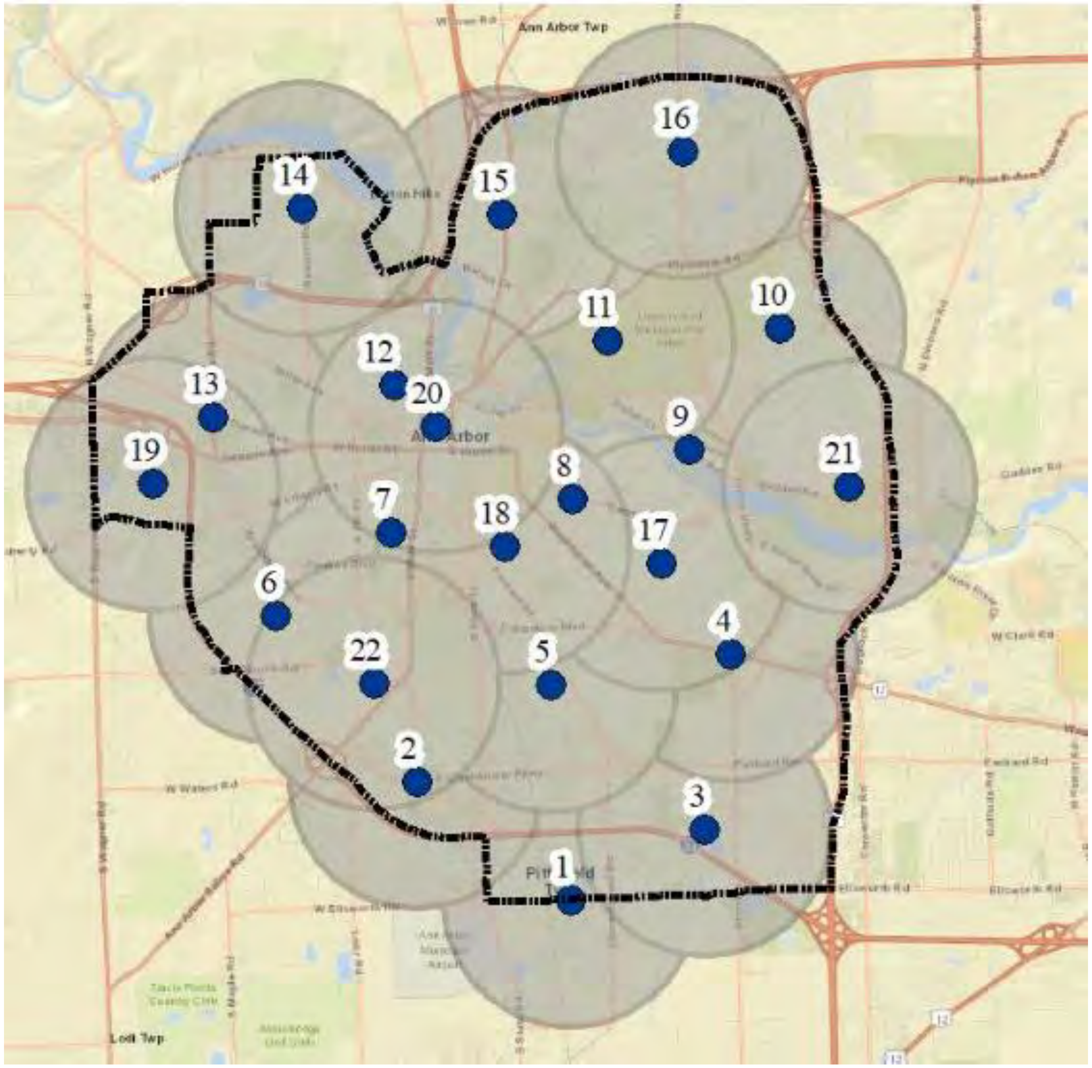

Figure 4-14: Ann Arbor Siren Warning System and Coverage Area

Public Health. No special public health issues are attributable to severe winds.

Impacts to Socially Vulnerable Populations. Severe wind events can disproportionally impact families living in manufactured homes or in housing built prior to modern building codes. As demonstrated by some of the previous storm events, powerful wind gusts can blow structures off their foundation. To reduce the threat of severe wind events, manufactured homes should be properly anchored. Ideally a storm shelter would be constructed for use by residents of the local mobile home park, and residents should be prepared for a severe wind event. Non-English speakers may not be able to understand warnings given in English in order to make life-saving decisions in a timely manner. Emergency procedures to be conducted during an event should be established ahead of time and exercised, ensuring that messaging and signage is provided in multiple languages. Income constrained households may face challenging repairing damages from windstorms.

Economic Impact. Communication lines, antennas, and towers can suffer damage from wind and downed branches/trees. Damages to buildings, roads, and vehicles can be costly. Businesses interruptions can occur due to power outages. Outdoor events may be cancelled. Flights may be delayed or canceled due to severe wind events. Each of these can result in business interruption.

Climate Change Impacts. Changes to severe wind intensity (extent) and frequency due to climate change are uncertain, and research is ongoing. Research cited by the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments in the Great Lakes Region (1.2 to 2.4 days per season from 2070-2099), which could lead to an increase in the frequency of thunderstorm wind events in Ann Arbor.

Tornadoes

Description

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the National Weather Service, tornado wind speeds normally range from 40 miles per hour to more than 300 miles per hour. The most violent tornadoes have rotating winds of 250 miles per hour or more, are capable of causing extreme destruction, and can turning normally harmless objects into deadly missiles.

Each year, an average around 1,200 tornadoes are reported nationwide, resulting in an average of 60 deaths and 1,500 injuries. According to the NOAA Storm Prediction Center (SPC), the highest concentration of tornadoes in the United States has been in Oklahoma, Texas, Kansas, and Florida, respectively. The Great Plains region of the Central United States favors the development of the largest and most dangerous tornadoes (earning the designation of "Tornado Alley"), counties in Colorado and Texas experienced the greatest number of tornadoes in all the U.S. states from 1950 to 2016.[xliii] Figure 4-15 shows tornado activity in the

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United States based on the number of recorded tornadoes per county from 1952 to 2010.[xliv] According to the map, Washtenaw County, where Ann Arbor is located, experienced 10 to 30 recorded tornadoes over the 58-year period.

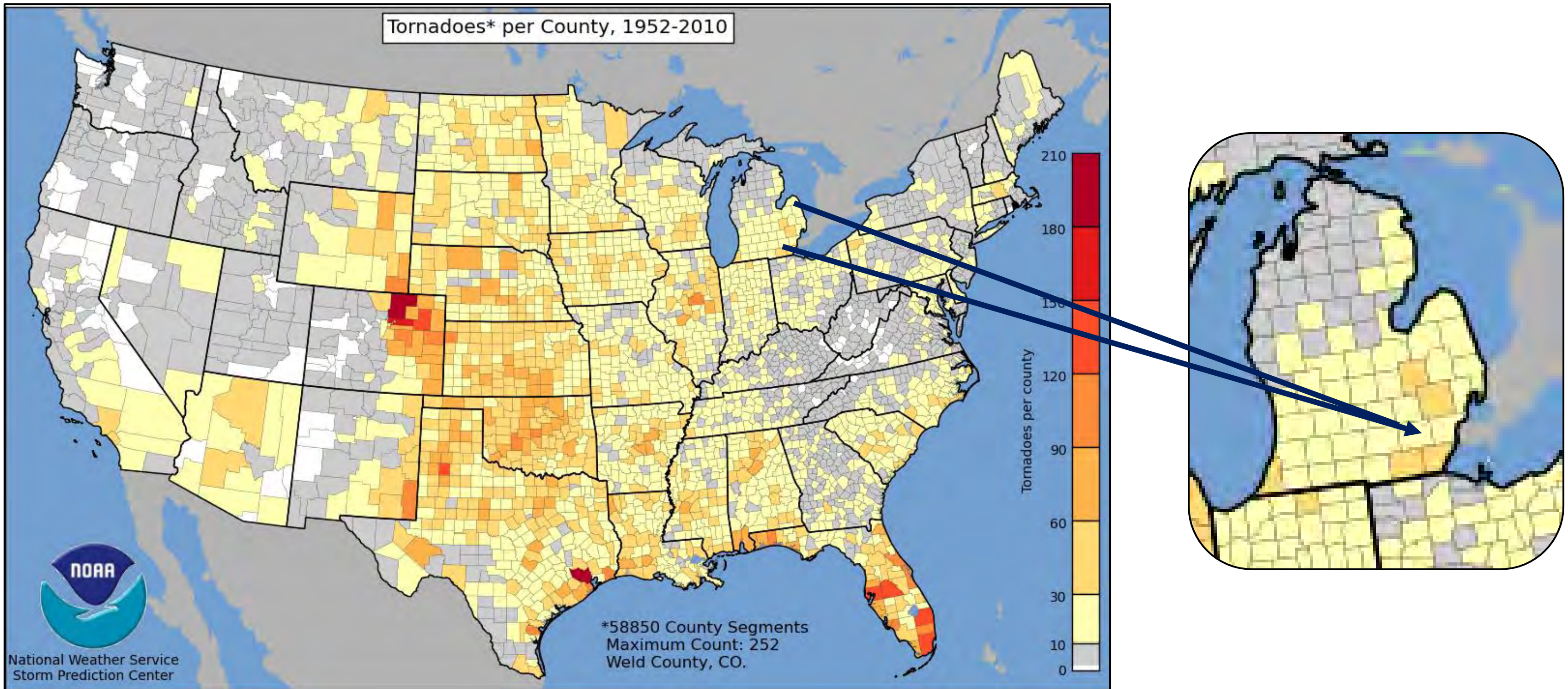

Figure 4-15: U.S. Tornado Occurrences by County

Tornadoes are most likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touchdown briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, including residential dwellings (particularly mobile homes). Tornadic magnitude is reported according to the Fujita and Enhanced Fujita Scales. Tornado magnitudes prior to 2005 were determined using the traditional version of the Fujita Scale, Table 4-19. The Enhanced Fujita Scale, used after 2005 (Table

4-20), identifies six different categories of tornadoes, EF0 through EF5. Tornado magnitudes that were determined in 2005 and later were determined using the Enhanced Fujita Scale.

Table 4-19: The Fujita Scale (effective prior to 2005)

F-Scale Number	Intensity	Wind Speed	Type of Damage Done
F0	GALE TORNADO	40–72 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
F1	MODERATE TORNADO	73–112 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	SIGNIFICANT TORNADO	113–157 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	SEVERE TORNADO	158–206 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F4	DEVASTATING TORNADO	207–260 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown, and large missiles generated.
F5	INCREDIBLE TORNADO	261–318 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.
F6	INCONCEIVABLE TORNADO	319–379 MPH	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

DRAFT

Table 4-20: The Enhanced Fujita Scale (effective 2005 and later)

Ef-Scale Number	Intensity Phrase	3 Second Gust	Type of Damage Done
EF0	GALE	65–85 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
EF1	MODERATE	86–110 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	SIGNIFICANT	111–135 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	SEVERE	136–165 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
EF4	DEVASTATING	166–200 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown, and large missiles generated.
EF5	INCREDIBLE	Over 200 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.

Tornado damage may include crop and property damage, power outages, environmental degradation, injury, and death. Tornadoes are known to blow off roofs, move cars and tractor trailers, and demolish homes. Typically, tornadoes cause the greatest damage to structures of light construction, such as residential homes.

In 1999, FEMA conducted an extensive damage survey of residential and non-residential buildings in Oklahoma and Kansas following an outbreak of tornadoes on May 3, 1999, which killed 49 people. The assessment found:

- The failure for many residential structures occurred where the framing wasn't secured to the foundation, or when nails were used as the primary connectors between the roof structure and the walls. A home in Kansas, for example, was lifted from its foundation. The addition of nuts to the foundation anchor bolts (connected to the wood framing) may have been all that was needed to prevent this.
- Roof geometry also played a significant role in a building's performance.
- Failure of garage doors, commercial overhead doors, residential entry doors or large windows caused a significant number of catastrophic building failures.

DRAFT

- Manufactured homes on permanent foundations were found to perform better than those that were not on solid foundation walls.

According to the State of Michigan Hazard Mitigation Plan, tornadoes are most frequent in Michigan in the spring and early summer when warm, moist air from the Gulf of Mexico interacts with cold air from polar regions, resulting in severe thunderstorms. Most tornadoes in Michigan come from the southwest and travel northeast, and most occur in the southern part of the Lower Peninsula. From 1950-2019, Michigan has averaged 15 tornadoes and 4 tornado-related deaths per year.

Location

Tornadoes have the potential to strike anywhere. They are more common in open spaces (such as the Great Plains). Tornadoes are rarer in areas where there are lots of hills or mountains. Once a touchdown occurs, it may only affect a small area or travel for miles, leaving substantial destruction in its path. Further, it is impossible to predict where and with what magnitude a tornado will strike. Therefore, it is assumed that all of Ann Arbor is equally exposure to tornadoes.

Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports tornado information by county and, when the information is available, by city or by coordinate location. Of the 28 tornado events reported for Washtenaw County between 1951 and 2022, 2 events occurred in Ann Arbor. Neither of these events resulted in deaths or injuries, and neither resulted in significant damages (under $100). Further, the NOAA Storm Predication Center noted another tornado event that tracked through Ann Arbor in 1988, resulting in just under $70,000 in damages. The locations of tornado occurrences in Ann Arbor are shown in Figure 4-16. Detailed information on events reported in Ann Arbor are presented in Table 4-21.

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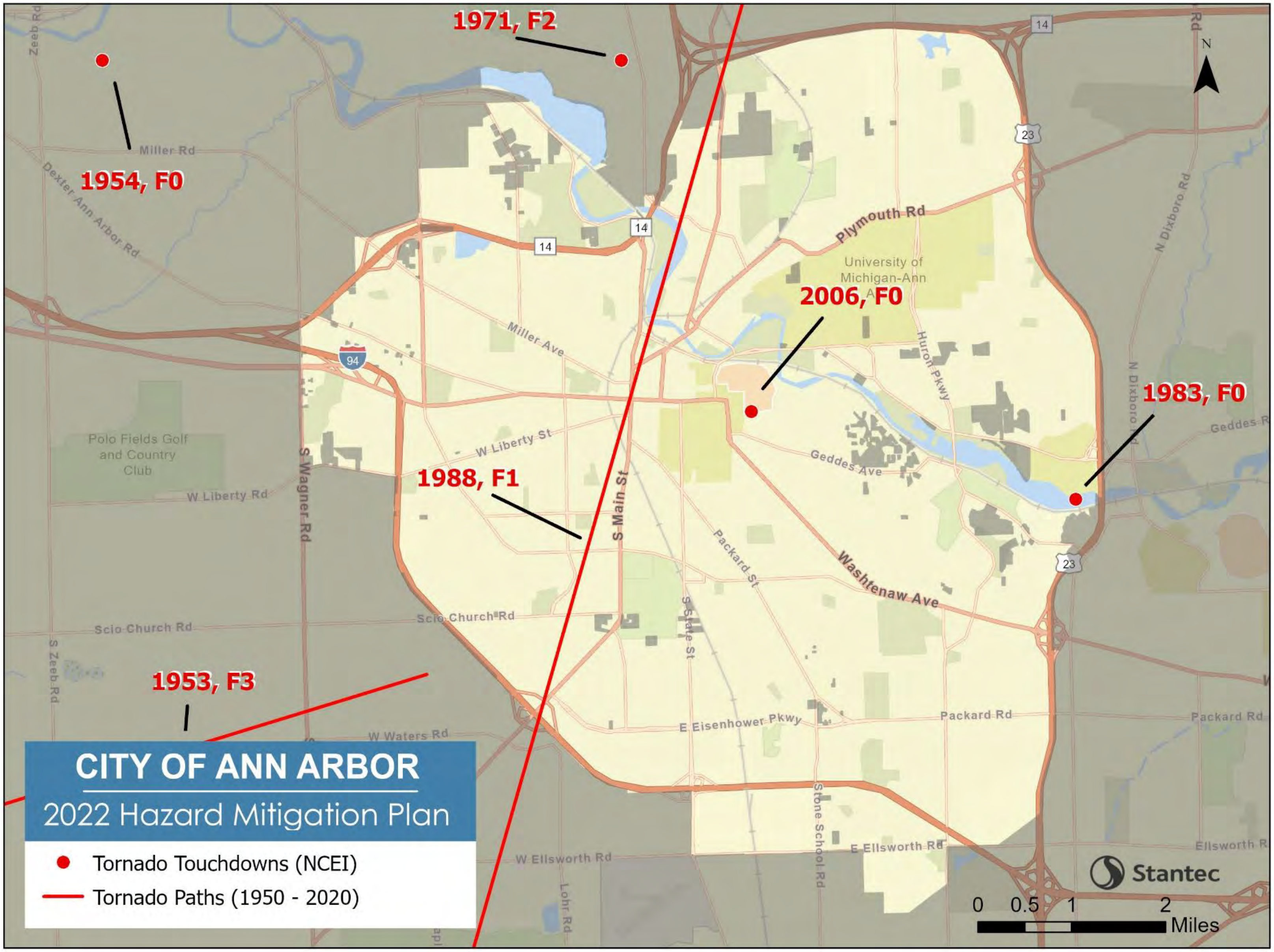

Figure 4-16: Historic Tornadoes in Ann Arbor

Table 4-21: NOAA Tornado Events in Ann Arbor

Date	Magnitude	Damages (2022 dollars)	Event Details
7/21/1983	F0	$99	Tornado was 0.1 miles long and 10 yards wide.
4/03/1988	F1	$69,613	None available
9/30/2006	F0	--	Washtenaw County Emergency Manager, trained spotters, and Michigan State Police all reported a weak tornado at the I94 and US 23 interchange. The Tornado/cold air funnel was very brief and just kicked up some dirt with wind speeds estimated between 40 and 50 mph. There were no injuries and no damages. Tornado was 0.2 miles in length and 25 yards wide.

In addition to the events noted above, the TAC noted a downburst or potential tornado event in summer 2021 that resulted in blocked roads and debris in the river.

Extent

The greatest extent tornado to impact Ann Arbor was an F1 on the Fujita Scale (73 to 112 mph). However, more severe events are possible. For example, the greatest extent tornado to impact Washtenaw County was an EF3 on the Enhanced Fujita Scale (136 to 165 mph), which resulted in just over $16 million in damages. A single tornado event has the potential to be devastating.

Probability of Future Occurrences

With 3 reported tornado events in 71 years, Ann Arbor experiences less than one tornado every 25 years. It is possible that other, unrecorded tornadoes have occurred. Being in the Midwest, Ann Arbor is located in a region with high potential for tornadoes. Further, a study performed by Northern Illinois University shows that over the last 40 years, tornado alley (typically Texas and the Great Plains) may be shifting eastward, with the Midwest and Southeast experiencing an increasing number of tornadoes (Figure 4-17).

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events), and research is ongoing.[xlv] Because tornadoes are usually generated from thunderstorms, trends in tornado frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation in the United States. For the Great Lakes Region spring season, the study

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indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments during 2070-2099.[xlvi] While it is difficult to quantify these trends in terms of future tornado occurrences, they can be considered when assigning future probability. Considering the above, a probability of possible (1 percent to 10 percent annual chance) was assigned.

Vulnerability Assessment

All of Ann Arbor is vulnerable to tornadoes. The potential for loss of life and property damage are significant given the amount of built environment in the area. This vulnerability continues to increase as Ann Arbor continues to expend and densify. All current and future buildings, infrastructure, and populations are considered at-risk to tornadoes. Negligible dollar losses are attributed to tornado events in Ann Arbor, but substantial future losses are possible. Potential impacts to buildings, infrastructure, life safety, public heath, and the economy are described below. Impacts to socially vulnerable populations and climate-related impacts are also described.

Damage to Buildings. All current and future buildings in Ann Arbor are considered at-risk to tornadoes. Buildings located above-ground in the path of a tornado can suffer extensive damage and/or complete destruction. Although some buildings adjacent to a tornado's path can stand with little or no damage, debris hurled by the wind makes all buildings vulnerable to damage. Although all buildings are vulnerable to tornadoes, three types of structures are more likely to suffer damage:

1. Mobile homes;
2. Homes on crawlspaces (more susceptible to lift); and
3. Buildings with large spans, such as airplane hangars, gymnasiums, and factories.

Schools are a particular concern for two reasons:

1. They have large numbers of people present, either during school or as a storm shelter.
2. They have large span areas (open areas with high ceilings), such as gyms and theaters.

University of Michigan is particularly vulnerable to tornadoes given large number of students and employees present on campus at any given moment. A parallel can be drawn to the University of Alabama, which in April 2011 experienced an EF4 tornado that resulted in 36 fatalities, including several students and university employees. Due to damages and loss of life, the university cancelled the rest of the school year and delayed graduation.

Damage to Infrastructure. All infrastructure in Ann Arbor is considered at-risk to tornadoes. Above-ground infrastructure in the path of a tornado can suffer extensive damage and/or complete destruction. When roads close, there are usually other transportation routes available.

Life Safety, Health, and Warning and Evacuation Procedures. Tornadoes can have severe impacts on life safety. Tornadoes can occur without warning, and reaction time may be short. Injuries or loss of life can result when people out in the open are in or near

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a tornado's path; exposed individuals can be picked by tornado winds or struck by debris. People inside structures that are impacted by tornadoes may suffer injuries or death if trapped in a collapsed building or struck by flying or falling objects. Motorists should not attempt to drive during a tornado event. The Centers for Disease Control recommend that any person in the path of a tornado find shelter or a tornado safe-room immediately. Sheltering in a basement or under a sturdy object is recommended when a tornado safe-room is not an option. Head injuries are a common cause of death from tornadoes; therefore, individuals should attempt to protect their heads during tornado events.

In the event of a tornado warning anywhere in Washtenaw County, the city's siren warning system will activate. The warning system consists of 22 sirens providing coverage for the entire city as demonstrated in Figure 4-12 under this profile's equivalent in the *Severe Winds* profile.

Public Health. Public health issues from tornadoes can include water contamination, as well as potential for fire and gas leaks. Damages to certain exposed infrastructure, such as pipelines or septic tanks, can result in hazardous materials spills and leaks.

Impacts to Socially Vulnerable Populations. Tornado events can disproportionally impact certain socially vulnerable populations. Individuals living in manufactured homes or in housing built prior to modern building codes. To reduce the threat of tornado events, manufactured homes should be properly anchored. Ideally a storm shelter would be constructed for use by residents of the local mobile home park, and residents should be prepared for a tornado. Emergency procedures to be conducted during an event should be established ahead of time and exercised, ensuring that messaging and signage is provided in multiple languages. Tornados can have devasting impacts with little warning time available; therefore, populations who are not able to quickly respond to warnings, such as those who are mobility challenged, non-English speakers, blind/sight impaired, or deaf/hard of hearing may have difficulty seeking shelter in a timely manner.

Economic Impact. When businesses and infrastructure are damaged by a tornado, the city may suffer economic loss. Heavily damaged businesses often must close, impacting business owners. Loss of business can alter the local economy depending on the duration of closures. In addition, the cost of repairs can severely affect businesses, and it is possible that small business owners may not be able to reopen at all. Power outages can affect a business, even if a business' structure is not damaged.

Public expenditures include search and rescue, shelters, and emergency protection measures. The large expenses are for repairs to public facilities and clean-up and disposal of debris. Many public facilities are insured, so the economic impact on the local treasury may be small.

Clean-up and disposal can be a larger problem (both structural and vegetative debris), especially if there is limited landfill capacity near the damage site.

Climate Change Impacts. There is still some uncertainty as to the specific link between tornadoes and changing climatic conditions, and more research is needed to understand the full impact of climate change on tornadic activity. Due to the small scale of tornado events, observation and modeling can be challenging. Because tornadoes are usually generated from thunderstorms,

DRAFT

trends in tornado frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation in the United States. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments during 2070-2099.[xlvii]

Another study cited by the Fourth National Climate Assessment highlighted that although the number of days with a tornado in the US have decreased; however, the number of days with multiple tornadoes has increased. This has resulted in increased variability in annual and monthly tornado trends, as well increasing variability in the start of tornado season. Additionally, a recent study published by Northern Illinois University, in partnership with the NOAA, indicates that tornado alley as we know it (e.g., Texas and the Great Plains) is shifting east, and that the frequency of tornadoes in the Southeast and Midwest regions is increasing.[xlviii] Figure 4-17 illustrates the study's findings of observed tornado trends over the last 40 years.

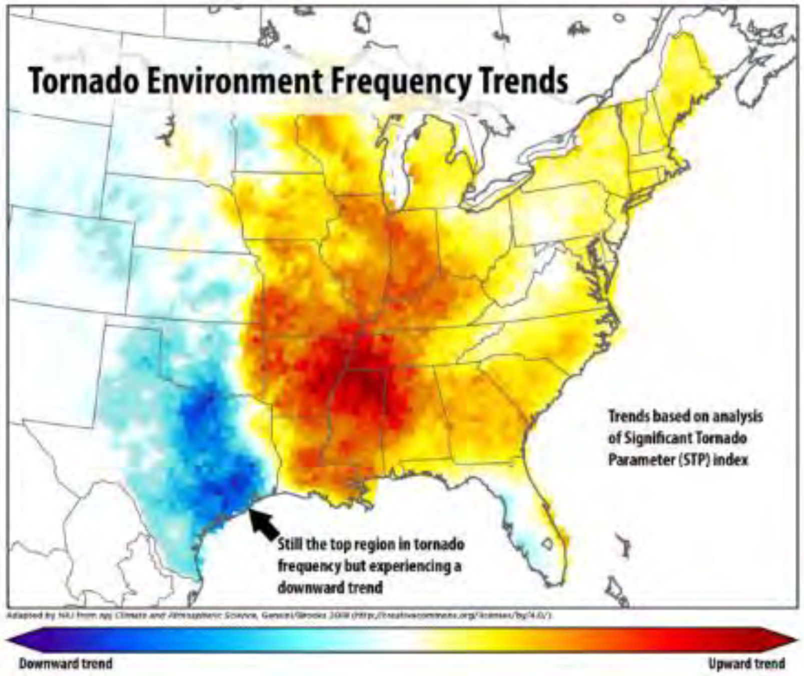


Figure 4-17: U.S. Tornado Frequency Shifting Eastward

Natural Hazards – Hydrological

Dam Failure

Description

A dam is an artificial barrier constructed across a stream channel or a man-made basin for the purpose of storing, controlling or diverting water. Dams typically are constructed of earth, rock, concrete or mine tailings. The area directly behind the dam where water is impounded or stored is referred to as a reservoir.

A dam failure is the partial or total collapse, breach or other failure of a dam that causes flooding downstream. Dam failures can result from natural events such as a flood event, earthquakes or landslides, human-induced events such as improper maintenance, or a combination of both. In the event of a dam failure, the people, property, and infrastructure downstream could be subject to devastating damage.

Dam failures can result from one or more of the following:

- Prolonged periods of rainfall and flooding (the cause of most failures);
- Inadequate spillway capacity resulting in excess flow overtopping the dam;
- Internal erosion caused by embankment or foundation leakage;
- Improper maintenance (including failure to remove trees, repair internal seepage problems, maintain gates, valves, and other operational components, etc.);
- Improper design (including use of improper construction materials and practices);
- Negligent operation (including failure to remove or open gates or valves during high flow periods);
- Failure of an upstream dam on the same waterway;
- Landslides into reservoirs which cause surges that result in overtopping of the dam;
- High winds which can cause significant wave action and result in substantial erosion; and
- Earthquakes which can cause longitudinal cracks at the tops of embankments that can weaken entire structures.

Although dam failure is not considered a direct result of a changing climate, changes in climate can impact dams and their functionality. In the Great Lakes Region, increases in precipitation, especially in extreme rainfall events, may result in dam failure

DRAFT

due to flooding or inadequate spillway capacity. Decreased snow accumulation and snowfall (falling instead as rain) due to warmer temperatures may have similar impacts.

Dam regulation and classification in Michigan. The Dam Safety Program administers the provisions of Part 307 (Inland Lake Levels) and Part 315 (Dam Safety) of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended to address dam safety and operation concerns for non-hydropower generating dams. There are over 2,500 dams in the state, 91 of those are regulated under the Inland Lake Levels Part and 816 regulated by the Dam Safety part.

Inland Lake Levels, Part 307, regulates dams that establish legal lake levels while Dam Safety (Part 315), regulates non-power dams over six feet in height and with more than five acres impounded during the design flood. A DEQ permit must be acquired prior to any construction or repair of regulated dams. Additionally, these dams must be inspected every three to five years based on hazard potential rating. Staff in the Dam Safety program are responsible for reviewing all inspection reports, inspecting all department owned dams, and inspecting municipal dams if requested. The U.S. Army Corps of Engineers National Inventory of Dams (NID) lists six dams as being located in and/or owned by the City of Ann Arbor, as listed in Table 4-22.[xlix] Argo, Barton, Geddes, and Superior Dams are classified as High Hazard Potential Dams (HHPDs) in the NID. HHPDs are those in which a failure or faulty operation may result in loss of life. All four of these HHPDs maintain Emergency Action Plans (EAPs). Barton Dam and Superior Dam are used to generate hydroelectric power. The City of Ann Arbor has completed inundation studies for the dams owned by city, including an assessment of populations, structures, and facilities at-risk to dam failure.

DRAFT

Table 4-22: Ann Arbor Dams (from the NID)

Name	Owner	River	Hazard Potential Class
Argo Dam	City of Ann Arbor	Huron River	High
Barton Dam	City of Ann Arbor	Huron River	High
Geddes Dam	City of Ann Arbor	Huron River	High
Superior Dam	City of Ann Arbor	Huron River	High
Traver Creek Retention Dam	Washtenaw County Drain Commissioner	North Branch Traver Creek	Low
Traver Lake Dam #5	IDES Realty Corporation	Middle Branch Traver Creek	Low

Location

Areas downstream of dams are considered at risk. The city has completed dam failure inundation analyses for city-owned dams, including 5-mile inundation areas and catastrophic failure analyses, maps of which are included in the Vulnerability Assessment. Figure 4-18 shows the location of the NID-listed dams in or owned by Ann Arbor. Of those listed, Argo Dam, Barton Dam, Traver

Creek Retention Dam and Traver Lake Dam #5 are located within Ann Arbor. Geddes Dam and Superior Dam are owned and operated by the City of Ann Arbor, but are located in Washtenaw County, outside of the Ann Arbor city limits.

DRAFT

Figure 4-18: Ann Arbor Dam Locations (from the NID)

Previous Occurrences

There have been two recorded instances of dam failure in Ann Arbor:

- July 26, 1997: As reported by NCEI, an unannounced release of water from Barton Dam resulted in the Huron River rising above its 15-foot flood stage. The river crested at 15.3 feet and fell back below flood stage 1.5 hours later. No injuries, deaths, or damages were reported as a result of the event.
- 1968: As reported by the 2012 Ann Arbor hazard mitigation plan, excessive flooding caused failure of the Argo and Geddes dams. There was no loss of life or injury as a result of the failure. The dams were rebuilt by 1972.

Extent

Dam failure can be measured in terms of loss or life or property. Due to the limited number of historic events, the extent of dam failure in Ann Arbor is difficult to determine, as no deaths or property damage has been reported. However, loss of life and property due to dam failure is possible.

Probability of Future Occurrences

Generally, dam failure in Ann Arbor is considered a high consequence, low probability hazard. With only two reported events, dam failure is not a common occurrence in Ann Arbor; one occurrence has been reported approximately every 25 years.

Probability of dam failure could increase with changing climate conditions. Increases in precipitation, especially in the frequency and intensity of extreme precipitation events, could increase the probability that dams will fail or overtop. Warmer temperatures may negate some of the flooding effects of increased precipitation but may also result in more snow falling as rain.

Considering the above, a probability of unlikely (less than 1 percent annual chance) was assigned to the dam failure hazard.

Vulnerability Assessment

All current and future buildings, infrastructure, and populations within dam inundation areas are considered at risk to dam failure. No dollar losses are reported as a result of dam failure in Ann Arbor.

Damage to Buildings. All buildings located in dam inundation areas are at risk to dam failure. (Text redacted).

Damage to Infrastructure. Infrastructure located within inundation areas is at-risk to dam failure. (Text Redacted).

Life Safety, Health, and Warning and Evacuation Procedures. All populations within dam inundation areas are considered at-risk to dam failure. Dam failure can result in injuries and loss of life, and result in the need for evacuations. (Text redacted).

DRAFT

Public Health. Dam failure can have many negative impacts on public health, which are similar to the public health issues associated with flooding (see this section's equivalent under the *Flood* hazard profile). In particular, having water and wastewater treatment facilities within dam inundation areas results in vulnerability to sewage spills and water contamination.

Impacts to Socially Vulnerable Populations. Dam failure has the potential to disproportionately impact socially vulnerable populations. In the event of a dam failure, certain populations may face difficulty evacuating, such as the elderly, disabled, or those who are otherwise mobility challenged. Individuals who do not speak English proficiently, or those who are hearing or visually impaired, may face challenges heeding and acting on dam evacuation warnings, especially when messaging is not provided in multiple languages or in accessible formats. Once evacuated, the elderly or infirm may have special needs for sheltering, such as access to medicines or medical devices. After an inundation event, economically constrained households have a lower capacity to repair homes, remediate mold, and replace destroyed belongings. Individuals that do not have paid time off or are unable to work remotely (such as those in food service and hospitality) may lose income in the event they cannot report to work due an inundation event.

Economic Impact. Economic impacts resulting from flooding from dam failure are similar to those from flooding, though generally contained to inundation areas. (See this section's equivalent under the *Flood* hazard profile).

Climate Change Impacts. Climate change can have many indirect impacts on dam failure. The cause of most dam failures is flooding from prolonged periods of rainfall. In Ann Arbor, increased future precipitation, and increases in extreme precipitation events, may increase the likelihood of dam failure due to increased flooding or inadequate spillway capacity. Warmer temperatures resulting in decreased snow accumulations and more snow falling as rain could have a similar effect. Further, many dams, including the ones analyzed for this plan, were constructed 30 or more years ago, and were originally designed based on climate conditions effective at the time of construction. Dam upgrades and renewals should consider changing climate conditions; such actions are typically addressed in a dam management plan and are out of the scope of this plan.

DRAFT

Drought

Description

Drought is conceptually defined by the National Drought Mitigation Center as "a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield." Although sometimes considered a rare and random event, drought is a normal, recurrent feature of climate. Climatic factors such as high temperatures, high wind, and low relative humidity are often associated with drought. Drought occurs in virtually all climatic zones, varying significantly from one region to another, and can be defined according to meteorological, hydrological, agricultural, socioeconomic, or ecological criteria, as categorized in Table 4-23.[i] Drought is differentiated based on the use and need for water.

Table 4-23: Drought Classification Definitions

Drought Classification	Description
Meteorological Drought	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. (Dry weather patterns dominate an area; can begin/end rapidly).
Hydrological Drought	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels. (Low water supply is evident; conditions take longer to develop and then recover.
Agricultural Drought	Soil moisture deficiencies relative to water demands of plant life, usually crops. (Crops significantly affected).
Socioeconomic Drought	The effect of demands for water exceeding the supply because of a weather-related supply shortfall.
Ecological Drought	A prolonged and widespread deficit in naturally available water supplies — including changes in natural and managed hydrology — that create multiple stresses across ecosystems

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. It is generally difficult to pinpoint the beginning and the end of a drought. Because the impacts of a drought accumulate slowly at first, a drought may not be recognized until it has become well established. Even during a drought there may be one or two months with above average precipitation totals. These wet months do not necessarily signal the end of a drought and generally do not have a major impact on moisture deficits. Droughts can be short, lasting just a few months. Conversely, they can persist for several years before regional climate conditions return to normal. While drought conditions can occur at any time throughout the year, the most apparent time is during the summer months. Nationally, drought impacts often exceed $1 billion due in part to the sheer size of the areas affected.

DRAFT

Research indicates climate change will have significant impacts on drought frequency and intensity, which will vary by region. Higher temperatures lead to increased evaporation rates, including more loss of moisture through plant leaves. Even in regions where precipitation does not decrease, increases in surface evaporation will lead to more rapid drying of soil if not offset by other changing factors, such as reduced wind speed or humidity. As soil dries out, a larger proportion of the sun's incoming heat will go toward heating soil and adjacent air rather than evaporating moisture, resulting in hotter temperatures and drier conditions.[li] In the Midwest region, there is uncertainty regarding how droughts will behave in the future. Future projections show a potential increase in seasonal drought, in which excessive soil moisture levels in spring will transition to insufficient levels in summer, driven by higher temperatures.[lii] In Michigan, trends appear to show a lessening of the long-term drought hazard as precipitation levels have increased over time.

Human activities often exacerbate the impact of drought. For example, excessive water use can deplete groundwater supply or result in low reservoir levels. The City of Ann Arbor's water supply comes from the Huron River.

Measuring Droughts. There are several quantitative methods for measuring drought in the United States. How these indices measure drought depends on the discipline affected (e.g., agriculture, hydrology, meteorology, etc.) and the region being considered. Two main methods are the Palmer Drought Severity Index (PDSI) and the U.S. Drought Monitor. The PDSI was the first comprehensive drought index developed in the United States. The U.S. Drought Monitor is a relatively new index that combines quantitative measures with input from experts in the field. The U.S. Drought Monitor is used in this plan to assess drought occurrences in Ann Arbor.

U.S. Drought Monitor. The U.S. Drought Monitor is designed to provide the general public, media, government officials, and others with an easily understandable overview of weekly drought conditions across a county throughout the United States. The U.S. Drought Monitor is unique because it assesses multiple numeric measures of drought, including the PDSI and three other indices, as well as the interpretations of experts to create a weekly map depicting drought conditions across the United States. The U.S. Drought Monitor uses five drought intensity categories, D0 through D4, to identify areas of drought. These categories are shown in Table 4-24.

DRAFT

Table 4-24: U.S. Drought Monitor Categories

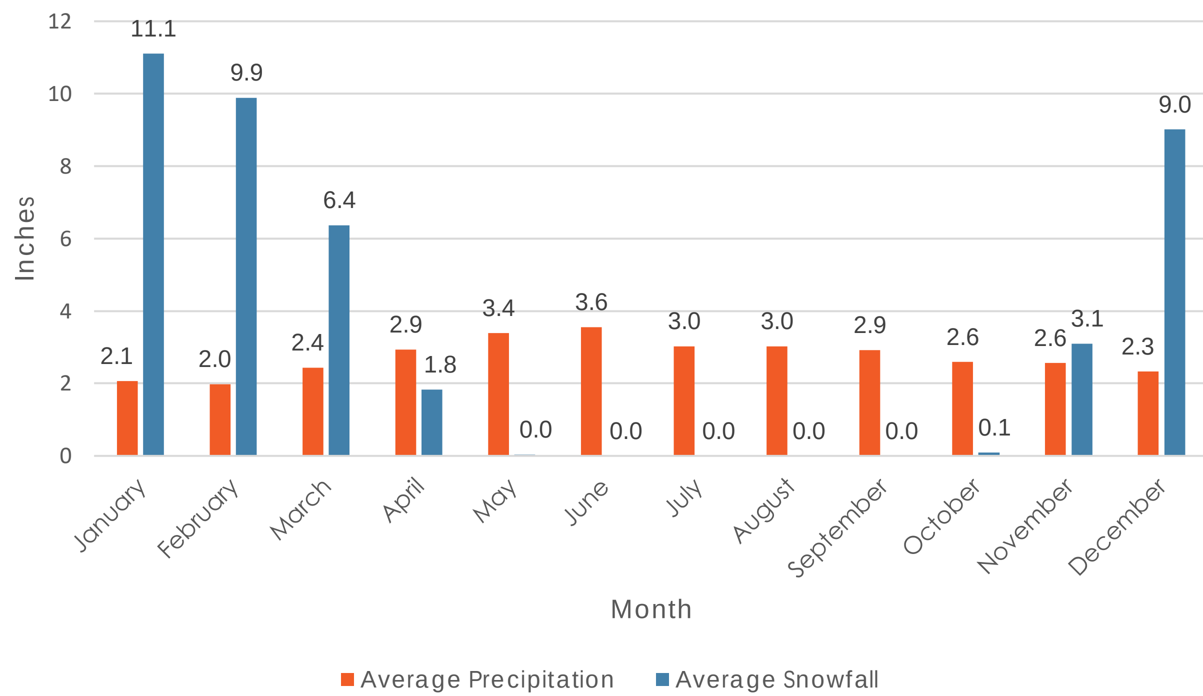
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

Location

A drought is a regional event that is not confined to geographic or political boundaries; it can affect several areas at once. It can also range in severity across those areas. All of Ann Arbor is at risk to drought occurrence and impacts.

Previous Occurrences

In order to understand the conditions of past drought, it can be helpful to understand the typical precipitation received each year. Ann Arbor experiences an annual average of 32.4 inches of precipitation and 41.7 inches of snowfall at the University of Michigan weather station. Monthly averages are shown in Figure 4-19.[liii]



Source: Western regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2022

Figure 4-19: Average Precipitation and Snowfall by Month in Ann Arbor

The U.S. Drought Monitor was used to ascertain historical drought levels for Ann Arbor. The U.S. Drought Monitor reports data on drought conditions from 2000 through 2021. Drought conditions are reported by category as percentages. Therefore, it is possible that more than one drought category was reported in each week. In such cases, the highest drought category reported was used. This information is compiled and presented in Table 4-25 below.

Table 4-25: Historic Drought Conditions in Ann Arbor

Abnormally Dry | Moderate Drought | Severe Drought | Extreme Drought | Exceptional Drought

Year	Duration
2000	Severe (up to 2 weeks)
2001	Moderate (up to 1 week)
2002	Moderate (up to 20 weeks)
2003	Severe (up to 10 weeks)
2004	Moderate (up to 2 weeks)
2005	Moderate (up to 5 weeks)
2006	Normal (52 weeks)
2007	Moderate (up to 5 weeks)
2008	Abnormal (up to 3 weeks)
2009	Normal (52 weeks)
2010	Moderate (up to 4 weeks)
2011	Abnormal (up to 2 weeks)
2012	Severe (up to 4 weeks)
2013	Abnormal (up to 9 weeks)
2014	Normal (52 weeks)
2015	Moderate (up to 10 weeks)
2016	Severe (up to 1 week)
2017	Abnormal (up to 6 weeks)
2018	Moderate (up to 11 weeks)
2019	Abnormal (up to 10 weeks)
2020	Moderate (up to 4 weeks)
2021	Severe (up to 1 week)

DRAFT

In the study period, severe drought conditions occurred in 2000, 2003, 2012, 2016, and 2021. However, a notable trend is that drought conditions were present in 19 of the 22 years studied, possibly indicating a long-term issue. As weeks in drought tend to last for several weeks or months at most, drought occurrences in Ann Arbor indicate the presence of seasonal droughts rather than long-term, persistent droughts (i.e., those lasting several years).

In addition to data from the U.S. Drought Monitor, previous Ann Arbor hazard mitigation plans describe three historic droughts that have impacted the city:

Heat Wave / Drought of 1988. The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan, including the Ann Arbor area. Nationwide, the drought caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the “dust bowl” days of 1934. During that 39-day stretch, the temperature in the Ann Arbor area topped the 100-degree mark on 5 occasions.

Drought of the 1960s. A period from 1962-1965 was the only clear and serious statewide drought event to take place since the 1930s, which partially demonstrates a general trend of lessening drought problems in Michigan (including the Ann Arbor area) during the second half of the 20th Century when compared with the first half. Nevertheless, this was definitely the worst drought event to strike Michigan since the 1930s. In this event, the entire Southern Lower Peninsula had to endure at least 30 consecutive drought months, many of which were at the D2 level, or worse. Again, there was a pattern in which the drought was felt more intensely the farther to the east one was located. Southeastern Michigan experienced 9 consecutive months at the exceptional D4 level of drought. The middle years of 1963-1964 were the worst phase of this event, for most parts of the state.

Droughts of the 1930s. Without a doubt, the “Dust Bowl” drought of the 1930s was the most famous drought ever to occur in the U.S. That drought was an ecological and human disaster of huge proportions. It was caused by misuse of the land combined with years with lack of rainfall. As the land dried up, great clouds of dust and sand, carried by the wind, covered everything and the term “Dust Bowl” was coined. As a result of this drought, millions of acres of farmland became useless, forcing hundreds of thousands of people to leave their farms and seek an existence elsewhere. Although exact figures were not kept, some researchers estimate that nearly $1 billion (in 1930s dollars) was provided in assistance to victims of the Dust Bowl drought. That event also ushered in a new era or farming and conservation programs and practices aimed at preventing a recurrence of a drought of the magnitude and impact of the Dust Bowl drought.

In Southwestern Michigan (including the Ann Arbor area), this “dust bowl” period took the form of a most severe statewide drought condition from 1930 to 1932, followed by a less severe period from 1933 to 1937, and finally a period of limited spotty problems between 1939 and 1940. Between 1930 and 1932, Michigan’s 10th climate division experienced a severe level of drought for about 24 continuous months. The entire state was struck very hard by this event. During December and January of 1934-1935 the southeastern Michigan region set an all-time state record for the longest number of consecutive months under drought conditions—

DRAFT

the 42 months between August 1933 and January 1937. Although the area had some months of relief in early 1938, drought conditions resumed by the end of the year for a period of 8 consecutive months; and then between 1939 and 1940, another 12-month period of drought followed.

The State of Michigan state hazard mitigation plan lists historic drought occurrences by division. Ann Arbor is in Division 10, for which the following drought occurrences are listed:

- The most extreme drought was in March 1931, when the Palmer index hit a record low of -6.82.
- Lengthy drought incidents took place in:
  - 1900-1902 (9 months)
  - 1922-1923 (10 months)
  - 1930-1931 (17 months)
  - 1933-1936 (34 months)
  - 1963-1965 (35 months)
  - 1971-1972 (9 months)
  - 1998-1999 (10 months)
  - 2002-2003 (8 months)
  - 1999-2000 (8 months)

Extent

Extent can be defined by the highest drought monitor category: Exceptional Drought. Using this metric, the most severe drought on record for Ann Arbor occurred between 1963 and 1964, southeastern Michigan experienced nine consecutive Exceptional Drought months. However, it is acknowledged that the Dust Bowl of the 1930s (especially in 1931) was the most severe drought in Ann Arbor's history as a city. It is likely that exceptional drought status was reached during the 1930s droughts. Since the U.S. Drought Monitor began in 2000, there have been no reported weeks where all or part of Ann Arbor experienced Exceptional Drought. The highest drought category experienced by Ann Arbor during this time was Severe Drought (18 weeks total) in 2000, 2003, 2012, 2016, and 2021. While climate trends in Ann Arbor show increasing precipitation overall and a lessening on the drought hazard, drought events more severe than those occurring in the 1930s and 1960s are possible.

Probability of Future Occurrences

An exact probability is difficult to quantify given the limited reporting period of the U.S. Drought Monitor (22 years; 2000-2021). Drought conditions were reported in 19 of the 22 years for the city. This equates to rate of drought presence of approximately 86 percent annually.

When determining future probability, the historic frequency must be considered along with projected future conditions. It is difficult to quantify the impact climate change will have on the future drought occurrence, as a number of factors, such as precipitation, humidity, and temperature, influence the formation of drought conditions. Drought is most likely to occur during summer months, when high temperatures increase the amount of surface evaporation. Summer temperatures in Ann Arbor are projected to

DRAFT

increase, as are extreme heat days (e.g., days above 90°F), as shown in Table 4-25. Further, climate trends show increasing precipitation in Ann Arbor. Data from Headwaters Economics indicates that under the high emissions scenario, annual average precipitation in Ann Arbor will increase by approximately 3 inches by end of century, from 33 inches to 36 inches. Even with overall increases in precipitation, there is potential for an increase in seasonal summer drought conditions.

Based on historic frequency and projected future conditions, the probability of future drought occurrences is highly likely (greater than 90 percent annual chance). However, the probability of extreme of exceptional drought is less likely.

Vulnerability Assessment

Ann Arbor is generally considered a water-rich community but has the potential to be significantly impacted by a drought. All current and future buildings, and populations in the city are at risk to drought. The atmospheric nature of drought and lack of specific boundaries make it difficult to quantify drought conditions. The majority of drought impacts, however, are not structural but societal in nature. A drought's impacts on society result from the interplay between a natural event and the demand people place on water supply.

Surface water levels in lakes, impoundments, and reservoirs can drop dramatically during drought. Groundwater supply can also be impacted. In Ann Arbor, recreational activities along the Huron River, such as canoeing, kayaking, tubing, and swimming have the potential to be impacted.

Damage to Buildings. As noted above, drought has minimal impacts on structures although it could have impacts on the functionality of the building if water supply is disrupted. In addition, structural issues could occur in the event that drought impacts building foundations or footings. There are no known losses associated with drought and buildings in Ann Arbor.

Damage to Infrastructure. Drought is expected to have minimal impacts on infrastructure. Green infrastructure, such as green stormwater infrastructure, may incur minor damages during drought occurrences if plants cannot resist drought.

Life Safety, Health, and Warning and Evacuation Procedures. As drought is a slow developing hazard, it is unlikely to have significant impacts on life safety and is not expected to result in warnings or evacuation. Drought occurrences may result in water use restrictions. In the extreme event of drought-related water shortages, the city's availability of water for firefighting may be impacted.

Public Health. Drought has the potential to impact public health by reducing the quality and quantity of available drinking water. While drought has never been severe enough to fully deprive the city of water, it is possible. In general, even a severe drought is unlikely to have detrimental impacts the health and safety of a community.

Impacts to Socially Vulnerable Populations. Economically constrained households may face difficulty paying for water in the event that a drought causes rate hikes introduced to spur conservation. Ability for economically vulnerable populations to pay should be

DRAFT

considered in any changes to water pricing. Economically constrained households may also face challenges in the event food prices rise due to drought, both locally and in areas from where food is grown.

Economic Impact. Drought can have (and has had) economic impacts on the city. One of the most pronounced economic impacts is that on agricultural holdings, as water supply is imperative for regional crops and livestock. There is limited agriculture within the Ann Arbor city limits, but a regional drought could have severe impacts to food prices in Ann Arbor and may even result in food shortages. Drought resulting in water shortage can also impact businesses (ranging from restaurants to manufacturing) which cannot operate without water. Lastly, in the case of a water shortage, the cost of water may increase (or the city may be forced to buy water from a water-rich area), which would have ripple effects in terms of a reduction in the local economic multiplier as money leaves the county.

Climate Change Impacts. In Ann Arbor, climate trends show increasing precipitation overall and a lessening of sustained-long term drought occurrences. However, trends from Drought Monitor data and future projections indicate a potential increase in seasonal summer droughts as excessive spring soil moisture levels become insufficient in the summer due to warmer temperatures and higher surface evaporation rates. While Ann Arbor does not have an abundance of agriculture in the city limits, loss of soil moisture could cause trees within the city to become heat stressed, and thus more susceptible to pests and diseases.

Flood (including Extreme Precipitation)

Description

Flooding is a very frequent, dangerous, and costly hazard. Globally, it accounts for 40 percent of all natural disasters and results in an average of over 6,500 deaths annually.[liv] In the U.S., flooding results in an average of 86 deaths annually.[lv] Nearly 90 percent of all presidential disaster declarations result from natural events where flooding was a major component. On average, flooding causes more than $2 billion in property damage each year in the United States. Floods cause utility damage and outages, infrastructure damage (both to transportation and communication systems), structural damage to buildings, crop loss, decreased land values and impede travel.

Flooding is the most common environmental hazard, due to the widespread geographical distribution of valleys and coastal areas, and the population density in these areas. The severity of a flooding event is typically determined by a combination of several major factors including stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and the degree of vegetative clearing and impervious surface. Flooding events can be brought on by severe (heavy) rain. There are several types of flooding, which are presented below.

Flash Flooding. Flash floods occur within a few minutes or hours of heavy amounts of rainfall and can destroy buildings, uproot trees, and scour out new drainage channels. Heavy rains that produce flash floods can also trigger mudslides and landslides. Most flash flooding is caused by slow-moving thunderstorms or repeated thunderstorms in a local area, or by heavy rains from hurricanes and

DRAFT

tropical storms (not applicable in Ann Arbor). Although flash flooding often occurs in mountainous areas, it is also common in urban centers where much of the ground is covered by impervious surfaces.

Sheet Flooding. Sheet flooding is a condition where storm water runoff forms a sheet of water to a depth of six inches or more. Sheet flooding and ponding are often found in areas where there are no clearly defined channels, and the path of flooding is unpredictable. It is also more common in flat areas. Most floodplains are adjacent to streams or oceans; although almost any area can flood under the right conditions where water may accumulate.

Urban (Pluvial) Flooding and Extreme Precipitation. Urban flooding, also called pluvial flooding, is usually caused by heavy rain over a short period of time. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Since sidewalks and roads are non-absorbent, rivers of water flow down streets and into sewers. Roads and buildings generate more runoff than forestland. Fixed drainage channels in urban areas may be unable to contain the runoff that is generated by relatively small, but intense, rainfall events. Urbanization increases runoff two to six times over what would occur on natural terrain. This high volume of water can turn parking lots into lakes, flood basements and businesses, and cause lakes to form in roads where drainage is poor or overwhelmed.

Urban flooding, which can include flash flooding and sheet flooding, can also occur where there has been development within stream floodplains. This is partly a result of the use of waterways for transportation purposes in earlier times. Sites adjacent to rivers and coastal inlets provided convenient places to ship and receive commodities. The price of this accessibility has increased flooding in the ensuing urban areas. Urbanization intensifies the magnitude and frequency of floods by increasing impermeable surfaces, amplifying the speed of drainage collection, reducing the carrying capacity of the land and, occasionally, overwhelming sewer systems.

In addition to urbanization, extreme precipitation events are occurring more frequency and becoming more intense in certain locations due to human-induced climate change, including the City of Ann Arbor. Extreme precipitation events may overwhelm existing drainage systems and result in urban flooding.

Riverine Flooding. Periodic flooding of lands adjacent to non-tidal rivers and streams (known as the floodplain) is a natural and inevitable occurrence. When stream flow exceeds the capacity of the normal watercourse, some of the above-normal stream flows onto adjacent lands within the floodplain. Riverine flooding is a function of precipitation levels and water runoff volumes within the watershed of a stream or river. According to USGS, the recurrence interval of a flood is defined as probability of an event in any given year (e.g., 1 percent annual chance). Flood magnitude increases with increasing recurrence interval.

In addition, there are several types of floodplains. These are identified areas of flood occurrence. However, not all flooding occurs in such areas. Localized urban flooding and flash flooding often occur outside of designated floodplain areas.

Floodplains. A floodplain is generally the land area susceptible to being inundated or flooded by water from any source (i.e., river, stream, lake, estuary, etc.). Floodplains are natural features of any river or stream. Streams that drain more than one square mile

DRAFT

have their estimated floodplain areas mapped in most areas. The mapped floodplain areas are called the regulatory floodplain. The regulatory floodplain mapping is a result of the hydrologic (rainfall) and hydraulic (runoff) analysis of the watershed and stream.

The regulatory floodplain is also known as the 100-year floodplain, base flood elevation, 1.0-percent annual chance floodplain or the Special Flood Hazard Area. The 100-year floodplain is the land area that is subject to a 1.0 percent or greater chance of flooding in any given year. The term "100-year flood" is often misinterpreted. The 100-year flood does not mean that it will occur once every 100 years. A 100-year flood has a 1/100 (1 percent) chance of occurring in any given year. A 100-year flood could occur two times in the same year or two years in a row. It is also possible not to have a 100-year flood event over the course of 100 years or more.

The floodway is portion of the floodplain required to convey the flood event. The flood fringe provides flood water storage. The floodway is the high velocity area and structures or obstructions in the floodway can increase flood heights. The floodway is regulated by the Michigan Department of Environmental Quality and local regulations. Michigan DEQ regulations prohibit residential construction in the floodway.[lvi]

While the 100-year (or base flood) is the standard most commonly used for floodplain management and regulatory purposes in the United States, the 500-year flood, also known as the 0.2-percent annual chance flood area, is the national standard for protecting critical facilities, such as hospitals and power plants (when federally funded). A 500-year flood has a 1/500 (0.2 percent) chance of occurring in any given year. It is generally deeper than a 100-year flood and covers a greater amount of area; however, it is statistically less likely to occur.

Special Flood Hazard Area and Flood Insurance Rate Maps. A Special Flood Hazard Area (SFHA) shown on a Flood Insurance Rate Map (FIRM) is the regulatory floodplain. FIRMs are produced by FEMA. SFHAs are delineated on the FIRMs and may be designated as Zones A, AE, AO, AH, AR V, VE, A-99. Structures located in the SFHA are highly susceptible to flooding. Structures located in the SFHA A-Zones are required by lenders to purchase flood insurance. Anyone in a community that participates in the NFIP may voluntarily purchase flood insurance. The following SFHA zones are present within Ann Arbor:

- Zone A: Zone A is the flood insurance rate zone that corresponds to the 1.0-percent annual chance floodplains determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no Base Flood Elevations (BFEs) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.
- Zone AE: Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains determined in the Flood Insurance Study by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

In addition to SFHA zones, Zone X is also present in Ann Arbor. Zone X corresponds to areas outside of the 1.0 percent annual chance flood area, and it includes areas in the 0.2 percent annual chance flood boundary and areas of minimal flood hazard.

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Flooding can occur any time of year. The severity of flooding is determined by a combination of topography and physiography, ground cover, precipitation and weather patterns and recent soil moisture conditions. Flooding is also governed by the size and the nature of the stream's watershed. A watershed is the geographic area of land where all runoff drains to a common point. Ann Arbor is located within the Huron River Basin, and its landscape includes seven watersheds that flow into tributaries of the Huron River. Including Honey Creek, Allen Creek, Malletts Creek, Swift Run, the Huron River, Traver Creek, Millers Creek, and Fleming Creek, as depicted in Figure 4-20.

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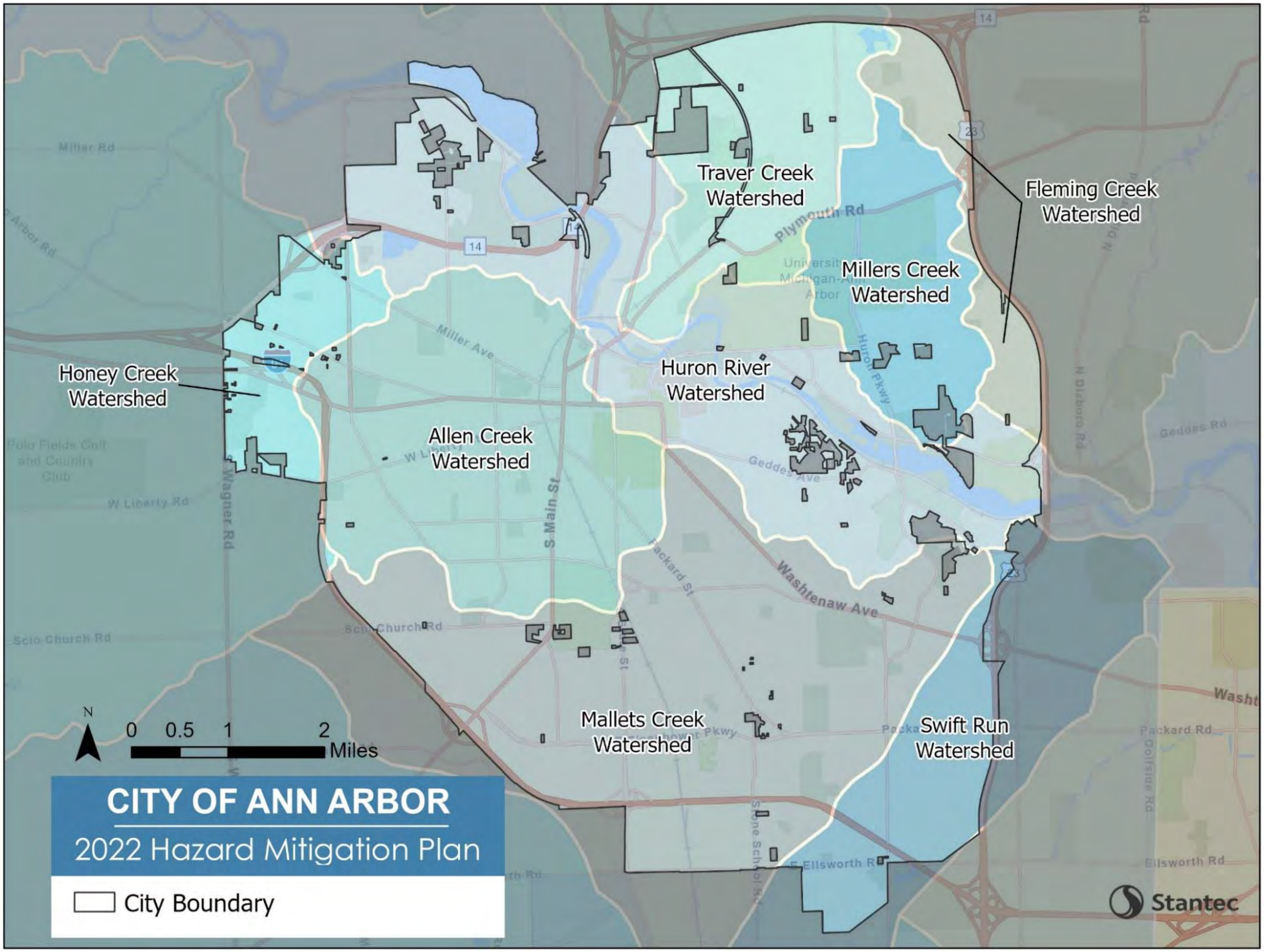

Figure 4-20: Ann Arbor Watersheds

Within the watershed, the condition of the land affects how precipitation flows or infiltrates. For example, more rainwater will run off the land's surface and into streams if the terrain is steep, if the ground is already saturated from previous rains, if the surface is significantly covered with impervious pavement (e.g., parking lots, rooftops), or if depressional water storage areas have been filled.[lvii]

Climate change will have significant impacts on flood frequency and intensity, which will vary by region. Generally, higher temperatures will result in drier conditions due to evaporation of moisture. In terms of precipitation, wet areas are generally expected to get wetter while dry areas become drier. Ann Arbor is in a water-rich area, and therefore should expect to receive increased precipitation, aside from overall increases in precipitation, an increase in the frequency and magnitude of extreme rainfall events is associated with increased flooding. Heavy rainfall events have increased for most of the United States over the last several decades, including Ann Arbor. The Midwest has experienced a 37 percent increase in the amount of precipitation falling in heavy rainfall events from 1958 to 2012, and climate projections suggest this trend will continue.[lviii] Extreme precipitation event projections for Ann Arbor are presented in Table 4-31.

Location

The Washtenaw County FIRMs, which include the City of Ann Arbor, indicate both the 1.0-percent annual chance (100-year) floodplain and 0.2-percent annual chance (500-year) floodplain areas in the city as shown in Figure 4-21. These FIRMs became effective in 2012. In Ann Arbor, there are approximately 1,052 acres in the 1.0-percent annual chance flood area (including 747 acres in the floodway), and approximately 353 acres in the 0.2-percent annual flood chance area. In total, Ann Arbor has a total of 1,405 acres in FEMA floodplain areas, which corresponds to 7.6 percent of the city's total acreage.

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Figure 4-21: Ann Arbor FEMA Floodplain Areas

However, it should be noted that flooding outside of the FEMA designated flood areas is possible. A more severe event could easily exceed the 0.2-percent annual chance (500-year) floodplain boundaries shown. Urban flooding and sheet flooding occur throughout the planning area.

In 2015, the city completed a 3-year stormwater model study (the SWMM Project) that analyzed the drainage system for the entire city. Among other objectives, the study used flow and water level data to simulate a 1-percent floodplain using a model called InfoSWMM and compared model results to the FEMA regulatory floodplain. The study compared model results to FEMA FIRMs for the Allen, Malletts, Millers, Swift, and Traver creeksheds (floodplain/floodway associated with the Huron River was not included). Model results compared to the FEMA regulatory floodplain are shown in Figure 4-22. According to the study, there are two main areas where the FEMA FIRM maps and the InfoSWMM model results differ:

- Allen Creek south of Hill Street (Figure 4-23) – On the effective FEMA FIRM, the area of Allen Creek located south of Hill Street is not included in the 1.0 percent annual flood chance area (it is included in the 0.2 percent annual chance flood area). Using the InfoSWMM model data, the floodplain delineation would extend south through Hoover and S. State Street.

- Upper Malletts Creek (Figure 4-24) – The scope of the existing FEMA floodplain delineation did not extend west of South Seventh Street because of tributary area size limitations in the mapping procedure. Using the citywide stormwater model for stormwater data would not have this restriction so the Upper Malletts Creek area was included in the delineation.

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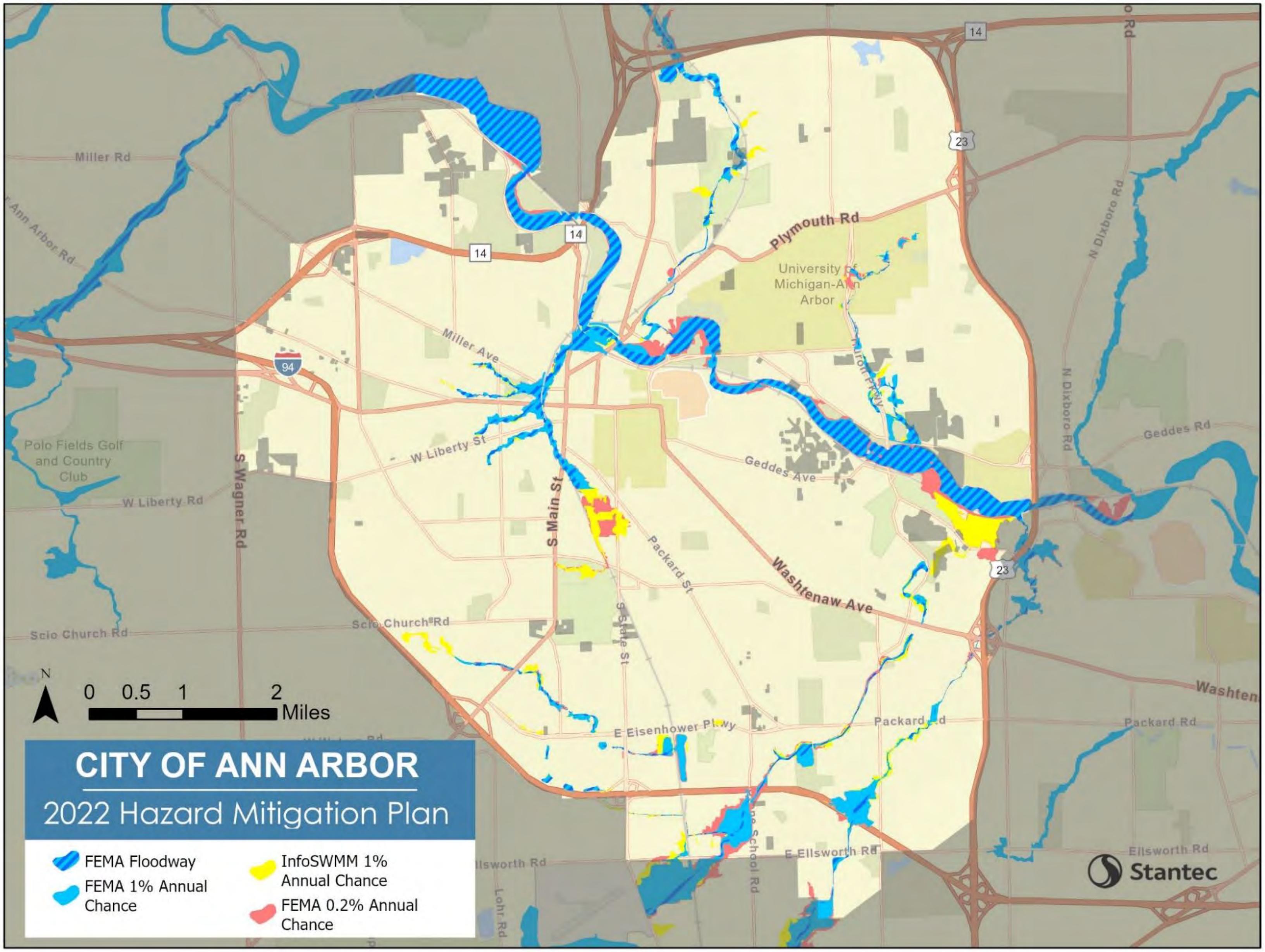

Figure 4-22: Ann Arbor InfoSWMM Model Flood Hazard Area and FEMA SFHA Comparison

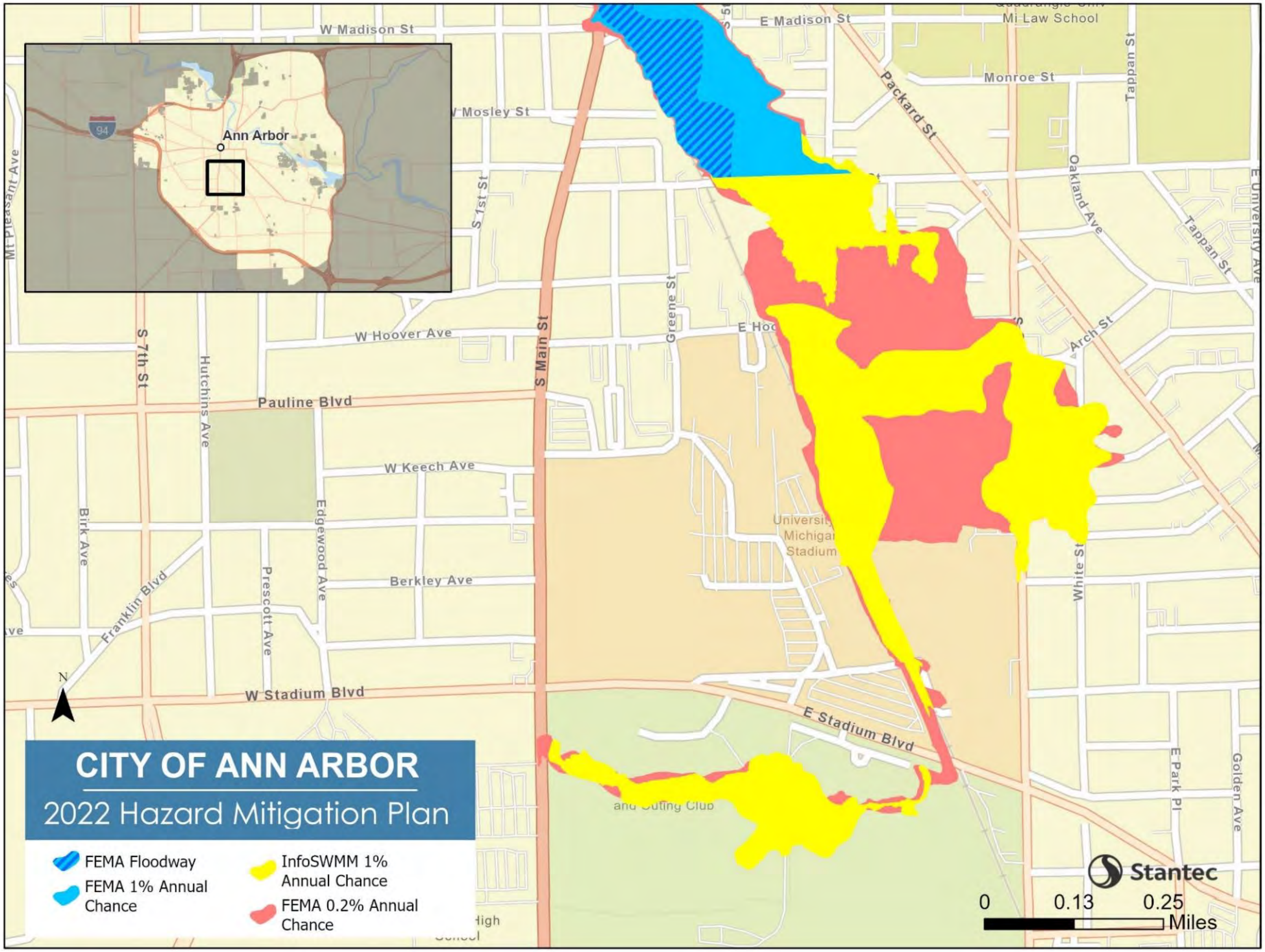

Figure 4-23: Ann Arbor InfoSWMM Model Comparison – Allen Creek South of Hill Street

Figure 4-24: Ann Arbor InfoSWMM Model Comparison – Malletts Creek West of South Seventh Street

In addition, the city officials provided locations where recorders for storm peak flood stage have been installed. These locations were chosen due to past flooding from extreme rainfall and are therefore good indicators of where flooding from extreme rainfall occurs in the city. Recorders are shown below in Figure 4-25. It Should be noted that while many fall within mapped FEMA or local (InfoSWMM) riverine flood areas, several are located well outside of mapped flood hazard areas, indicating that the city experiencing significant pluvial flooding (flooding from extreme rainfall) in addition to riverine flooding.

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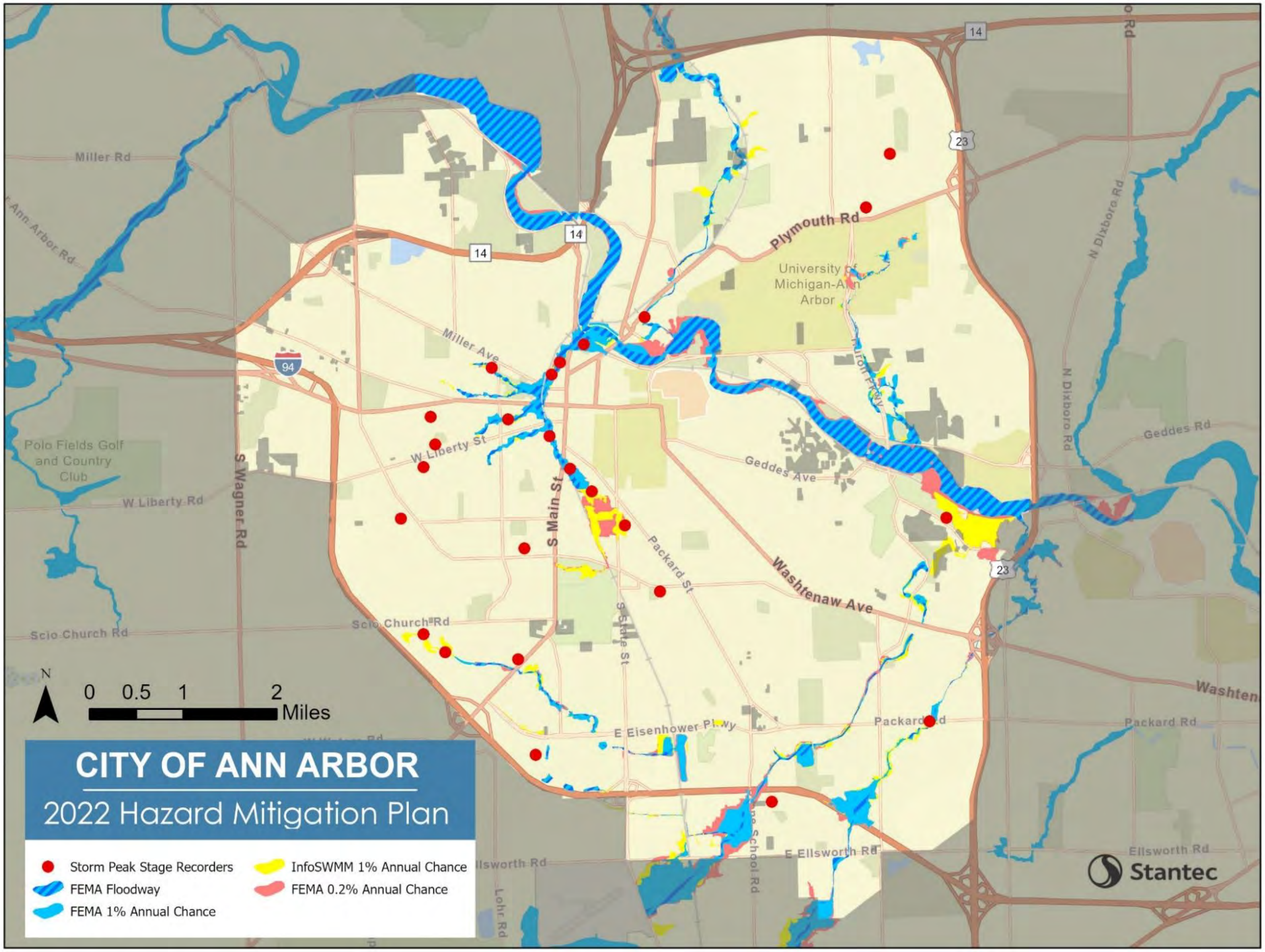

Figure 4-25: Additional Areas of Known Flood Occurrence

Previous Occurrences

Several outside data sources were used to assess past flood events in Ann Arbor: NCEI Storm Events Database and National Flood Insurance Policy (NFIP) claims data provided by the city. Descriptions of notable flood occurrences from previous Ann Arbor hazard mitigation plans, as well as accounts from local news sources, the TAC, and the public, are also included.

Table 4-26 summarizes the previous flooding occurrences reported in Ann Arbor between 1996 and July 2021 by NCEI. Details for each reported event can be found in Appendix C. Out of 35 events recorded for Washtenaw County, 17 were reported to have impacts in Ann Arbor. No injuries or fatalities were reported as a result of flooding. Over $9.7 million (2022 dollars) in damages were reported in association with these events, although all reported damages may not have occurred in Ann Arbor.

Table 4-26: NCEI Reported Flood Events in Ann Arbor

Event Type	Number of Events	Deaths/Injuries	Property Damage (2022 dollars)
Flood	7	0/0	$262,691
Flash Flood	10	0/0	$9,446,091
Total	17	0/0	$9,708,782

Descriptions of notable flood events in Ann Arbor reported by NCEI and previous Ann Arbor hazard mitigation plans are presented below.

June 1968 Flood Event. This event is considered one of the most severe flood events in Ann Arbor's history. Until the development of FEMA FIRMs in the 1980s, this flood was used to as a baseline for a 100-year flood in Ann Arbor. As measured at the University of Michigan, rainfall totals reached 5.28 inches. Widespread damage occurred to buildings, bridges, dams, roads, and personal property. Hundreds of basements were flooded, and sewers were backed up throughout the city. Approximately 1,400 feet of railroad tracks were washed out, and multiple dams failed.[lix]

August 1998 Flash Flood. Thunderstorms and heavy rainfall developed over southeast Michigan. Ann Arbor received 4.12 inches of rain, which led to flooding in urban areas. In Ann Arbor, Mallets Creek rose out of its banks. The creek destroyed sidewalks in the Briarwood Mall area and swept three cars into a retention pond. Some flooding also took place on the Athletic (South) Campus of the University of Michigan. Resulting damages were $1,616,762 (2022 dollars). This event was by far the costliest event reported by NCEI.

June 2000 Flood. Thunderstorms resulted in flooding over southeast Michigan. Ann Arbor received 2 to 3 inches of rain. Newport Road was closed after a culvert failed and the road collapsed. Westbound Interstate 94, on the west side of Ann Arbor, was closed for much of the 25th, as water covered the road. Resulting damages were estimated at approximately $38,322 (2022 dollars).

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July 2000 Flood. Up to three inches of rain fell on the south side of Ann Arbor, resulting in basement flooding and sewer backups. Damages were estimated at approximately $76,644 (2022 dollars) which likely does not include residential impacts.

September 2000 Flash Flood. Thunderstorms developed over southeast Michigan, leading to heavy rains. Many places had seen heavy rain the day before, meaning the ground was saturated and vulnerable to flooding. In Ann Arbor, 2.26 inches of rain fell after receiving 1.32 inches the previous day. The storms had a broad impact. Ann Arbor had numerous stalled cars and flooded intersections, including a foot of water over Huron Street and Washtenaw Avenue. The heavy rain indirectly contributed to a fatality, when a female pedestrian was struck and killed by a University of Michigan bus during a blinding downpour. Regionally, over 30,000 households were affected by power outages. About one hundred flights out of Detroit Metro Airport were cancelled, and numerous people were stranded at the airport overnight due to the multitude of flooded roads in the area. Resulting damages were estimated at approximately $76,644 (2022 dollars).

February 2001 Flood. The Huron River in Ann Arbor rose above flood stage of 15 feet on the evening of February 9th. The river crested at 15.7 feet at in the early morning hours of the 11th. There was isolated road flooding across the county, with some cars stalled out in water. Resulting damages in Ann Arbor were estimated at approximately $9,301 (2022 dollars).

June 2010 Flash Flood. Intense thunderstorm rain led to rainfall totals of 3 to 7 inches, generally in a 12-hour period of less, which lead to flash flooding across counties in southeast Michigan, including Washtenaw County. This is substantial, as the 100-year, 24-hour heavy rainfall event in Ann Arbor is approximately 5 inches. Widespread flooding was reported in the Ann Arbor, with cars stranded on Jackson Road and I-94.

June 2021 Riverine and Pluvial Flood. An extreme rainfall event occurred in the evening of June 25th resulting in reports of flooding and basement backups throughout the city. The Pittsfield Village neighborhood and surrounding streets reported the most issues. All five rainfall gauges throughout the city recorded a minimum of 2 inches of rainfall, but the Southeastern rain gauge recorded 5.25 inches in less than 24 hours, indicating this event was a 100-year storm (see Table 4-30 in the *Extent* section for mean storm parameters by recurrence interval for the region in which Ann Arbor is located). Some notable impacts from this event include:

- Swift Run Creek flooded, resulting in the closure of Packard Road;
- Sanitary sewer backups were prevalent in Pittsfield Village;
- Basements flooded as sumps could not keep up with rainfall, and/or water seeped through basement walls;
- In many parts of the city, the storm sewer system was overwhelmed (city's design storm is for a 50-year peak flow, adopted in 2015), which exceeds state design requirements.

According to NCEI, damages from this event exceeded $7.5 million, although this estimate may include damages that occurred outside of Ann Arbor and likely does not include comprehensive residential damages.

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Aside from the events detailed above, the city experienced additional 100-year flood events in 1902 and 1947, but little information was available regarding these events. In addition, flooding caused by water rising from a high groundwater table (i.e., seepage or groundwater flooding) has been documented in Ann Arbor.

NFIP Considerations

The city became a member of the NFIP in 1982. NFIP data shows 321 active policies, and at 58 flood losses incurred as of June 30, 2022. A total of $281,600 was paid for those claims, averaging $4,855 paid per claim. Ann Arbor joined the Community Rating System (CRS) in May 2017 and participates as a Class 6 (20 percent discount). At the time of the city's previous hazard mitigation plan, 327 properties were covered under the NFIP. Table 4-27 provides a summary of flood insurance claims paid for all flood events. It should be noted that the city maintains self-insurance for city-owned buildings and therefore does not purchase flood insurance for these structures through the NFIP.

Table 4-27: Summary of Ann Arbor NFIP Properties and Flood Losses*

Location	Number of NFIP Policies in Force	Insurance in Force ($)	Total Number of Flood Losses (Closed) Incurred	Total Claims Payments ($)	Average Payment ($)
City of Ann Arbor	317	$80,787,200	58	$281,600	$4,855

Source: NFIP Community Information System (CIS), 4/28/2022

NFIP Repetitive Flood Loss (RL) Structures:

FEMA defines a "repetitive loss structure" as a flood-insured structure that has received two or more flood insurance claim payments of more than 25 percent of the market value within any 10-year period. The city's floodplain manager provided repetitive loss data as of December 2020. The data showed five RL structures throughout Ann Arbor. The previous version of this plan listed 7 properties, indicating a decrease in RL properties. Two of five properties identified as RL are not in the FEMA floodplain. These RLs resulted in 20 losses total, and over $240,800 in payments, or an average of $12,000 per loss. RL property types include single family residential, other residential, and non-residential structures within the city. RL data is presented in Table 4-28. Ann Arbor does not have any severe RL properties. General locations of RL properties in the city are shown in Figure 4-26.

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Table 4-28: Ann Arbor NFIP RL Properties

Location	Number of Properties	Types of Properties	Total Number of Losses	Building Payments ($)	Content Payments ($)	Total Payments ($)	Average Payment ($)
City of Ann Arbor	5	Single Family Residential, Other Residential, and Non-Residential	20	192,338	48,480	240,819	$12,041

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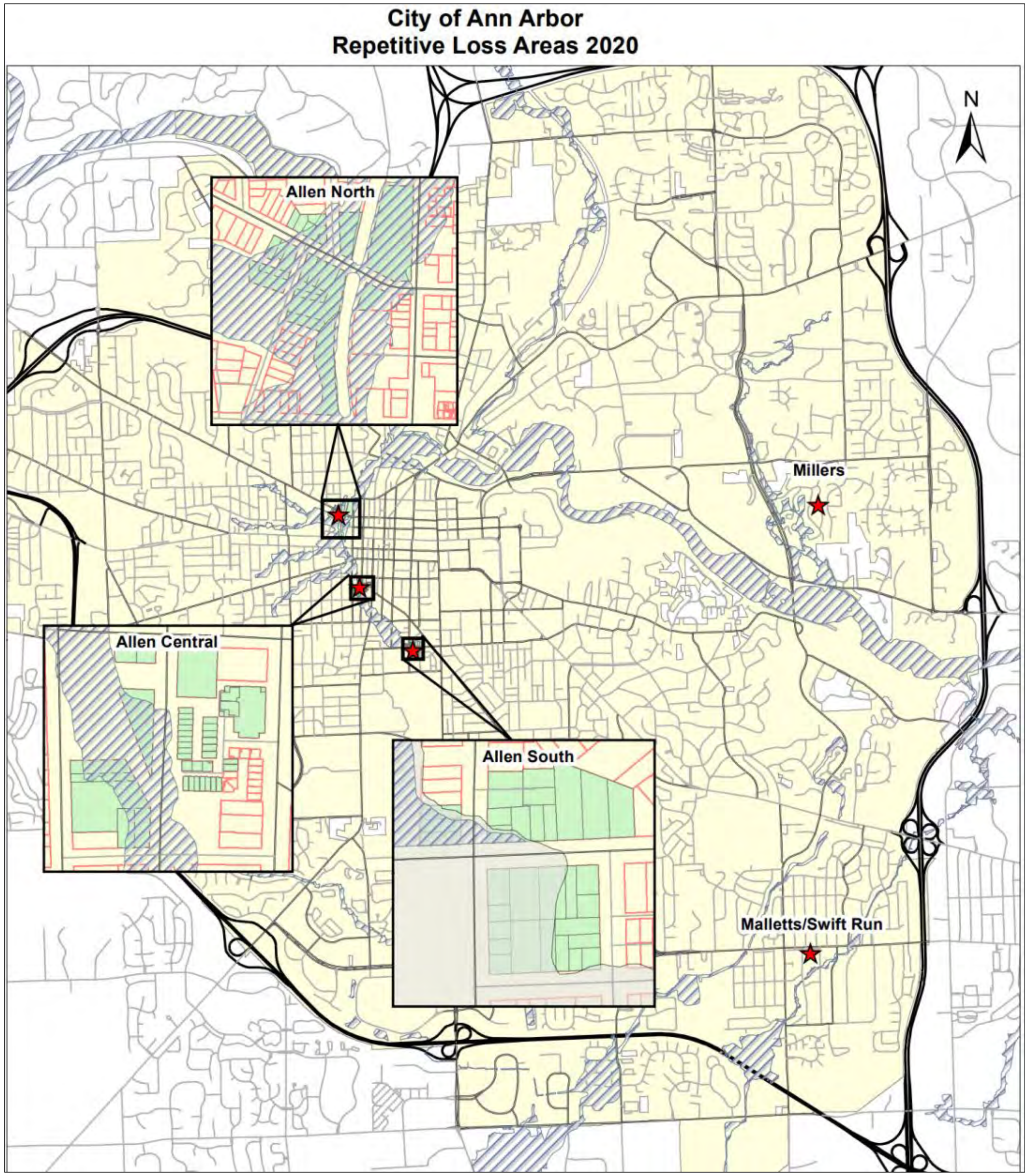

Figure 4-26: Repetitive Losses Property General Locations

Extent

Flood extent, or magnitude, can be defined in several ways including peak flow or discharge rate (cubic feet per second), height of flood waters, and damages. United States Geological Survey (USGS) stream gage data can often be used to determine the above factors. There are three USGS stream gages in Ann Arbor: one on the Huron River, a second on Allen Creek, and a third on Mallets Creek. Discharge rates were available for the Huron River gage; drainage area, discharge rates, and available flood stage data are shown in Table 4-29. Maximum discharge and maximum mean gage height are used to indicate extent. Median gage height data was not available.

Table 4-29: USGS Stream Gage Data for Ann Arbor[lx]

Water Feature	Median Discharge (cubic feet/second)	Max Discharge (cubic feet/second) (year)	Drainage Area (square miles)	Max Gage Height (feet/year)
Huron River	288	2,610 (1968)	729	17.5 (1968)

Extent for extreme rainfall events can be measured in terms rainfall measured during an extreme precipitation event. The severity of rainfall amounts can be measured by its corresponding recurrence interval. A recurrence interval is the average amount of time that elapses between precipitation events of that particular severity level. Longer recurrence intervals indicate a more severe event. Table 4-30 displays recurrence intervals for Ann Arbor, indicated by precipitation falling within a specified storm event duration. The most extreme events listed in the table are those with a 100-year recurrence interval. Such events are so severe that they are expected (on average) to occur only about one time per century.

The most severe extreme precipitation event reported for the City of Ann Arbor is the 1968 flood event, in which 5.28 inches of rain fell in 24 hours. This event is closely followed by the June 2021 flood event, in which parts of the city received 5.25 inches of rain in 24 hours. Both of these events exceeded the 100-year recurrence interval rainfall amount of 4.36 inches.

Table 4-30: Mean Storm Period Frequency Distribution by Recurrence for Ann Arbor (inches)

Storm Period	10-year	25-year	50-year	100-year
1-hour	1.47	1.69	1.87	2.05
12-hour	2.72	3.13	3.46	3.79
24-hour	3.13	3.60	3.98	4.36
72-hour	3.76	4.31	4.74	5.16

Source: 2019 State of Michigan Hazard Mitigation Plan (Thunderstorm Hazards), Mean Storm Period Frequency Distribution by Recurrence Interval for Division 10

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Climate change impact projections indicate an increase in the severity of extreme precipitation events in Ann Arbor, meaning more severe events than those experienced in the past are possible and more likely. In addition, injuries, and loss of life, as well as damages can be associated with the flood hazard and used as a measure of severity. Table 4-31 shows extreme precipitation projections for Ann Arbor, summarized from various sources.

Greater floods are possible, especially with increasing precipitation due to climate change and development pressure within the watershed (see *Development Trends* subsection under the *Vulnerability Assessment* section). Increasing impervious cover results in increased runoff volumes and consequently, increased flooding. In addition, development within floodplains can, over time, increase base flood elevations as well as increasing the number of people and businesses located in flood hazard areas, resulting in more property damage, injuries, and loss of life.

Table 4-31: Summary of Extreme Precipitation Projections for Ann Arbor (RCP8.5)

Source	Climate Projection
Headwaters Economics	Annual days with a minimum of 1.0 inch of rainfall will increase from a baseline value of 2.7 days to 3.0 days by 2050 and 3.6 days by 2080.
ERA5/CORDEX Analysis	Annual days with a minimum of 1.25 inches of rainfall will increase from a baseline value (1980-2010) of 2.1 days to 3.3 days by 2050 and 4.0 days by 2080.
Fourth National Climate Assessment	Total annual precipitation falling within the heaviest 1 percent of events will increase by 40 percent or greater by the late 21st Century (2070-2099).

Probability of Future Occurrences

In the last 25 years, there have been 16 reported flood occurrences (riverine and flash flood) according to NCEI. These records do not consider events that occurred prior to NCEI recorded (1996) or prior to the city joining the NFIP (1982). Further, many events go unreported.

Probability of flooding is expected to increase with changing climate conditions. Increases in precipitation, especially in the frequency and intensity of extreme events, could increase the probability of both riverine and urban flooding, as well as the probability of dam failure or overtopping. Data from multiple sources, such as Headwaters Economics and an analysis performed using ERA5/CORDEX data, indicate that days with at least one inch of rainfall will increase in Ann Arbor by the end of the century (see Table 4-31). In addition, warmer temperatures may negate some of the flooding effects of increased precipitation but may also result in more snow falling as rain.

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Based on the above, a probability of likely (between 10 and 90 percent annual chance) was assigned. While flooding, especially urban flooding, is a regular occurrence within Ann Arbor, it is possible to have years with no flood events and years with multiple flood events.

Natural Floodplain Functions

Environmental assets are important to consider when assessing flood risk and potential mitigation actions. Environmental assets may be used to leverage additional drainage or water storage capacity. Environmental assets also offer co-benefits. For example, wetland areas protect sensitive wildlife habitat while slowing and storing floodwater, and natural areas can serve both as recreation and water storage. Ann Arbor has several natural resources that are considered environmental assets. For example, the city has an above average tree canopy, and plans for its expansion are outlined in the city's Urban and Community Forest Management Plan. In addition, the Huron River and several of its tributaries run through the city, resulting in the presence of riverine habitat, riparian lands, and freshwater wetlands. Many of these areas in Ann Arbor are preserved as open space, parks, or greenways. Wetlands are areas in which soils are permanently or intermittently saturated. Wetlands are considered waters of the United States and are subject to the jurisdiction of the U.S. Army Corps of Engineers as well as the Michigan Department of Environmental Quality. The U.S. Fish and Wildlife Service may also have authority over any wetlands that provide habitat for endangered species.

Wetlands provide many valuable ecological services, including benefits to water quality, wildlife protection, recreation, and lastly, natural hazard mitigation. Wetlands provide water storage during flood peaks and slowly release floodwaters downstream. The flow of water is reduced in wetlands by soils, rocks, and vegetation. The reduction in floodwater velocity reduces the rate at which sediments are eroded and may even allow sediments and other pollutants to settle out of the water column. However, wetlands cannot perform these functions when they become severely degraded or are filled and covered with impervious material. Therefore, protecting wetlands in their natural state, through parks, open space, or natural preserves, aids in flood mitigation. During stakeholder interviews, city officials noted that the Swift Creek marsh is not currently fulfilling its needed floodplain storage function due to sedimentation and is in need of restoration.

Wetlands are often found in floodplains and low-lying areas of a watershed. Ann Arbor is home to many wetlands, including freshwater forested, emergent, riverine, lake, and pond wetlands. Types of wetlands within the city, as reported by the National Wetland Inventory (NWI), are presented in Figure 4-27 overlayed by the city's parks and natural areas. There are 1,165 acres of NWI wetlands within the city. In addition, Figure 4-28 shows wetlands in Ann Arbor available from the Michigan DEQ Wetland Mapper Tool, which includes NWI wetlands as well as state-identified wetlands. Ann Arbor has over 260 acres of open space in the floodplain, 126 of which are natural areas.

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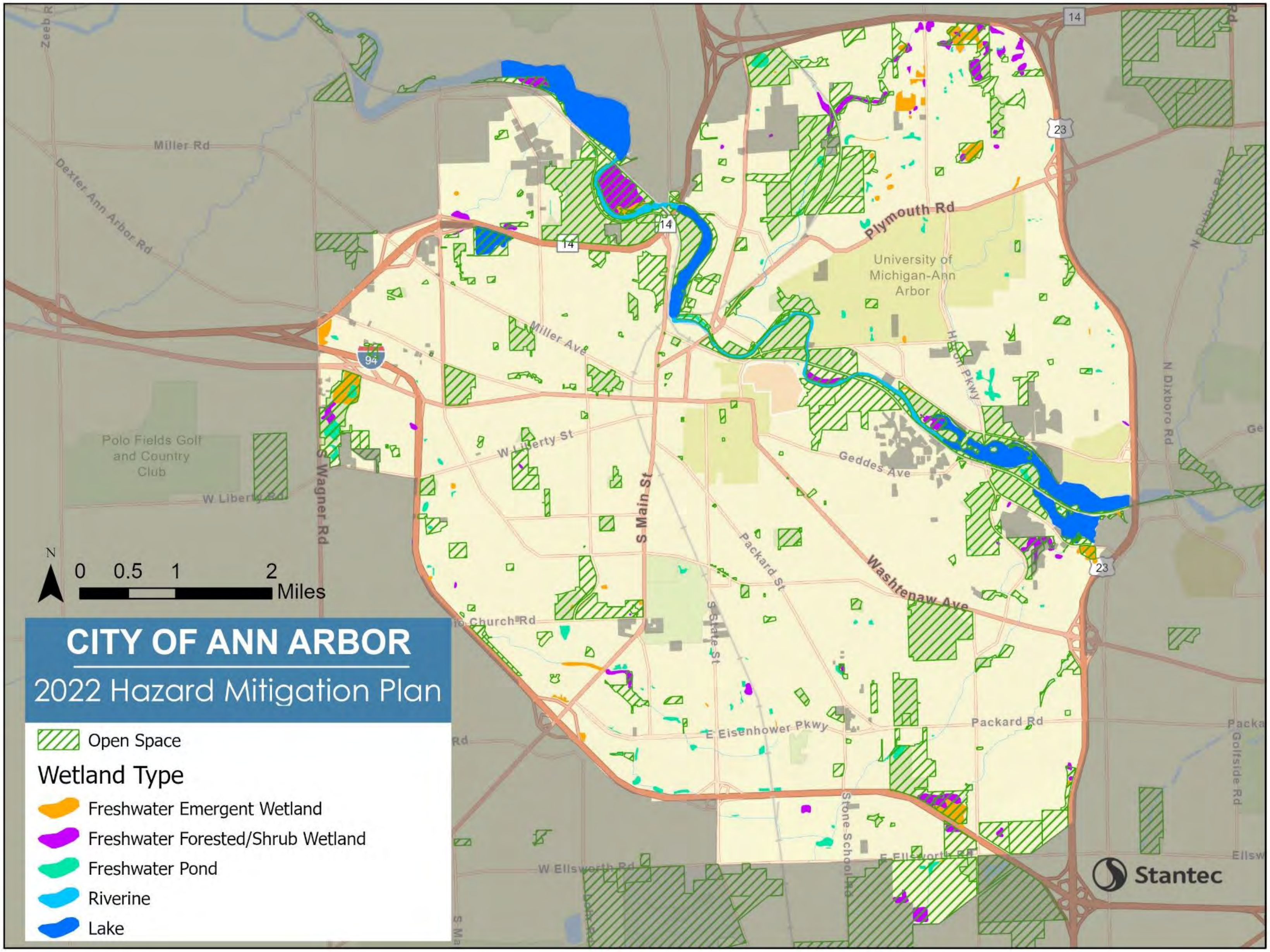

Source: U.S. Fish and Wildlife National Wetlands Inventory

Figure 4-27: Ann Arbor NWI Wetlands and Parks

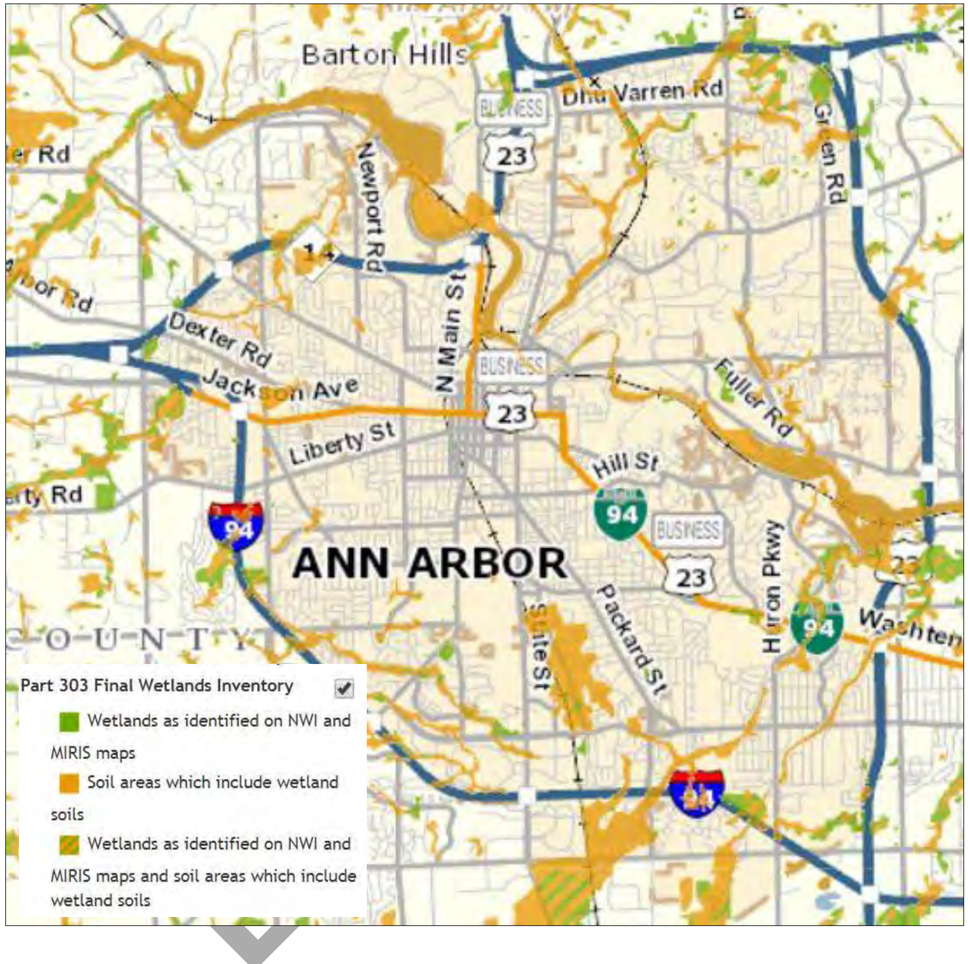

Figure 4-28: Ann Arbor Wetlands (Michigan DEQ)

Vulnerability Assessment

With a growing population and increasing development, Ann Arbor is susceptible to increased flooding. Being aware of this fact, Ann Arbor has taken steps through the Ann Arbor Flood Mitigation Plan and comprehensive planning to protect against new flood damages. In addition, in 2021 the city adopted a new floodplain management overlay zoning district. Ann Arbor has also adopted stormwater management guidelines for public streets. These efforts are discussed in *Section 5: Capability Assessment*.

Despite these steps, Ann Arbor is still vulnerable to significant flooding due to existing development. Potential annualized loss from flooding is estimated at $55,170 (2022 dollars). GIS analysis was used to determine FEMA special flood hazard areas (A and AE Zones) cover approximately 1.6 square miles of the city (5.7 percent of the city's area). An examination of land parcel data and the digital FIRM (100-year floodplain map), shows 1,151 parcels of land that are either within or touch the FEMA mapped 100-year floodplain (3.6 percent). However, buildings outside of these areas are still at risk. In fact, about 20 percent of flood insurance claims are from properties outside of regulatory special flood hazards areas (FEMA 1.0 percent ACF).[lxi] Flooding caused by extreme precipitation events occurs in Ann Arbor, both within and outside of mapped floodplain hazard areas. As a result, all current and future buildings, infrastructure, and populations in Ann Arbor are considered at risk to flooding.

Flooding concerns in the Huron River watershed are increasing as additional runoff is discharged by new development. In Ann Arbor, new development and densification of previously developed areas, including those within mapped flood hazard areas. As previously noted, flooding from water rising from a high water table is also a concern in several areas of the city.

Damage to Buildings. In order to assess flood risk, a GIS-based analysis was used to estimate exposure to flood events using FIRM data in combination with building footprint data and local tax assessor records for the city. Results from the city's local flood model (InfoSWMM) were also reviewed. The determination of assessed value at-risk (exposure) was calculated using GIS analysis by summing the total assessed building values for improved properties that were confirmed to be located within or partially within an identified floodplain. The figures below highlight flood hazard areas.

- Figure 4-29 shows building footprints located within the FEMA 1.0 percent area, FEMA 0.2 percent area (non-regulatory), and the InfoSWMM 1.0 percent area (non-regulatory).
- Figure 4-30 shows building footprints within flood hazards areas in the downtown area, associated with Allen Creek and the Huron River.
- Figure 4-31 shows building footprints in flood hazard areas located in the southern part of the city, associated with Mallets Creek and Swift Run.
- Figure 4-32 show at risk buildings in the eastern part of the city, associated with Miller Creek and the Huron River.

The number of building footprints, parcels, improvements, and their associated value are presented in Table 4-32. The number of buildings in flood hazard areas, categorized by use, is presented in Table 4-33. It should be noted that for each flood hazard area, there are more improved parcels than building footprints; it can be deduced that the difference in these totals occurred when an improved parcel was partially located in a flood hazard area but building(s) on that parcel were located out of the flood hazard area. This is an approximate analysis for planning purposes. This analysis does not account for building elevations. It should also be noted that flooding occurs outside of mapped floodplains.

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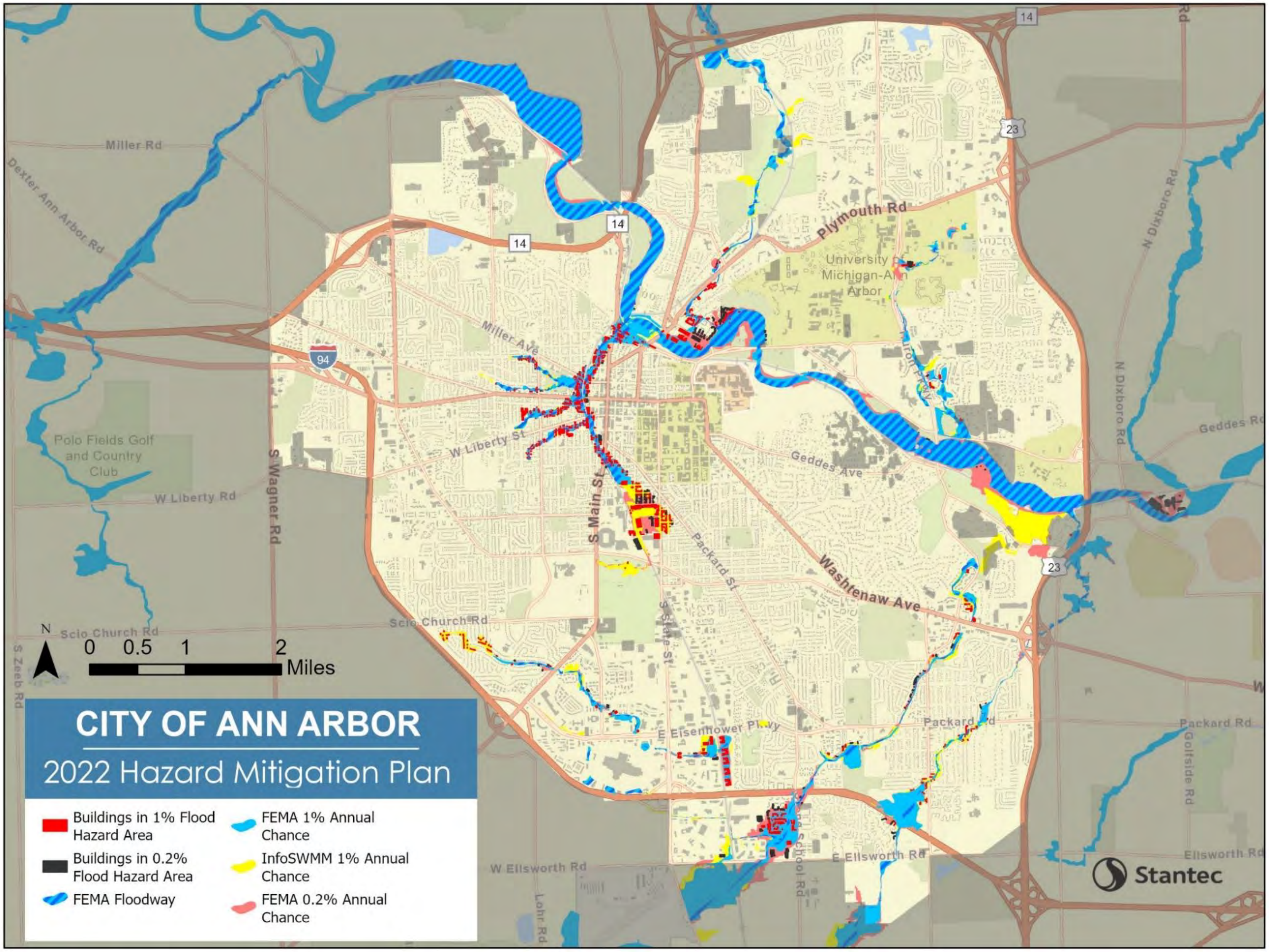

Figure 4-29: Ann Arbor Structures Located in Floodplain Hazard Areas

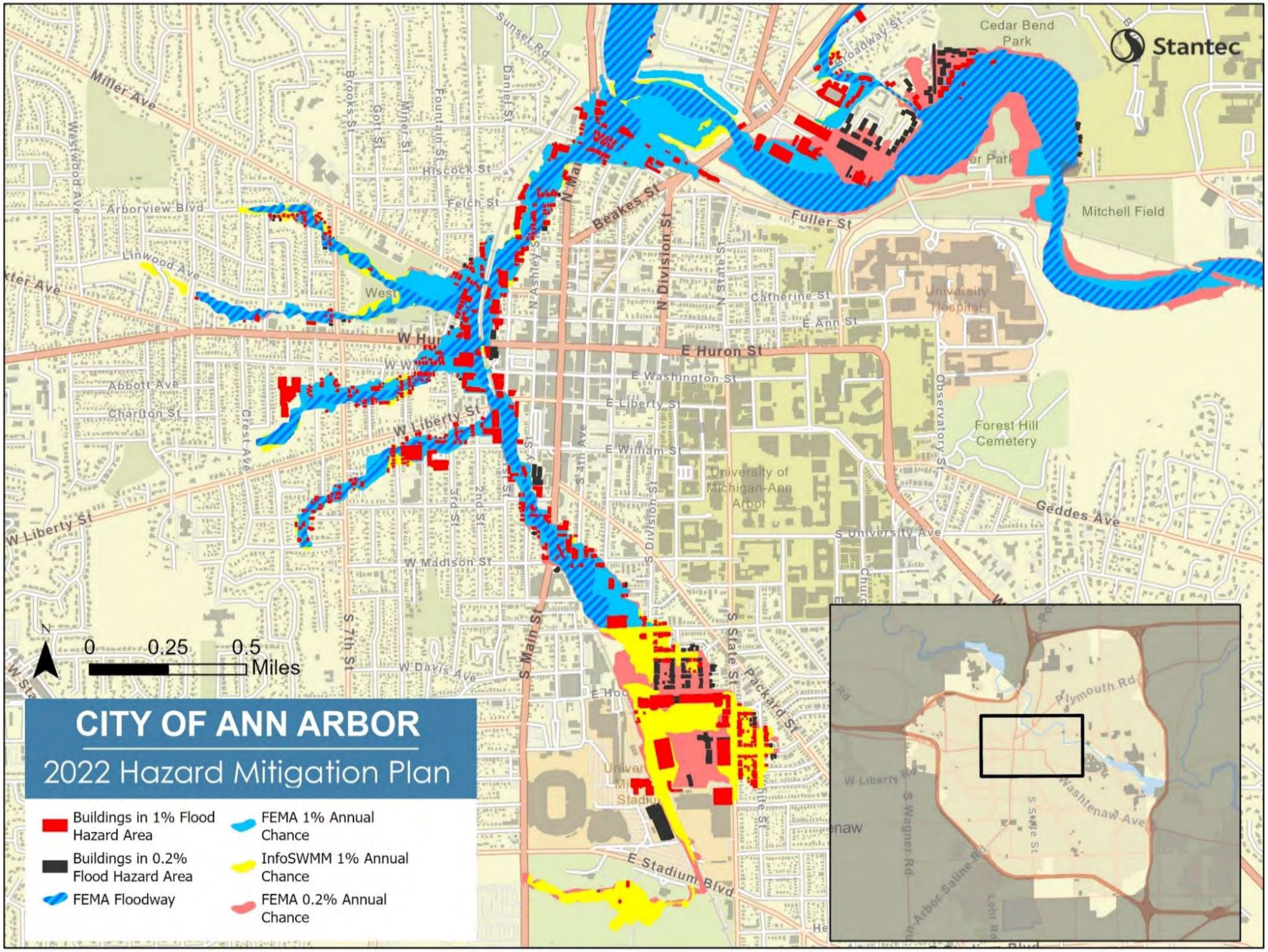

Figure 4-30: Structures Located in Floodplain Hazard Areas – Downtown/Allen Creek Area

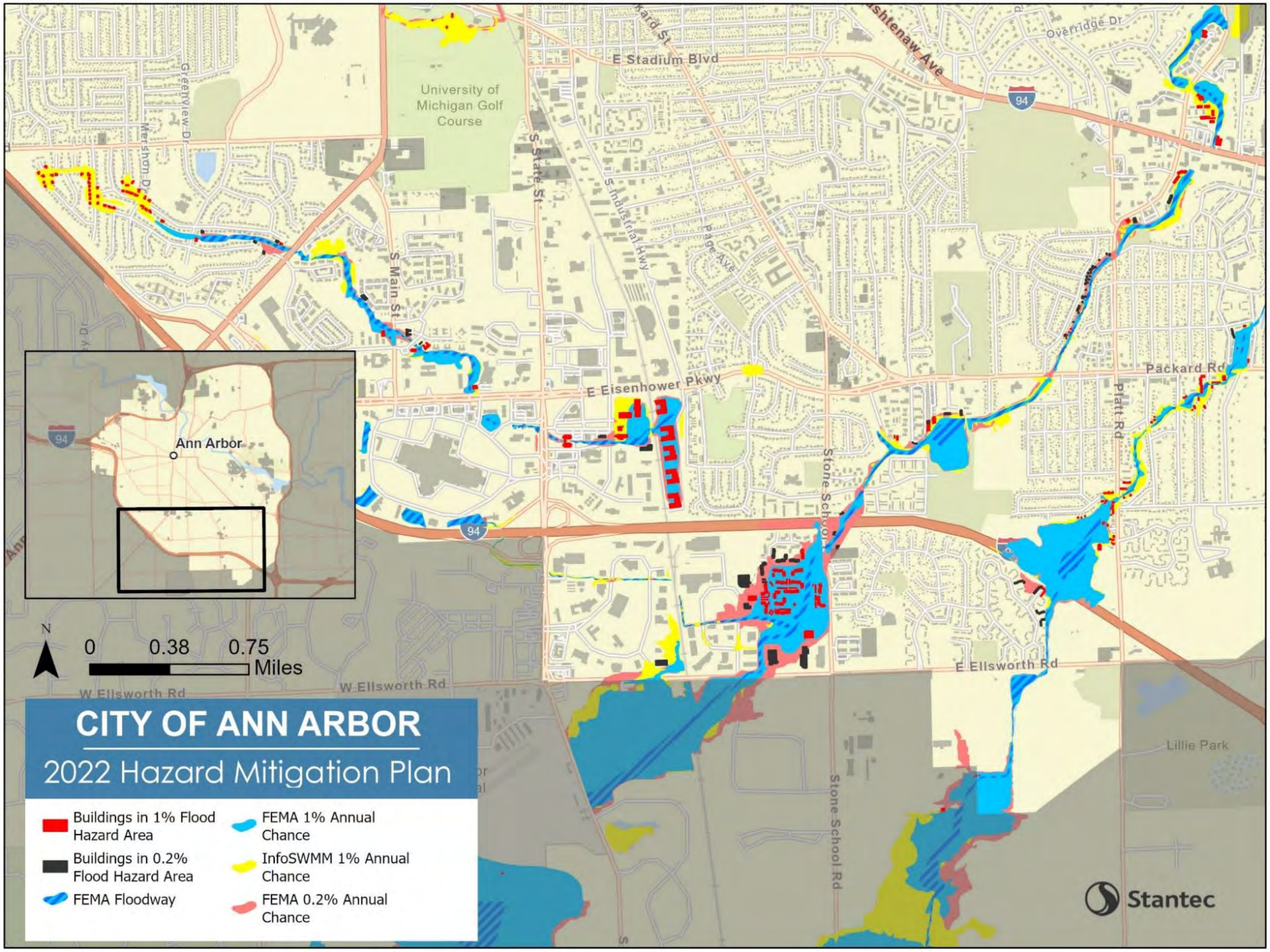

Figure 4-31: Structures Located in Floodplain Hazard Areas – South Ann Arbor

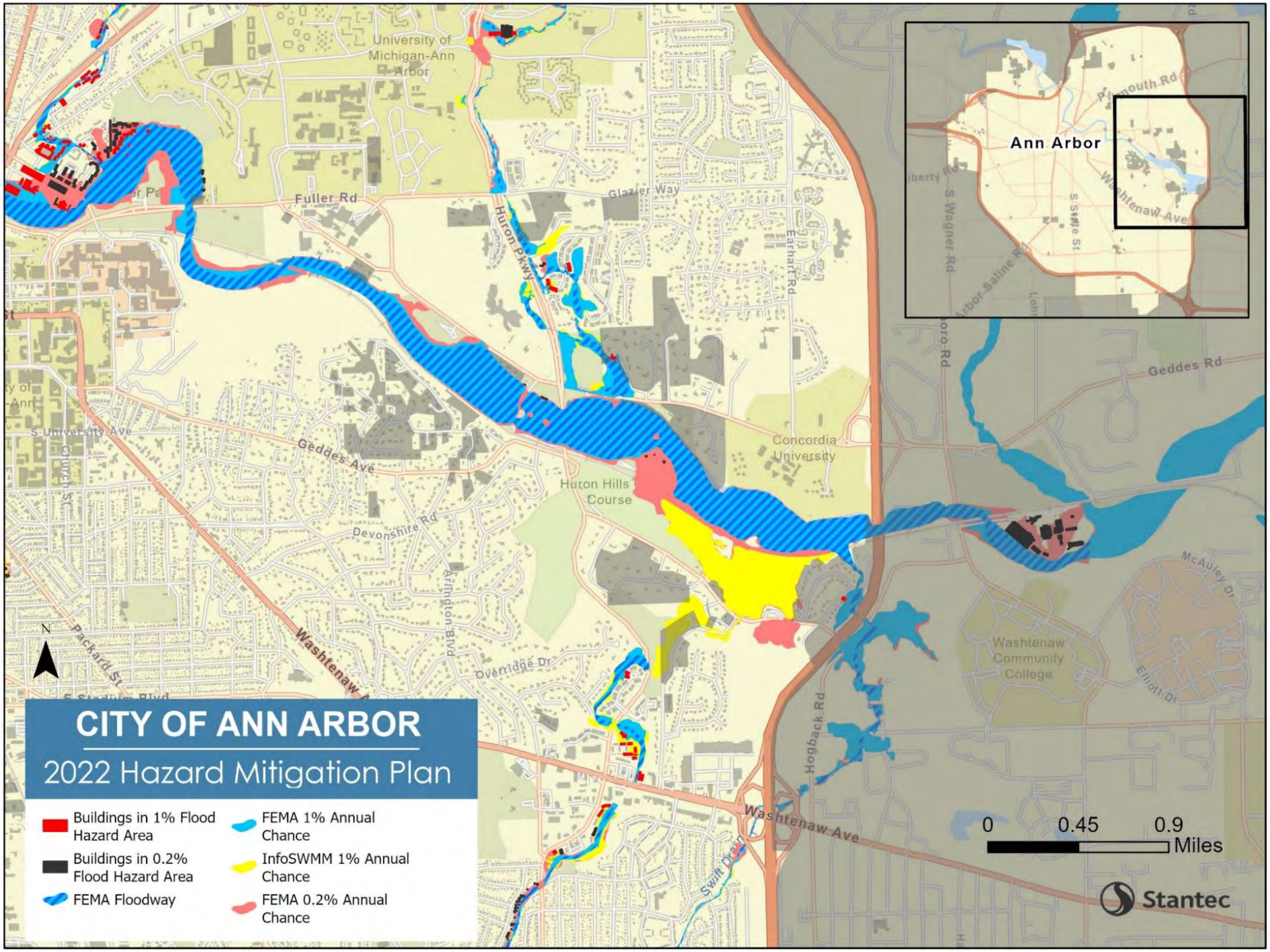

Figure 4-32: Ann Arbor Structures Located in Floodplain Hazard Areas – Eastern Ann Arbor

Table 4-32: Potentially At-Risk Parcels, Buildings, and Improvement Value in Floodplain Hazard Areas

Flood Hazard Area	Number of At-Risk Parcels	%	Number of At-Risk Improved Parcels	%	Value of At-Risk Improvements*** (2022 Dollars)****	%	Number of At-Risk Building Footprints ***	%
FEMA 1.0 percent ACF Area	1,151	3.6%	991	3.3%	$ 416,831,174	6.2%	509	1.5%
InfoSWMM 1.0 percent ACF Area*	387	1.2%	356	1.2%	$ 79,271,828	1.2%	238	0.7%
FEMA 0.2 percent ACF Area**	270	0.8%	260	0.9%	$ 83,763,600	1.2%	203	0.6%
Total	1,808	5.7%	1,607	5.3%	$579,866,602	8.6%	950	2.7%

**The Ann Arbor InfoSWMM 1.0 percent ACF (non-regulatory) includes only parcels and building footprints that are not accounted for in the FEMA 1.0 percent ACF area.*
***The FEMA 0.2 percent ACF (non-regulatory) includes only parcels and building footprints that are not accounted for in either the FEMA or InfoSWMM 1.0 percent ACF areas.*
****Value of "At-Risk Improvements" may exclude the value of tax-exempt improvements.*
*****Number and value of improvements is tied to parcels, not building footprints. Therefore, the improvement (i.e., building) on a parcel partially located in a flood hazard area may be located outside of the flood hazard area.*

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Table 4-33: Uses of Buildings Potentially At-Risk to Flood in Ann Arbor

Flood Hazard Area	Commercial	Office	Public	Residential
FEMA 1.0 percent ACF Area	49	41	31	388
InfoSWMM 1.0 percent ACF Area	6	0	22	210
FEMA 0.2 percent ACF Area	9	6	32	156
Total	64	47	85	754

The data in the table above indicates that there are approximately 1,808 parcels potentially in or partially within floodplain areas, and that 1,607 of the parcels are improved. The improved value of property on these parcels is just under $580 million, although this estimate may not include the improvement value of tax-exempt properties. This methodology to assess potential flood damage includes some level of uncertainty. In the case of the parcel value analysis, building footprints were not connected to parcels, so flooding on the parcel was equated to damage. Also, this is improved value, which is not synonymous with insured or replacement value.

Most buildings within flood hazard areas are residential in use (754 buildings, 79 percent). Eighty-five buildings within the floodplain are public use, indicating they are owned by the city or the University of Michigan.

Structures exposed to flooding can be severely damaged. Building contents can be lost, damaged, or destroyed, and structures themselves can be compromised by floodwaters. Pressure from floodwater, especially as seepage through soil, can damage building foundations. After a flood, wooden structures may rot.

Development and Redevelopment Trends. In addition to current at-risk structures, future structures in the floodplain are also at risk. Ann Arbor was built out in the 1970s, before floodplain and drainage regulations; most of the current development in the city is infill and redevelopment rather than new or greenfield development. Green space within Ann Arbor typically consists of parks, school grounds, and detention basins. City officials noted several locations within the city where new development is occurring:

- State Street / Eisenhower Corridor (bounded by the railroad to east, I-94 to the south, Briarwood/Main Street to the west, and Oakbrook to the north);
- North Maple/West Stadium Corridors (roughly Pauline to Miller);
- Downtown district and areas near downtown; and,
- Pontiac Trail/Dhu Varren/Leslie Park area.

Another way to assess potential future risk is to analyze future land uses designated for flood hazard areas. Figure 4-33 shows generalized future land uses from Ann Arbor's Future Land Use Map overlayed with flood hazard areas. While much of the floodplain and floodway, especially that which is associated with the Huron River, are designated as open space, certain areas are designated for growth, such as residential, commercial, and institutional uses in the Allen Creek floodplain, and high density residential, industrial/research, and public uses in the floodplain associated with Malletts Creek.

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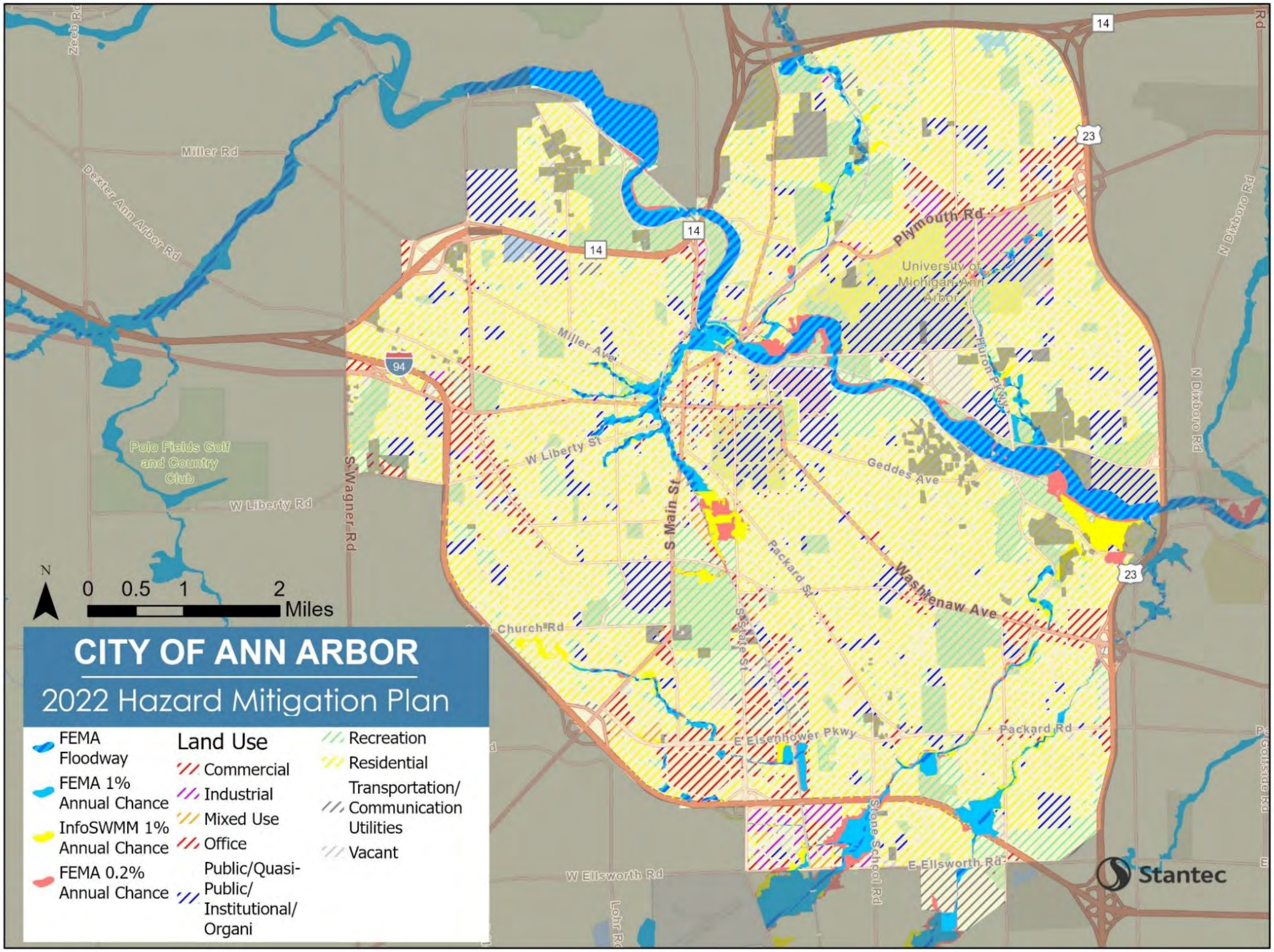

Figure 4-33: Ann Arbor Future Land Uses in Floodplain Hazard Areas

Damage to Infrastructure. Ann Arbor has infrastructure, including critical infrastructure, which is considered at-risk to flooding. Types of infrastructure that are vulnerable to flooding include roads and highways, bridges, railroads, dams, and water/sewer infrastructure. Table 4-34 describes at-risk critical infrastructure identified by Ann Arbor community officials and potential vulnerabilities. Figure 4-34 shows the location of critical infrastructure.

Table 4-34: Ann Arbor At-Risk Infrastructure

Infrastructure Type	At-Risk Infrastructure in Ann Arbor	Vulnerability to Flooding
Railroads	The Great Lakes Central Railroad runs north-south through Ann Arbor (along the Allen Creek floodplain and Traver Creek), and the Norfolk Southern Railway runs east-west, along the Huron River.	Flooding can result in the need to divert trains due to high waters, or even result in train derailments from washed-out tracks. In Ann Arbor, floods caused by groundwater have washed out tracks. Over 1,400 feet of track were washed out during the 1968 flood.
Highways	Several major highways cross flood hazard areas in the city, including Highway 14, Highway 23, and Interstate 94.	Floods can wash out roads. High, quick-moving floodwaters on highways can sweep up vehicles and pedestrians. Flooding on major roads can interfere with evacuations. Newport road in Ann Arbor collapsed during a flood event in 2000.
Bridges	The city has 135 documented bridges. As expected, many of these are in the floodplain as they are used to cross water features.	Bridges can become washed out or inundated during flood events. This happened during the 1968 flood in Ann Arbor.
Dams	The city owns and operates four critical dams along the Huron River: the Barton, Argo, Geddes, and Superior. As is expected, these are located within flood hazard areas.	Dams are vulnerable to failure during flood events. Failed dams can result in damage to the dam itself, as well as increased flooding downstream. Barton dam is used to generate hydroelectric power; therefore, if the dam fails the city may lose power or have to rely on a secondary source. Several dams failed during the 1968 flood.

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Figure 4-34: Ann Arbor Railroads, Roads, and Bridges in Floodplain Hazard Areas

Life Safety, Health, and Warning and Evacuation Procedures. The public often underestimates the dangers presented by floodwaters. Flooding is often localized to certain parts of a community (e.g., certain roads, intersections, or neighborhoods), and floodwaters can prevent normal access to buildings and facilities. This presents a danger when motorists and pedestrians attempt to traverse floodwaters. Motor vehicles and pedestrians can get swept up in flood currents, increasing the risk for drowning. Even in shallow waters, fast-moving currents can carry individuals or vehicles into deeper waters, where pressure from flowing water can prevent drivers from escaping submerged vehicles. As little as 6 inches of floodwater can move a vehicle, and as little as 2 inches can move a person. In addition, floodwaters often conceal conditions that are a danger to those on foot, including electrical wires, debris, nails, and open manholes hidden beneath the surface. In addition, roads and bridges can be weakened by flood impacts, making them unsafe for travel. Flood conditions necessitate warnings, such as flash flood warnings, road closure warnings, and flood advisories, in Ann Arbor, especially during extreme precipitation events.

While it is fortunate that Ann Arbor has not experienced a flood devastating enough to require evacuation for some time, this makes Ann Arbor more vulnerable if such an event were to occur. In communities that are not often required to evacuate, evacuation procedures may not be well-known to the public. During a large-scale flood event, residents may not be familiar with proper routes to lead them out of harm's way. Furthermore, Ann Arbor regularly experiences an influx of people for University of Michigan game days (upwards of 100,000 people). If a flood event were to occur on a game day, it is likely that visitors would not be familiar with evacuation routes. Exercises and road markers are ways communities can become familiar with evacuation procedures. On a positive note, the traffic management employed during game days helps keep local officials up to date on evacuation needs.

There are approximately 754 residential structures in the flood hazard areas (FEMA and InfoSWMM). According to American Community Survey 2016-2020 estimates, Ann Arbor averages a household size of 2.25 people per household. Therefore, it can be estimates that approximately 1,700 people are living within flood hazard areas. However, this is a planning-level analysis and does not account for structures with multiple units (such as apartment buildings). Therefore, the number of people in the floodplain could be much higher.

Public Health. Floodwaters often contain contaminants such as bacteria and chemical hazards. Flooding often results in combined sewer overflows, resulting in sewage in floodwaters. Individuals traversing floodwaters or children playing in floodwaters contract diseases, injuries, and infections. In Ann Arbor, basement backups have occurred during extreme precipitation events.

Structures exposed to floodwaters can also present public health hazards. Damaged electrical systems and natural gas tanks present risk of fire and explosions. Structures exposed to flooding may develop mold or wood rot. People with asthma, allergies, or breathing conditions may be at a higher risk to mold.[lxii]

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Trains or trucks carrying hazardous materials during flood events have the potential spill or release hazardous materials due to crashes or derailments, which could negatively impact public health. Fixed sites, such as factories or industrial facilities, can also release hazardous materials when their buildings are flooded.

Impacts to Socially Vulnerable Populations. Floods have the potential to disproportionately impact socially vulnerable populations. Economically constrained households (homeowners and renters) may have trouble affording flood insurance premiums. In the event of a flood, these households have a diminished capacity to repair homes, remediate mold, and replace destroyed belongings. In Ann Arbor, extreme precipitation events have caused basement flooding and sewer backups. Economically constrained households may not be able to afford preventative measures, such as backwater check valves or sump pumps. Individuals that do not have paid time off or are unable to work remotely (such as those in food service and hospitality) may attempt to traverse floodwaters to commute or may lose income in the event they cannot report to work due to a flood. Further, certain populations may face difficulty evacuating during an extreme flood event, such as the elderly, disabled, or those who are otherwise mobility challenged. Individuals who do not speak English may face challenges heeding flood warnings and advisories, especially when messaging is not provided in multiple languages.

In the US in general, low-income and minority populations are more likely to live in high-risk flood zones. One way to consider exposure of socially vulnerable populations to flood risk in Ann Arbor is by assessing the number of buildings within census tracts with high social vulnerability. A GIS intersect analysis was performed using buildings within flood risk areas (FEMA 1.0 percent, InfoSWMM 1.0 percent and FEMA 0.2 percent annual chance) and social vulnerability census tract ratings from the NRI. Results show that the majority of buildings in Ann Arbor within flood hazard areas are not located in census tracts defined as having the highest social vulnerability. Of the 950 buildings at risk to flood, seven (0.7 percent) are located within tracts with "relatively high" social vulnerability and 130 (13.7%) are located within tracts with "relatively moderate" social vulnerability. Figure 4-35 shows buildings within flood hazard hazards alongside NRI social vulnerability ratings by census tract.

The Washtenaw County Opportunity Index can also be used as an indicator of exposure of socially vulnerable populations to flood risk. Therefore, a similar intersect analysis was performed to determine the number of buildings at risk to flood within census tracts with the lowest access to opportunity. No census tracts within Ann Arbor are within the lowest opportunity category of "very low access to opportunity" but five tracts are categorized as having "low access to opportunity." About one-third (298) of the buildings within flood hazard areas are located within these census tracts, as shown in Figure 4-36.

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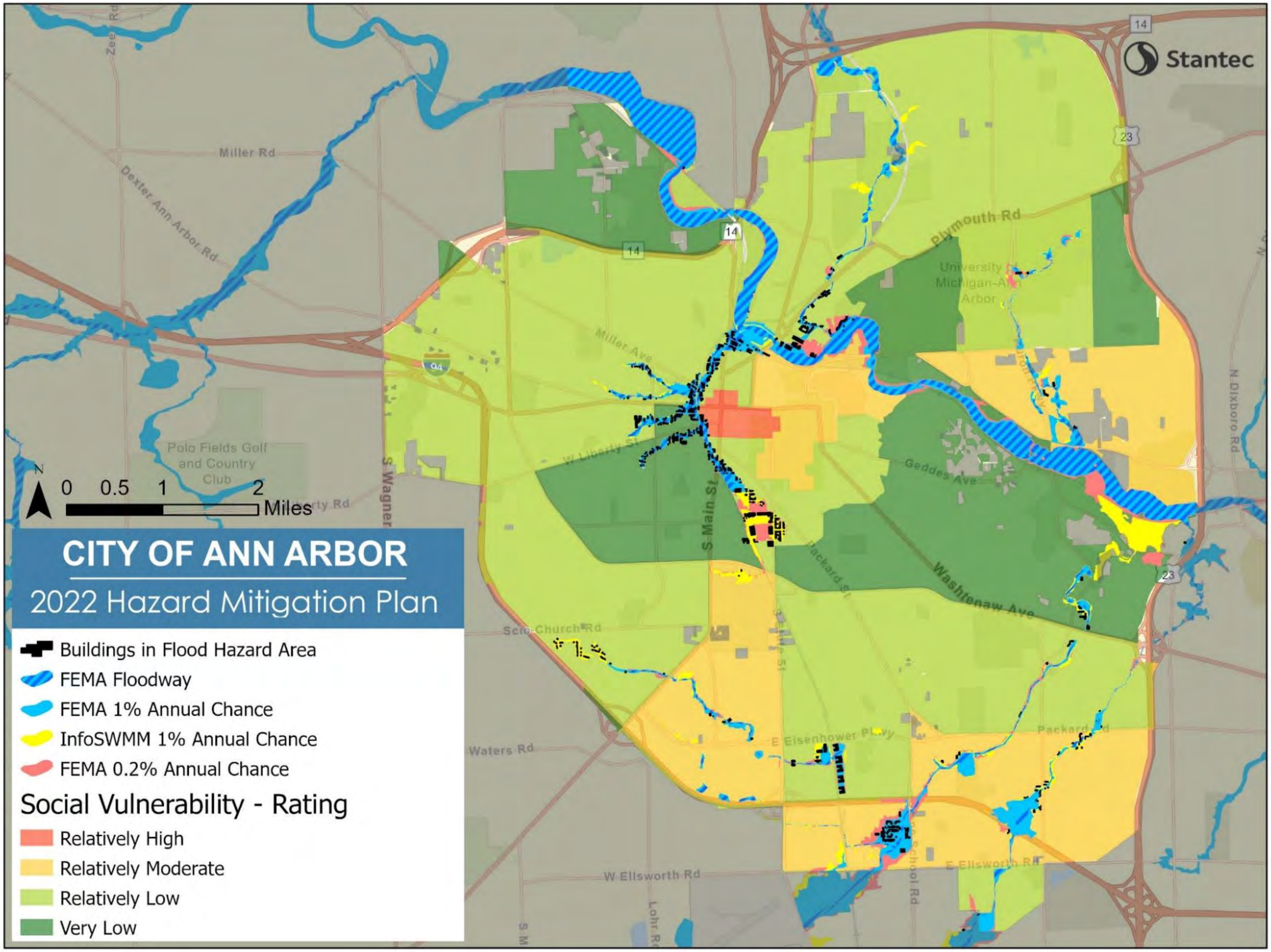

Figure 4-35: Buildings at Risk to Flood within Socially Vulnerable Census Tracts

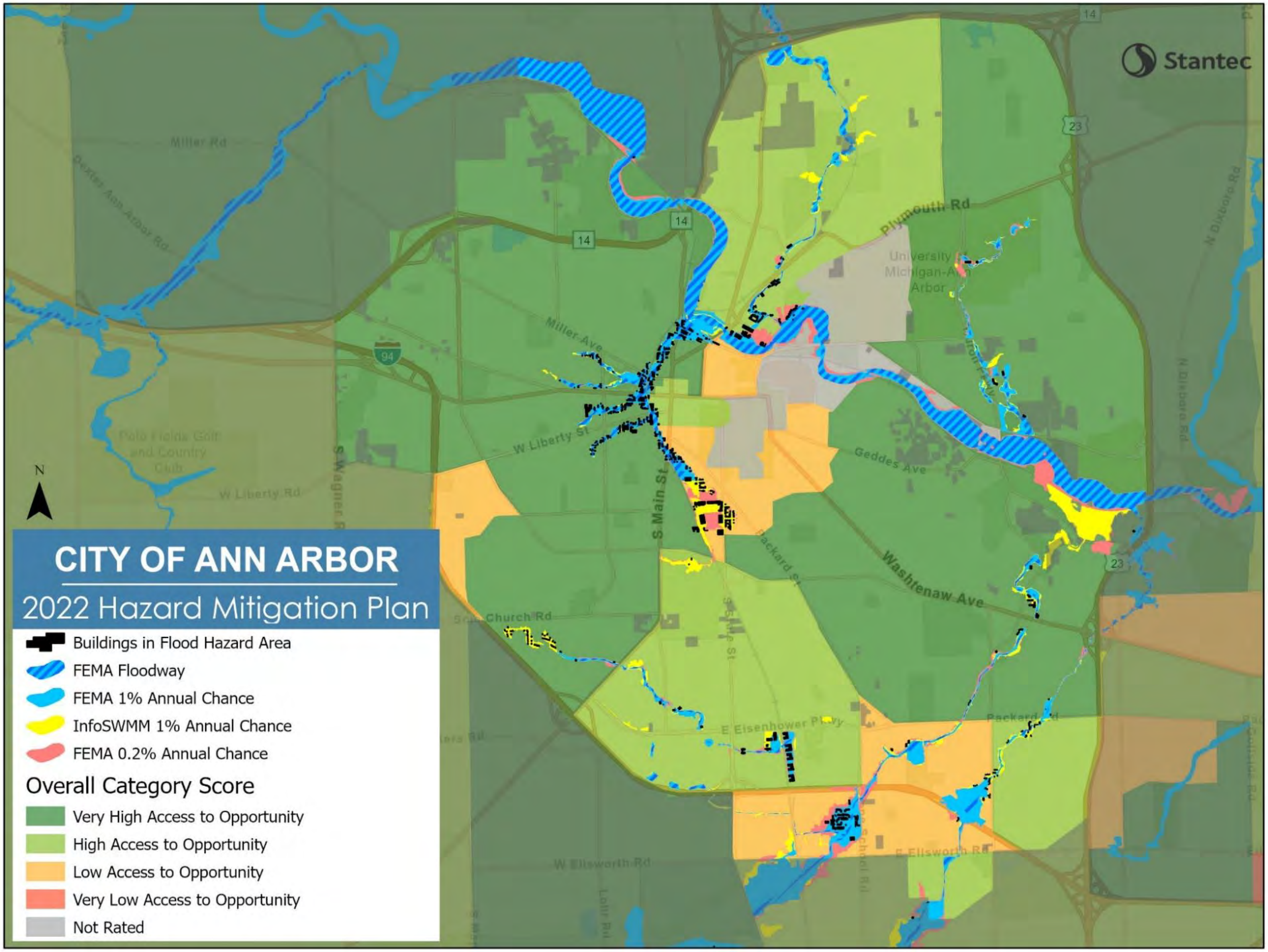

Figure 4-36: Buildings at Risk to Flood within Tracts with Low Access to Opportunity

Economic Impact. Flood damage to businesses is difficult to estimate. Businesses that are disrupted by floods often have to be closed. They lose their inventories, customers cannot reach them, and employees are often busy protecting or cleaning up their flooded homes. Business can be disrupted regardless of the business being located in the floodplain when customers and clients cannot reach their location, such as when roads are flooded. Business interruption is also forgone sales tax revenue for the city. As with flooded roads, public expenditures on flood fighting, sandbags, public works, fire department calls, clean-up and repairs to damaged public property affect all residents of the city, not just those in the floodplain.

Climate Change Impacts. Climate change will likely affect future flood impacts in Ann Arbor as data shows increasing extreme precipitation trends for the city. Ann Arbor precipitation showed an observed increase of 48 percent from 1951 to 2021.[lxiii] That is a 6 percent increase from the last update of this plan, which showed an increase of 42 percent from 1951 to 2014. Further, the frequency of severe precipitation events has increased in Ann Arbor over the last 30 years; the frequency of the 25-year, 24-hour storm event has increased by 9 percent, and the 100-year, 24-hour storm event has increased by 17 percent.[lxiv] Climate projections indicate these trends will increase through the end of the century, as summarized in Table 4-31. In addition, more snow falling as rain in the winter months, as temperatures warm, could increase rain precipitation totals and exacerbate flooding. According to the State of Michigan Hazard Mitigation Plan, spring flooding could worsen as snowfall melting patterns change with increasing temperatures.

It should also be noted that warmer temperatures could negate some of the projected increases in precipitation by increasing evaporation and creating drier conditions, especially in the summer months. Future flood-risk will depend upon a number of future factors: realized increases in temperature combined with realized increases in precipitation and heavy rainfall events, as well as future development trends and adopted mitigation actions.

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Natural Hazards – Ecological

Invasive Species

Description

An invasive species is defined as a species that is (1) non-native (alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species' introduction for this profile (thus distinguishing the situation from natural shifts in the distribution of species). Invasive species can have substantial impacts. Nationally, the current environmental, economic, and health costs of invasive species were estimated as exceeding the costs of all other natural disasters combined.

Invasive species can be transported in many ways, such as on animals, vehicles, ships, commercial goods, produce, and clothing. Non-native species are the foundation of U.S. agriculture, and also are used to prevent erosion, to provide fishing and hunting opportunities, and as ornamental plants and pets, occasionally a non-native organism flourishes too well and causes unwanted economic, ecological, or human health impacts. The terms "invasive" or "nuisance" are used to describe such species. New environments may affect rates of reproduction, susceptibility to disease, and other features that affect a species' success. Consequently, a plant or animal that causes little damage to agriculture or natural ecosystems in one area may cause significant problems in another. Certain non-native species are very successful in their new habitats because they out-compete native plants or animals and have no natural controls (predators, diseases, etc.) in the new area. Well non-native species flourish, they can become invasive and event result in an infestation. At least 200 well-known, high-impact, non-native species are present in the United States. They range from the European gypsy moth and emerald ash borer to crabgrass, dandelions, and German cockroaches. Non-native species annually cost well over a billion dollars to control. Some even pose human health risks. Others, like the zebra mussel, threaten widespread disruption of ecosystems and the displacement or loss of native plants and animals.

As the climate changes, native species are more likely to be stressed under new conditions, leading to increased vulnerability to invasion from non-native species that are better able to complete in the climate, often without any natural predators. Flora and fauna have already began responding to climate change. The Fourth National Climate Change states that changes overserved in the Midwest include species range shifts (shifting their location), changes in population size, shifts in body size and growth rates, and changes in the timing of seasonal events (phenology)[lxv]

Location

It is assumed that all of Ann Arbor is exposed to invasive species.

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Previous Occurrences

Ann Arbor is home to a large number of invasive species and pests. Invasive species that have a history of causing an infestation in the planning area include:

- Emerald Ash Borer (EAB) is an exotic wood boring beetle that was discovered in southeast Michigan in 2002. The beetle destroys the water and nutrient-carrying vessels, causing an infested tree to die within 2 to 3 years of infestation. Ann Arbor has removed nearly all publicly managed ash trees along streets and in mowed areas of parks; however dead ash trees still remain standing in city-managed natural areas. According to the Michigan Department of Agricultural and Rural Development, Washtenaw County was in a Quarantine area as of February 2016, which prohibits the transport of firewood (a vector for the spread of EAB) and the sale of ash trees at nursery and garden centers.[lxvi]
- Gypsy Moth Caterpillar and Gypsy moth are present throughout Michigan. The insect has four life stages: egg mass, caterpillar, pupa, and moth. It is only in the caterpillar state of the gypsy moth life cycle that is destructive and a potential health concern. The caterpillars are serious tree defoliators, feeding on leaves of several hardwood trees including, oak, birch, basswood, apple, and aspen. While healthy trees can usually withstand one or two defoliations without suffering permanent damage, older, diseased, or stressed trees may not.
- Dutch Elm Disease Dutch Elm Disease is vascular disease of primarily American Elms. Trees are infected with the disease from elm bark beetles that carry the spores from diseased trees to healthy ones. The disease begins by killing branches but eventually the whole tree can succumb to the disease. Dutch elm disease began killing elm trees in Ann Arbor in the 1960's. Today, the city manages about 540 American elms larger than 8" in diameter. The average size of these trees is 20" DBH. Dutch elm disease still threatens the remaining elms, and the city loses several dozen each year.

In addition to the pests listed above, the Ann Arbor Parks and Recreation Department maintains a list of invasive plant species present in the city, which can be found at: http://www.a2gov.org/departments/Parks-Recreation/NAP/Pages/InvasivePlants.aspx.

Extent

The extent of invasive species and infestation can be measured in terms of invasive species population size or damages incurred by an invasive species. No population counts or damages figures were available for invasive species in Ann Arbor.

Probability of Future Occurrences

Since there are no detailed records of historical occurrences or detailed studies available, determining an accurate probability based on past events is not feasible. Once a non-native species becomes invasive, it is challenging to eradicate. Given the current number of invasive species in Ann Arbor, along with the threat of new or unknown invasive species (especially due to climate

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change), the probability of the invasive species hazard is Ann Arbor was assigned a probability of highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

Ann Arbor is vulnerable to the impacts of invasive species. Invasive species have the potential to damage buildings and infrastructure as well as impact life safety, public health, and the local economy. Impacts to socially vulnerable populations and the influence of climate change is also discussed.

Damage to Buildings. The emerald ash borer has caused extensive damage to trees in Michigan, and those weakened trees have often collapsed and caused property damage. Dead trees become dry and brittle and are especially prone to snap and falling during ice storms or when subject to high winds. While Ann Arbor does not have extensive forest lands, they do have a significant tree canopy within the city that could become vulnerable to invasive species, such as pests, diseases, or competing non-native trees.

Furthermore, some invasive plant species have the potential to overtake buildings and structures. For example, Kudzu, an invasive plant species in the southeastern U.S. (which is working its way north and west), is a vine plant that is known for overwhelming buildings and causing structural damage.

Damage to Infrastructure. Similar to potential damages to buildings, trees weakened by emerald ash borers can collapse and cause damage to surrounding infrastructure, including utility poles and power lines.

Life Safety, Health, and Warning and Evacuation Procedures. Invasive species can have a range of impacts on life safety and health, depending on the species and the severity of the infestation. Dead trees resulting from invasive pest infestations can fall, potentially causing injuries. Dead and decaying trees are also more prone to catching on fire. It is unlikely that an invasive species infestation would directly result in the need for evacuations.

Public Health. Invasive species can have a range of impacts on public health, depending on the species and the severity of the infestation. Invasive microbes have the potential to contaminate water sources, while invasive pests have the potential to spread disease to humans, plants, and livestock. Certain diseases carried by invasive species could wipe out large segments of an animal population, creating a potentially serious public health emergency and the need to properly (and rapidly) dispose of the dead animal carcasses. Climate-driven changes to the habitats for disease-carrying mosquitos and ticks have been attributed to increased rates of infection in the region.[lxvii]

Impacts to Socially Vulnerable Populations. Invasive species that have adverse public health impacts (such as those that spread disease) have the potential to disproportionately impact elderly and immunocompromised populations. Economically constrained households and those without health insurance may face challenges obtaining or paying for care associated with health impacts from invasive species.

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Economic Impact. Invasive species can have a devastating impact on local economies that are dependent on forestry, agriculture, horticulture, fishing, and eco-tourism. For example, quarantines placed on counties restrict certain host plants from being able to enter and leave an area, impacting nursery businesses. In addition, dead trees resulting from invasive pest infestations can be expensive to remove and replace.

Climate Change Impacts. As the climate changes, the city will have to contend with a wide range of invasive species. Some existing species will adapt to changes, while others will not be able to thrive in new conditions. Climate change also brings about the threat of new species that could not exist in the previous climate but will thrive in future conditions. Different patterns of wildlife have already been observed as a result of the lengthening average growing season in Michigan. Species that had previously been found only in warmer areas to the south have started to appear in Michigan. Although the definition of invasive species specifically refers to human species introduction, to distinguish these patterns from naturally occurring ones, species transported by human action can be more likely to survive (and thus to become invasive) as climatic changes occur. Ann Arbor is observing a switch from its traditional tree cover of maple, beech, and birch to species like oak and hickory, which are generally associated more with its southern neighbors. Figure 4-37 shows USDA Plant Hardiness Zone Maps from 1990 and 2012, which show that Ann Arbor's plant hardiness zone has shifted from Zone 5 to Zone 6 as the climate becomes warmer. In general, lower zone numbers are associated with colder climates and higher zone numbers with warmer climates.[lxviii]

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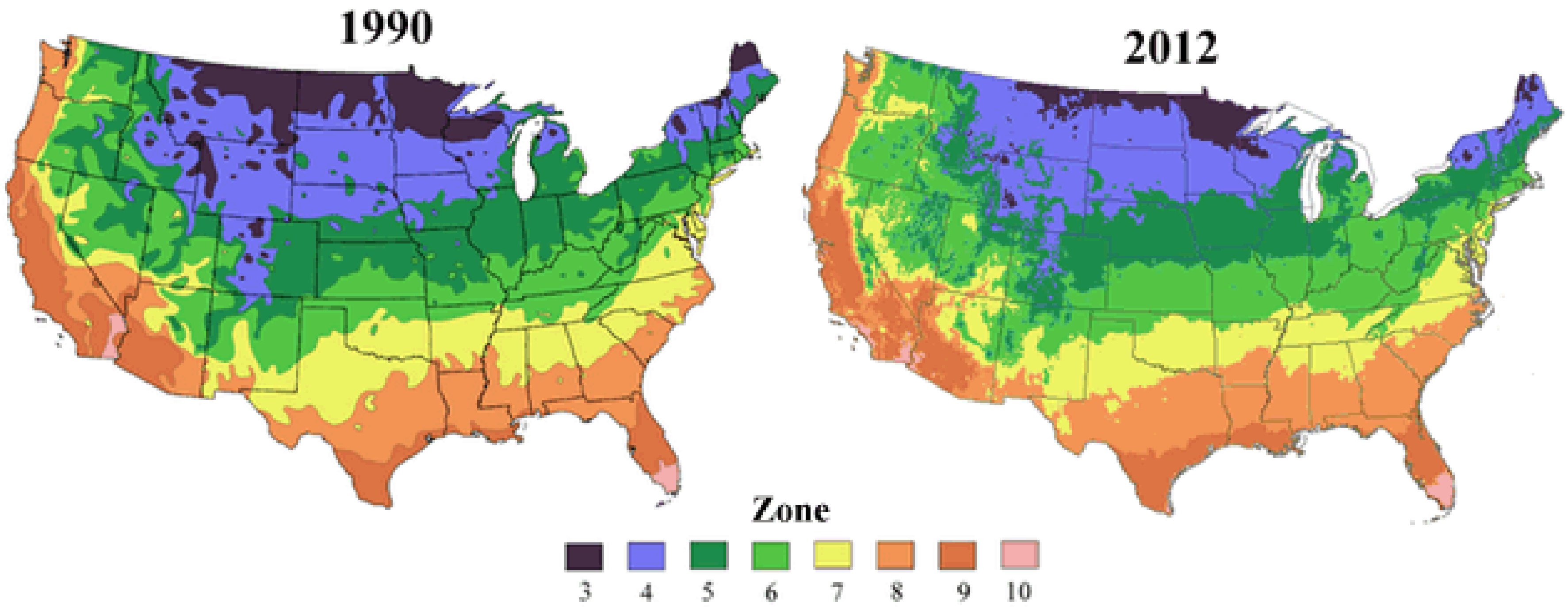

Figure 4-37: USDA Plant Hardiness Zone Maps, 1990 and 2012

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Natural Hazards – Geologic

Earthquake

Description

Earthquakes are scientifically defined as the sudden release of strain (or displacement of rock) in the earth's crust, resulting in waves of shaking that radiate outward from the earthquake source. They may result from crustal strain, volcanism, landslides, or the collapse of caverns. Earthquakes can occur underwater or on land. Earthquakes can affect hundreds of thousands of square miles. Their intensity ranges from very minor (shaking not detected by humans without instruments) to very violent (catastrophic in nature). Damages follow this intensity ranging from minor to catastrophic. Earthquakes also occur without warning, resulting in deaths and injuries.

To understand the nature of earthquakes, the composition of the earth must be explored. The earth is made up of four major layers and several sub layers (Figure 4-48)[lxix] a solid inner core, a liquid outer core, a semi-molten mantle, and the rocky crust (the thin outermost layer of the earth). The upper portion of the mantle combined with the crust forms the lithosphere. This area is susceptible to fractures and is referred to as a shell. The lithosphere breaks up into large slabs, known as tectonic plates. This area is where earthquakes occur.

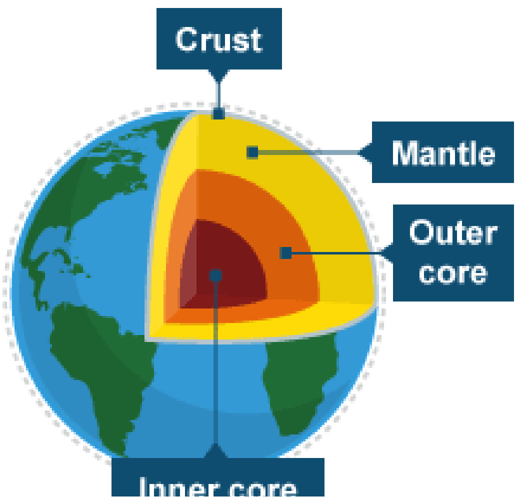

Figure 4-38: **Earth's Sub Layers**

There are approximately twelve major plates and several dozen more minor plates on the Earth's crust, as shown in Figure 4-39. Plates are regions of the crust that continually move over the mantle. Areas where these plates meet, grind past each other, dive under each other, or spread apart, are called plate boundaries. Most earthquakes are caused by the release of stresses accumulated due to the sudden displacement of rock along opposing plates in the Earth's crust. The location below the earth's surface where the earthquake starts is known as the hypocenter or focus. The point on the earth's surface directly above the focus is the epicenter. Areas bordering the Pacific Plate, also known as the "Pacific Ring of Fire", are at a particularly high risk since most of the largest earthquake events of the last century have occurred in the region.

While earthquakes typically occur along plate boundaries, they can affect hundreds of thousands of square miles, causing damage to property (measured in the tens of billions of dollars), resulting in loss of life and injury to hundreds of thousands of persons, and disrupting the social and economic functioning of the affected area.

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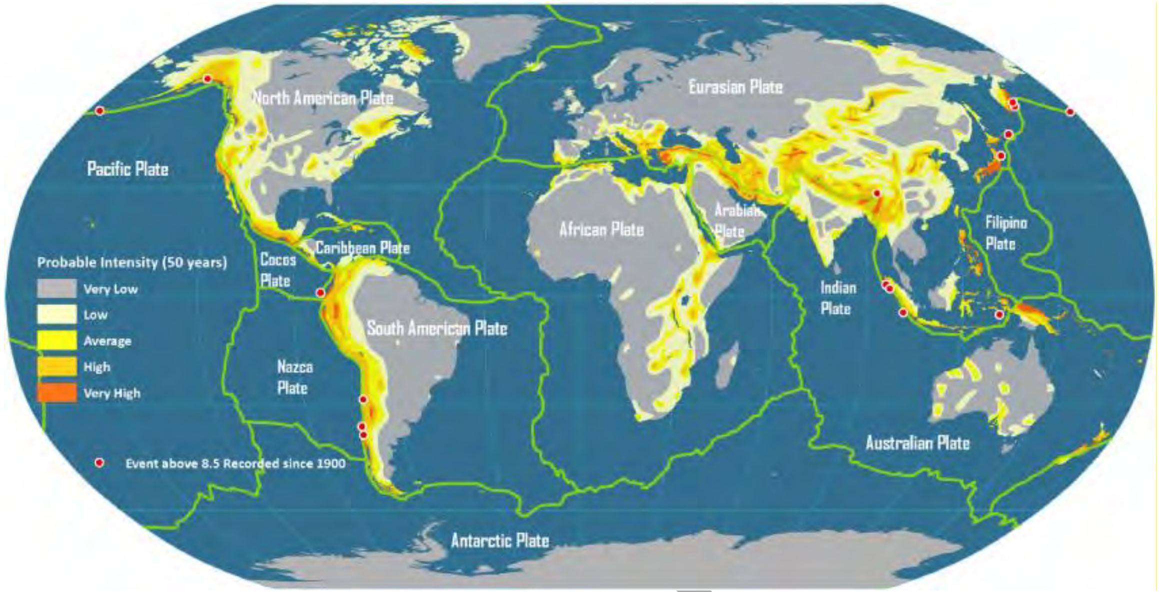
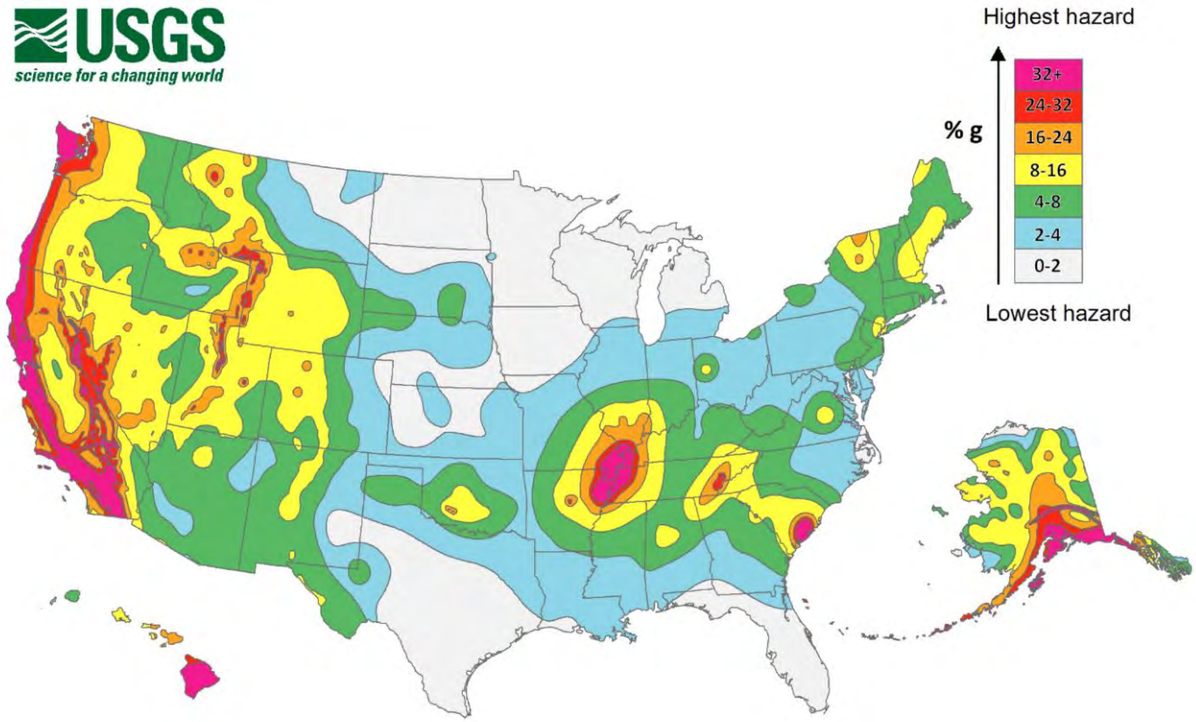


Figure 4-39: Global Plate Tectonics and Seismic Activity[lxx]

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault, site, and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quicksand. In the case of liquefaction, anything relying on the substrata (the layer of rock and soil beneath the ground) for support can shift, tilt, rupture, or collapse.

The greatest earthquake threat in the United States is along tectonic plate boundaries and seismic fault lines located in the central and western states; however, the Eastern United State does face moderate risk to less frequent, less intense earthquake events. Figure 4-40 shows relative seismic risk for the United States.



Source: United States Geological Survey

Figure 4-40: United States Earthquake Hazard Map

Earthquake magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude (Table 4-35)[lxxi]. Each unit increase in magnitude on the Richter Scale corresponds to a 10-fold increase in wave amplitude, or a 32-fold increase in energy. Beginning in 2002, the USGS began using Moment Magnitude as the preferred measure of magnitude for all USGS earthquakes greater than magnitude 3.5. This was primarily due to the fact the Richter Scale has an upper bound, so large earthquakes were difficult to measure. Moment Magnitude also has a scale, but no instrument is used to measure it. Instead, factors such as the distance the earthquake travels, the area of the fault, and land that was displaced (also known as "slip") are used to measure moment magnitude. Table 4-36 shows the Moment Magnitude Scale.

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Table 4-35: Richter Scale

RICHTER MAGNITUDES	EARTHQUAKE EFFECTS
<3.5	Generally, not felt, but recorded.
3.5 - 5.4	Often felt, but rarely causes damage.
5.4 - 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1 - 6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0 - 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or >	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Source: Federal Emergency Management Agency

Table 4-36: Moment Magnitude Scale

SCALE VALUES	EARTHQUAKE EFFECTS
<3.5	Very weak; unlikely to be felt
3.5 - 5.4	Generally, felt; rarely causes damage
5.4 - 6.0	Will not cause damage to well-designed buildings; will damage poorly designed ones
6.1 - 6.9	Considered a "major earthquake" that causes a lot of damage
7.0 - 7.9	Large and destructive earthquake that can destroy large cities
8 or >	Large and destructive earthquake that can destroy large cities

Source: Federal Emergency Management Agency

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Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, ranging from "I" corresponding to imperceptible (instrumental) events to "XII" for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in Table 4-37. Table 4-38 compares the Richter scale magnitudes and MMI magnitudes for several well-known historic earthquakes in the U.S.

Table 4-37: Modified Mercalli Intensity Scale for Earthquakes

SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER MAGNITUDE
I	INSTRUMENTAL	Detected only on seismographs.	
II	FEEBLE	Some people feel it.	< 4.2
III	SLIGHT	Felt by people resting; like a truck rumbling by.	
IV	MODERATE	Felt by people walking.	
V	SLIGHTLY STRONG	Sleepers awake; church bells ring.	< 4.8
VI	STRONG	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	VERY STRONG	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	DESTRUCTIVE	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	
IX	RUINOUS	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	DISASTROUS	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	VERY DISASTROUS	Most buildings and bridges collapse; roads, railways, pipes, and cables destroyed; general triggering of other hazards.	< 8.1

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SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER MAGNITUDE
XII	CATASTROPHIC	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

Table 4-38: Richter vs. Moment Magnitude Values

Earthquake	Richter Scale	Moment Magnitude
New Madrid, MO 1812	8.7	8.1
San Francisco, CA 1906	8.3	7.7
Prince William, AK 1964	8.4	9.2
Northridge, CA 1994	6.4	6.7

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Location

An earthquake event would impact the entire planning area. Earthquakes can be felt and cause damage hundreds of miles from a fault or event epicenter. Fault locations and earthquake risk areas defined by the USGS help define locations that may experience an earthquake. There are no known active faults in Ann Arbor. The Grenville Front is a dormant regional fault zone that crosses underneath Washtenaw County and is not a major concern at this time.

The New Madrid Seismic Zone comprised of the New Madrid and Wabash Valley seismic zones are the most significant seismic zones to threaten Ann Arbor. Figure 4-51 is a USGS map of the New Madrid and Wabash Valley seismic zones and shows earthquakes as circles.[lxxii] While Ann Arbor is not shown here, these are the major seismic zones nearest to the city, which is approximately 315 miles northeast of the zone. Red circles indicate earthquakes that occurred from 1974 to 2002 with magnitudes larger than 2.5 located using modern instruments (University of Memphis). Green circles denote earthquakes that occurred prior to 1974 (USGS Professional Paper 1527). Larger earthquakes are represented by larger circles.

Another seismic zone that presents a threat to the city is the Charlevoix-Kamouraska Seismic Zone (CSZ) in Quebec, Canada. The CSZ is one of the most seismically active regions in Canada and runs along the St. Lawrence River (Figure 4-42).[lxxiii] The CSZ is approximately 400 miles northeast of Ann Arbor.

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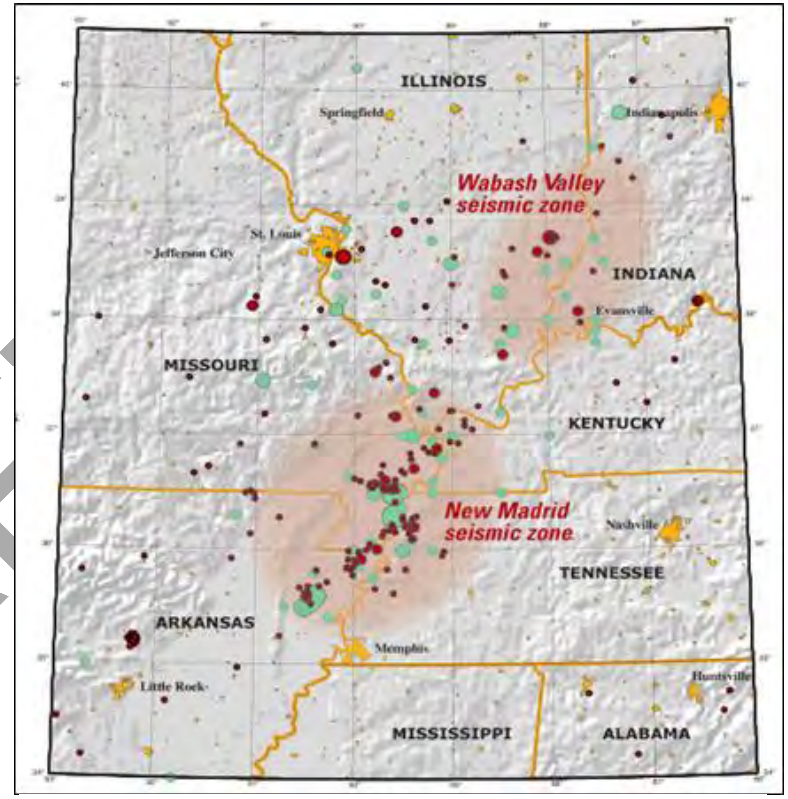

Figure 4-41: USGS New Madrid and Wabash Valley Seismic Zones

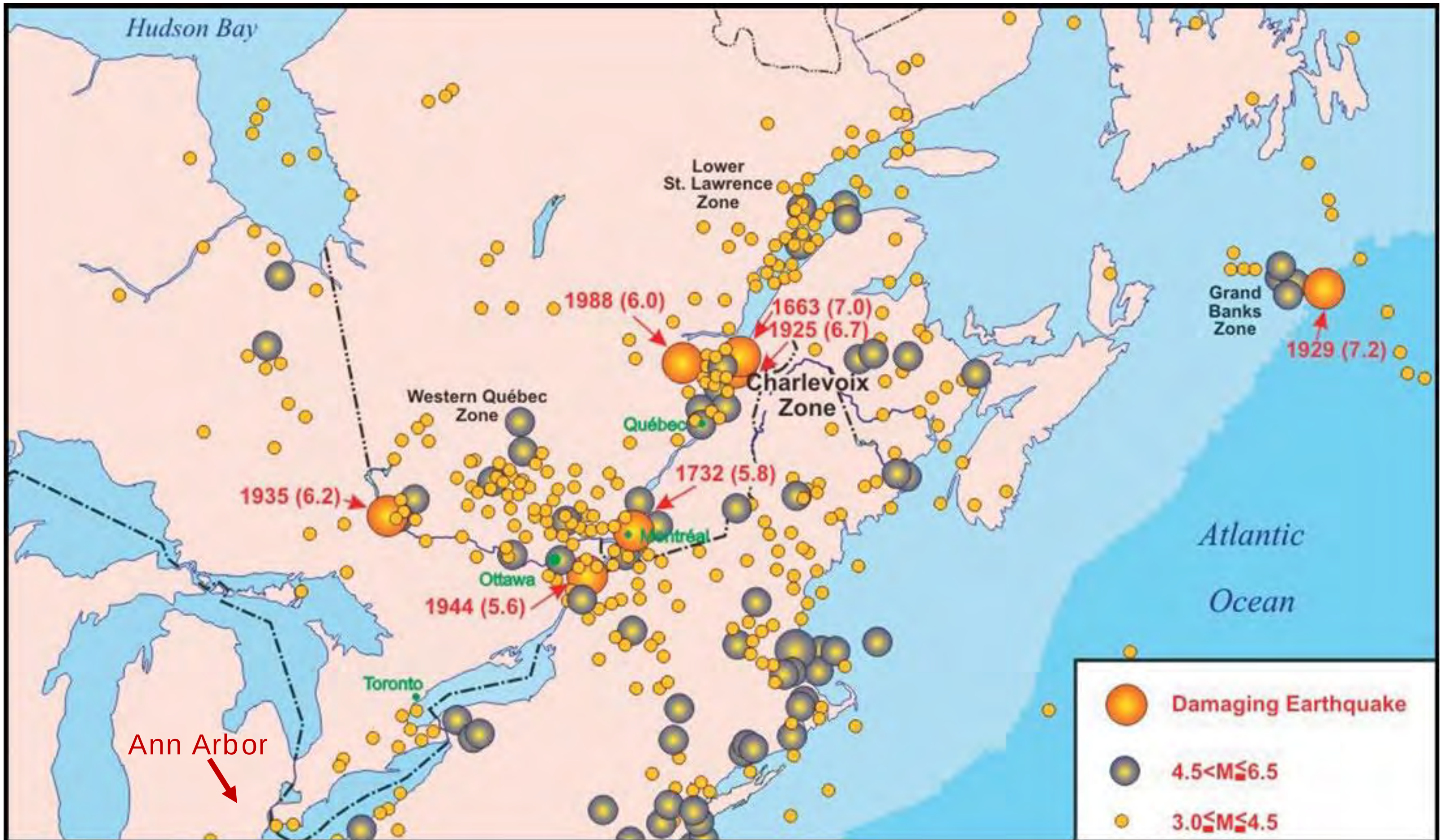

Figure 4-42: USGS New Madrid and Wabash Valley Seismic Zones

In 2015, a 4.2 magnitude earthquake occurred 12 miles southeast of Kalamazoo, MI (approximately 90 miles west of Ann Arbor), leading researchers to discover a fault that runs between Kalamazoo and Coldwater, MI.

Earthquake science continues to evolve; it is possible that there are additional faults located under or near Ann Arbor. It is also possible for faults thought to be dormant to become active.

Previous Occurrences

Ann Arbor has a limited recorded history of earthquakes. Based on reviewed sources, Ann Arbor has experienced between 10 to 15 earthquakes since the 1880s. However, it is possible additional earthquakes have been felt in Ann Arbor but were not documented as the city was not the primary impact area. Table 4-39 shows earthquakes recorded in Ann Arbor between 1638 and 1985, as reported by NCEI.[lxxiv] Eight earthquakes were reported, none of which had associated damages, deaths, or injuries.

Table 4-39: NCEI Reported Earthquakes in Ann Arbor, 1638-1985

Year	Magnitude	Modified Mercalli Intensity (MMI)
1886	--	5
1925	7	2
1935	--	3
1937	--	4
1937	5.5	3
1943	--	3
1947	--	3
1968	5.3	4

Several earthquakes occurring in Quebec's CSZ have been felt in Ann Arbor, including one in 1925 (6.7 magnitude) and another in 1935 (6.1 magnitude). The 1935 earthquake, called the Timiskaming Quake, had an MMI of VI at its epicenter, and an MMI of III in Ann Arbor (Figure 4-43).[lxxv] Although fault information is not provided with past occurrences in NCEI, it is assumed that the 1925 and 1935 quakes reported in the table above are the ones that occurred in the CSZ. Other earthquakes along CSZ that were likely felt in Ann Arbor include ones in 1663 (magnitude 7.0), 1732 (5.8), 1944 (magnitude 5.6), and 1988 (magnitude 6.0). The locations of these earthquakes are shown in the figure of the CSZ, above.

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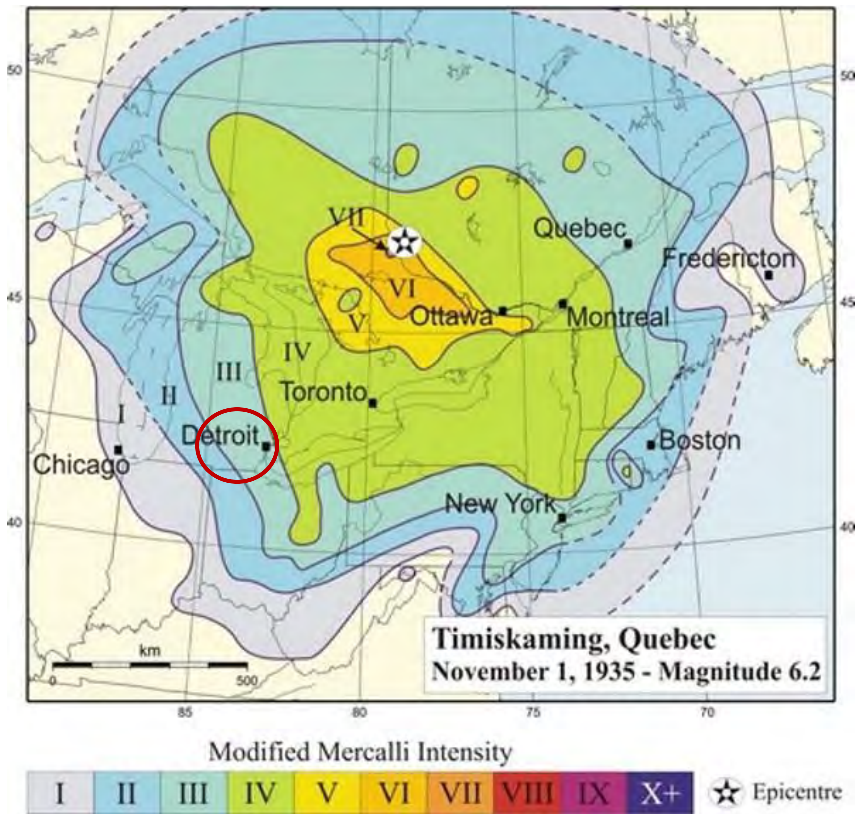

Figure 4-43: 1935 Timiskaming Earthquake Map

More recently, a 4.2 magnitude earthquake occurred near Kalamazoo, MI, on May 2, 2015. According to Figure 4-44, the intensity of the earthquake in Ann Arbor was an II-IV on the MMI, equating to weak/light shaking and no damages. Similarly, a 5.2 magnitude earthquake occurred in southern Illinois on April 18, 2008. According to Figure 4-1 the intensity of the quake in Ann Arbor was an I-III on the MMI, resulting in weak shaking and no damages. It is possible other earthquakes occurring in nearby locations were felt in Ann Arbor but were not well-recorded due to lack of damages or shaking.

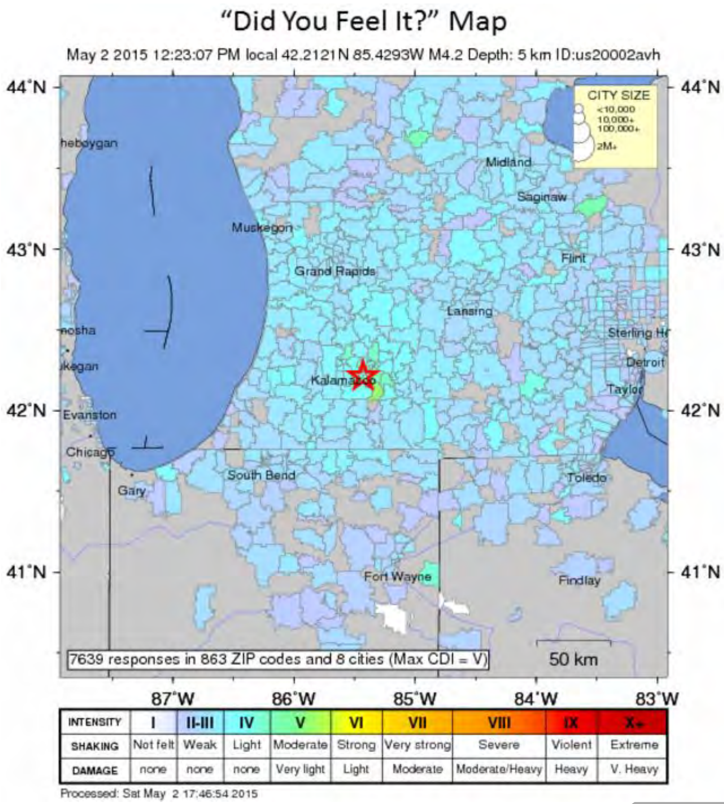

Figure 4-44: 2015 Kalamazoo Earthquake Location

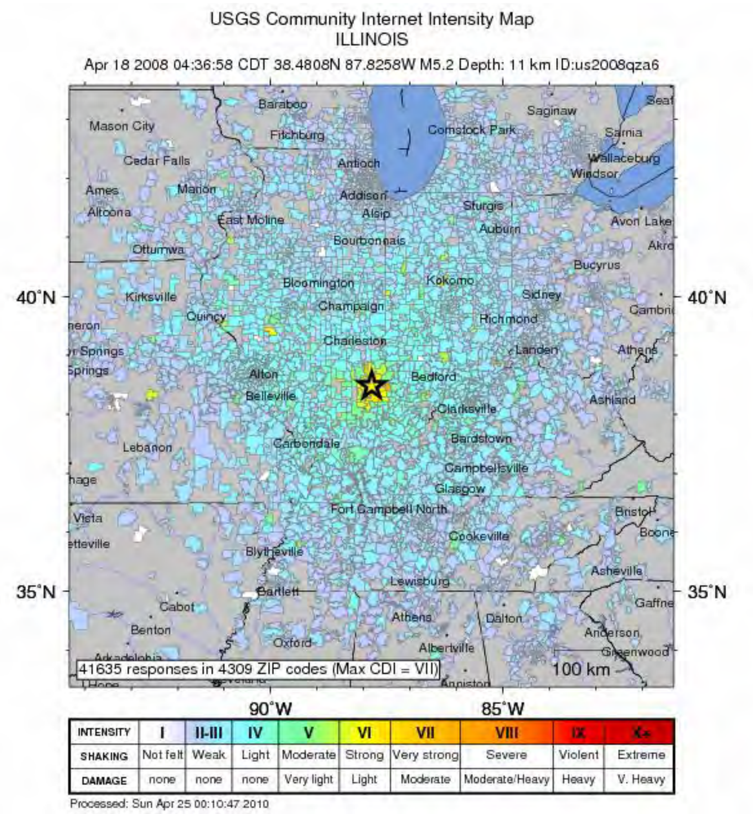

Figure 4-45: 2008 Illinois Earthquake Location

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Figure 4-46 illustrates previous earthquake occurrences within 300 miles of Ann Arbor. The largest previous earthquake to occur within the State of Michigan was a 4.2 magnitude earthquake in 2015, and the largest occurrence within 300 miles of Ann Arbor was a 5.0 magnitude earthquake near Cleveland, Ohio in 1986.

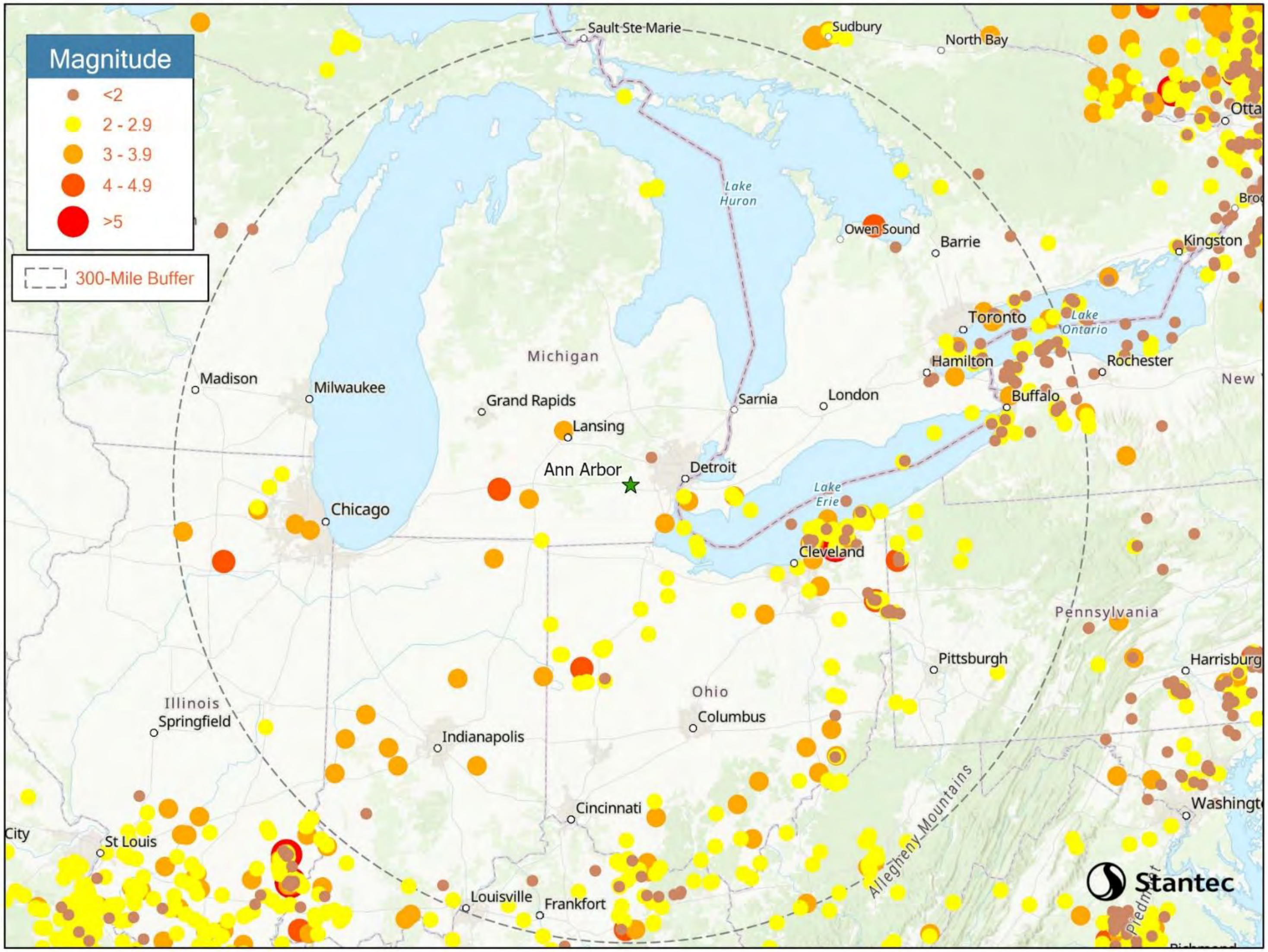

Figure 4-46: Previous Earthquake Occurrences within 300 Miles

Extent

There are several ways to measure the extent of an earthquake including magnitude and intensity experienced. From past recorded events, the strongest magnitude earthquake to be felt in Ann Arbor was a magnitude 7.0 in 1925, and the strongest intensity earthquake felt in Ann Arbor was a V (Slightly Strong; sleepers awake, church bells ring) on the Modified Mercalli Scale, which equates to light moderate and light damages. Greater extent events are possible, but, in general damaging, earthquakes are not common in the planning area.

Probability of Future Occurrences

The probability of significant, damaging earthquake events affecting Ann Arbor is unlikely. In fact, earthquake probability in general is difficult to estimate. Only 10 to15 earthquakes have been recorded as being felt in Ann Arbor over several hundred years; earthquakes are not regular occurrences for the city. However, the presence of two major seismic zones near the region suggest an increased likelihood. In addition, Ann Arbor and the surrounding region are composed of bedrock, which is better able to carry seismic energy than sandy soils, such as those on the west coast. Considering historic occurrences, the probability assigned to an earthquake with the potential to cause damage in Ann Arbor is unlikely (less than 1 percent annual probability).

Vulnerability Assessment

Earthquakes are considered a lower risk hazard in Ann Arbor. However, all current and future buildings, infrastructure, and populations in Ann Arbor are considered at-risk to earthquakes. Earthquake risk in Ann Arbor may be more significant than is currently assumed. While a catastrophic event is not likely, earthquakes that can be felt, and potentially result in light to moderate damage are feasible given the surrounding hazard areas.

Damage to Buildings. Although a catastrophic event is unlikely, it is still possible that an earthquake could result in damages to buildings in Ann Arbor. All current and future buildings are considered at risk to earthquakes. In Ann Arbor, it is possible for earthquakes to cause structural damage, fallen shelves, and toppled furniture. Fires caused by ruptured pipes or downed power lines have the potential to cause structure fires.

Damage to Infrastructure. In the event of an earthquake, there is potential for minor damages to the city’s infrastructure, including all pipes, roads, bridges, railroads, dams, and utility poles. During earthquakes, underground infrastructure, such as water and sewer systems and natural gas pipelines, is especially vulnerable. In addition, in the event that a dam is damaged during an earthquake, there is potential for dam failure or an energy shortage (in the case of hydroelectric dams).

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Life Safety, Health, and Warning and Evacuation Procedures. It can be assumed that all existing future populations are at risk to the earthquake hazard. While a devastating earthquake is unlikely, injuries are possible if earthquake shaking causes items to fall off shelves or walls. Damages to structures or infrastructure could have impacts on the population. For instance, downed power lines could result in power outages. Evacuations are unlikely for an earthquake event, but individuals should take cover under a heavy, sturdy object (such as a desk or table) in the event of an earthquake.

Public Health. Earthquakes that are strong enough to damage infrastructure may have public health impacts, such as contaminated water supply, fires from natural gas leaks, or prolonged power outages (which can especially impact public health when combined with extreme temperatures. Such an earthquake is unlikely in Ann Arbor, but possible.

Impacts to Socially Vulnerable Populations. In the event of a serious earthquake, vulnerable populations may be susceptible to negative consequences resulting from the event. Individuals living in older housing (prior to modern building codes), substandard housing, or housing not built to code the greatest risk to structural damage from an earthquake in Ann Arbor. Individuals or families in high-density living situations may struggle to safely navigate damaged structures or evacuate quickly after an earthquake should a structural fire break out as a result of the hazard. Households experiencing economic constraints may lack the necessary funds to repair damages. However, damage-causing events are unlikely in the city. Populations with limited access to telephone and internet services may experience delays in receiving and acting upon alerts and information in the aftermath of an earthquake, and the earthquake may also disrupt these communication mechanisms. Additionally, those who do not speak English well may experience further difficulty receiving and comprehending hazard incident or preparedness information.

Economic Impact. The economic impact of an earthquake in Ann Arbor would likely be limited to losses from damaged building contents (e.g., goods falling off shelves). However, business disruptions or costs for infrastructure repairs are possible, particularly to broadband and communication assets. In general, the economic impact from earthquake events in Ann Arbor is minimal.

Climate Change Impacts. Climate Change is not considered to have a significant impact on earthquakes in Ann Arbor.

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Technological Hazards

Hazardous Materials Release

Description

Hazardous materials can be found in many forms and quantities that can potentially cause death; serious injury; long-lasting health effects; and damage to buildings, homes, and other property in varying degrees. Such materials are routinely used and stored in many homes and businesses and are also shipped daily on the nation's highways, railroads, waterways, and pipelines. This subsection on the hazardous material hazard is intended to provide a general overview of the hazard, and the threshold for identifying fixed and mobile sources of hazardous materials is limited to general information on rail, highway, and local and FEMA-identified fixed HAZMAT sites determined to be of greatest significance as appropriate for the purposes of this plan.

Hazardous material (HAZMAT) incidents can apply to fixed facilities as well as mobile, transportation-related accidents in the air, by rail, on the nation's highways, and on the water. Approximately 18, 951 HAZMAT events occur annually based on the last 10 years of data.[lxxvi] Of these, an average of 17,044 highway incidents, 544 railroad incidents, and 1,364 are due to other causes. In essence, HAZMAT incidents consist of solid, liquid, and/or gaseous contaminants that are released from fixed or mobile containers, whether by accident or by design as with an intentional terrorist attack. A HAZMAT incident can last hours to days, while some chemicals can be corrosive or otherwise damaging over longer periods of time. In addition to the primary release, explosions and/or fires can result from a release, and contaminants can be extended beyond the initial area by persons, vehicles, water, wind, and possibly wildlife as well.

HAZMAT incidents can also occur as a result of or in tandem with natural hazard events, such as floods, hurricanes, tornadoes, and earthquakes, which in addition to causing incidents can also hinder response efforts. In the case of Hurricane Floyd in September 1999, communities along the Eastern United States were faced with flooded junkyards, disturbed cemeteries, deceased livestock, floating propane tanks, uncontrolled fertilizer spills, and a variety of other environmental pollutants that caused widespread toxicological concern.

Hazardous material incidents can include the spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of a hazardous material, but exclude: 1) any release which results in exposure to poisons solely within the workplace with respect to claims which such persons may assert against the employer of such persons; 2) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft, vessel or pipeline pumping station engine; 3) release of source, byproduct, or special nuclear material from a nuclear incident; and 4) the normal application of fertilizer.

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Location

As a result of the 1986 Emergency Planning and Community Right to Know Act (EPCRA), the Environmental Protection Agency provides public information on hazardous materials. One facet of this program is to collection information from industrial facilities on the releases and transfers of certain toxic agents. This information is then reported in the Toxic Release Inventory (TRI). TRI sites indicate where such activity is occurring. There are 17 TRI sites located in Washtenaw County, two of which are located within Ann Arbor. These sites are shown in Figure 4-47.

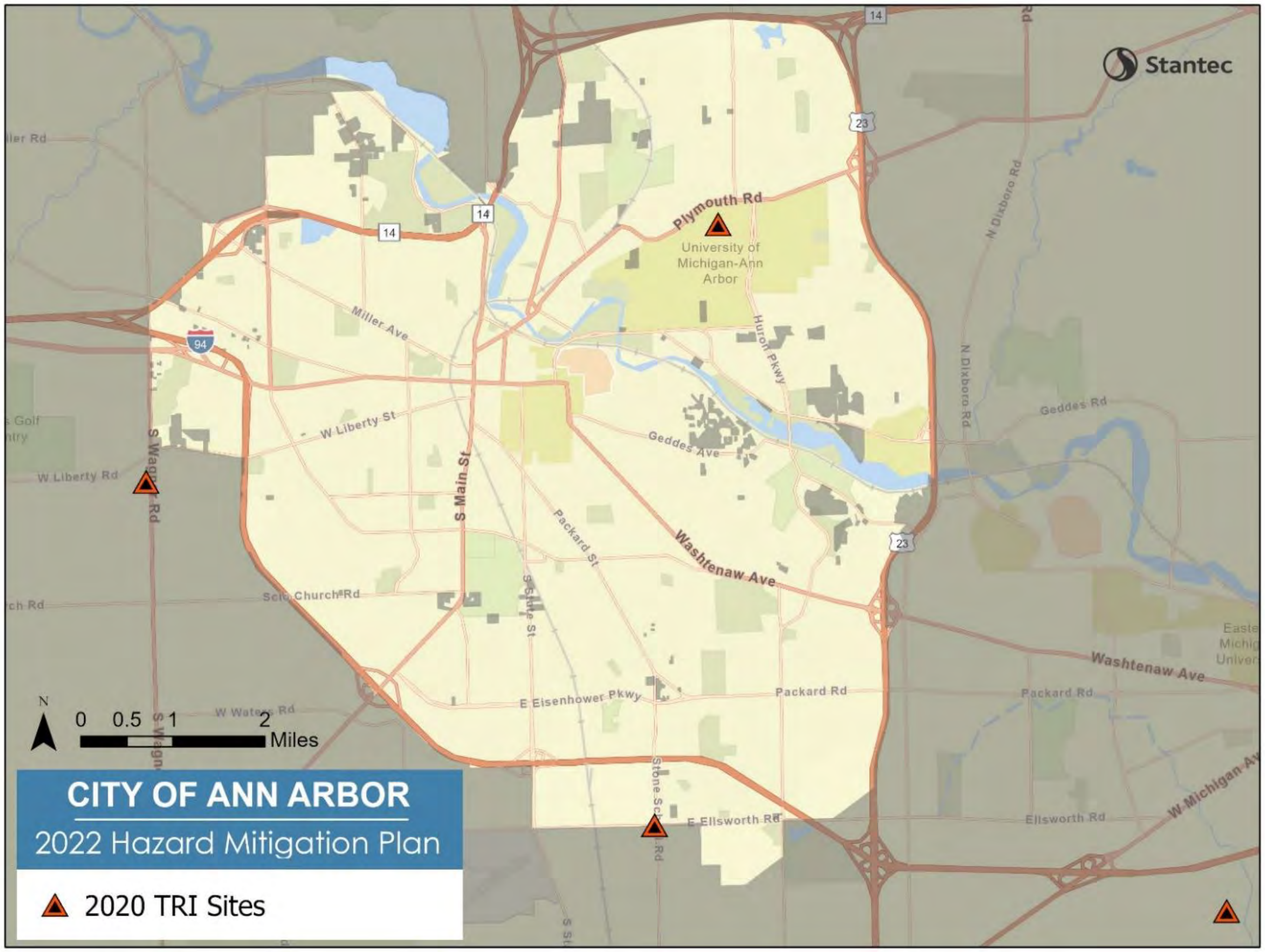

Figure 4-47: TRI Sites in Ann Arbor

In addition, corridors along major roads, highways, and railroads within Ann Arbor are at an elevated risk for HAZMAT incidents due to the transport of hazardous materials. These areas are analyzed further in this hazard's *Vulnerability Assessment*.

Previous Occurrences

As shown in Figure 4-48, there are two TRI sites located within Ann Arbor. Of these locations, Cayman Chemical Company, Inc. recorded an on-site release in 2020. A record of this release does not imply there was or is a threat to the community and further investigation would be required to determine if there were any impacts to residents.

The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) lists historical occurrences throughout the nation. A "serious incident" (in bold in the table below) is a hazardous materials incident that involves:

- A fatality or major injury caused by the release of a hazardous material,
- The evacuation of 25 or more persons as a result of release of a hazardous material or exposure to fire,
- A release or exposure to fire which results in the closure of a major transportation artery,
- The alteration of an aircraft flight plan or operation,
- The release of radioactive materials from Type B packaging,
- The release of over 11.9 galls or 88.2 pounds of a severe marine pollutant, or
- The release of a bulk quantity (over 199 gallons or 882 pounds) of a hazardous material.

However, prior to 2002, a hazardous materials "serious incident" was defined as follows:

- A fatality or major injury due to a hazardous material,
- Closure of a major transportation artery or facility or evacuation of six or more persons due to the presence of hazardous material, or
- A vehicle accident or derailment resulting in the release of a hazardous material.

Table 4-40 presents detailed information on historic HAZMAT incidents reported in Ann Arbor. From 2000 to 2022, 54 HAZMAT incidents have occurred in Ann Arbor, including 51 highway incidents and 3 air incidents. These incidents did not result in any injuries or fatalities but did result in a total of $227,746 (2022 dollars) in damages. Four incidents are considered "serious incidents" as defined by PHSMA.

DRAFT

Table 4-40: PHSMA-Reported HAZMAT Incidents

Report Number	Date	Quantity Released (LGA or SLB)	Injuries/Deaths	Damages (2022 dollars)	Mode of Transportation
I-2000011014	1/2/2000	1.25	0/0	$7,252	Highway
I-2000051254	5/8/2000	0.26	0/0	--	Air
I-2000060754	5/23/2000	0.06	0/0	--	Air
I-2000060375	5/26/2000	2.00	0/0	--	Highway
I-2000101064	10/9/2000	0.19	0/0	$240	Highway
I-2000121327	11/28/2000	0.63	0/0	$240	Highway
I-2001072009	7/20/2001	0.03	0/0	$233	Highway
I-2002061533	5/17/2002	0.01	0/0	$948	Highway
I-2002070330	6/20/2002	0.26	0/0	$948	Highway
I-2002070727	6/28/2002	0.75	0/0	$948	Highway
I-2002080290	7/24/2002	0.08	0/0	$948	Highway
I-2002080719	7/25/2002	0.02	0/0	$948	Highway
I-2003080571	7/31/2003	0.008	0/0	$921	Highway
I-2004010033	8/8/2003	0	0/0	$105	Highway
I-2003090488	8/26/2003	0.02	0/0	$921	Highway
I-2004050808	5/5/2004	2.50	0/0	$894	Highway
I-2004060599	6/4/2004	0.25	0/0	$894	Highway
I-2004080058	7/16/2004	1.06	0/0	$894	Highway

DRAFT

Report Number	Date	Quantity Released (LGA or SLB)	Injuries/Deaths	Damages (2022 dollars)	Mode of Transportation
I-2005020158	1/24/2005	0.5	0/0	--	Highway
I-2005100857	8/4/2005	0.02	0/0	--	Highway
E-2006080225	8/8/2006	312.50	0/0	$4,012	Highway
I-2007060966	5/11/2007	0.25	0/0	--	Highway
X-2007080096	8/2/2007	1.00	0/0	--	Highway
X-2007080321	8/16/2007	1.88	0/0	--	Highway
X-2007100056	9/20/2007	0.05	0/0	--	Highway
X-2007120281	12/21/2007	0.20	0/0	--	Highway
X-2008010082	1/8/2008	0.50	0/0	--	Highway
X-2008010210	1/17/2008	0.50	0/0	--	Highway
X-2008010211	1/17/2008	0.60	0/0	--	Highway
X-2008010267	1/23/2008	1.000	0/0	--	Highway
X-2008020068	1/26/2008	0.13	0/0	--	Highway
X-2008020147	2/6/2008	0.50	0/0	--	Highway
X-2008070056	6/18/2008	0.50	0/0	--	Highway
X-2008070277	7/3/2008	0.50	0/0	--	Highway
X-2008070378	7/9/2008	0.50	0/0	--	Highway
X-2008100094	9/25/2008	0.05	0/0	--	Highway
X-2008120324	12/22/2008	0.09	0/0	--	Highway
X-2009010178	1/16/2009	0.05	0/0	--	Highway
X-2009030004	2/17/2009	0.50	0/0	--	Highway

DRAFT

Report Number	Date	Quantity Released (LGA or SLB)	Injuries/Deaths	Damages (2022 dollars)	Mode of Transportation
I-2011080051	7/1/2011	30.00	0/0	$14,014	Highway
E-2011100265	10/12/2011	0.05	0/0	--	Highway
I-2012070193	5/27/2012	25.00	0/0	$7,499	Highway
X-2013060075	5/9/2013	0.02	0/0	--	Highway
I-2014020120	9/17/2013	40.00	0/0	$68,057	Highway
E-2014090354	8/25/2014	25.00	0/0	$22,802	Highway
X-2016090193	8/12/2016	0.09	0/0	--	Highway
E-2017105219	10/10/2017	2.00	0/0	--	Highway
X-2017110198	10/11/2017	0.03	0/0	--	Highway
E-2018015109	1/19/2018	4.00	0/0	$3,939	Highway
I-2019020346	1/7/2019	0.003	0/0	--	Air
I-2019070295	6/3/2019	1,643.41	0/0	$90,090	Highway
X-2020060260	12/18/2019	0.08	0/0	--	Highway
X-2020060337	12/18/2019	0.08	0/0	--	Highway

Previous hazard mitigation plans for Ann Arbor reported 180 HAZMAT incidents in Washtenaw County, with 24 related injuries. The most serious of these events are noted below, although none occurred specifically in Ann Arbor.

FIXED SITES

- A chemical facility explodes on the evening of December 7, 1992; a 9-1-1 call was placed from a business in Scio Township reporting an explosion. Firefighters checked emergency plans to make sure the facility had no hazardous materials on the premises, and then entered the building with breathing apparatus to check for fire. Despite use of protective equipment, one of the firefighters began to complain of chest pain and difficulty breathing and noted the facility was littered with 55-gallon barrels. An employee had accidentally mixed two incompatible chemicals into a drum, resulting in explosion after

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he left the workplace. 277 barrels of various hazardous materials were discovered during the clean-up. The business was immediately shut down.

- A chemical fire occurred on May 18, 1996, when the main transformer of a 345-Kilovolt electrical power substation in Salem Township containing poly-chlorinated biphenyls ("PCB's") suddenly exploded, sending flames eighty-feet into the air. Approximately 800 residents who lived downwind of the facility were immediately evacuated until the fire could be extinguished and the toxic smoke cleared. 11,380 cubic yards of contaminated soil and 162,076 gallons of contaminated water and oil had to be removed after the fire was extinguished.
- Employees were subjected to toxic fumes on the afternoon of January 23, 1997, when an employee of a photographic production facility in Scio Township placed a 9-1-1 call. The employee complained of sudden dizziness and nausea. Once responders arrived, it was determined that the entire facility was permeated with toxic solvent fumes, and that these fumes were periodically igniting small, short-lived gas fires in the laboratory. Five employees required medical treatment, and the facility was immediately shut down until it was cleaned, and proper ventilation systems could be installed.
- Hazardous gases were released from a plating plant on the evening of May 11, 2003, when a chemical accident occurred at a major electroplating facility in the City of Ypsilanti. Fire and HAZMAT crews arrived to find a large cloud of toxic vapors being released into the air. A Civil Emergency Message was issued to the public through the media directing nearby citizens to "shelter in-place". By 1:00 a.m. HAZMAT crews were able to activate a shut-off valve to a tank of hydrochloric acid inside the facility, suspected to be responsible for the leak and subsequent vapor cloud.

TRANSPORTATION

Below are descriptions of more serious hazardous material transportation incidents that have occurred in Ann Arbor.

- Chemicals mix after a truck crashes in the early morning hours of March 24, 1993, when the driver of a tractor/trailer rig fell asleep at the wheel while transporting five different hazardous materials in two trailers. The truck hit two trees, splitting the front trailer open, and forcing the mixture of strong acids and bases which generated a toxic cloud on the freeway. One police officer and two good Samaritans, thinking the gasses were just fog (it was a foggy morning) rushed in to help the driver but soon collapsed from chemical inhalation. The freeway was closed for more than 12 hours during the complicated clean-up, creating chaotic travel conditions for miles around.
- State workers were injured investigating an illegal dumping on June 12, 1996, when 13 state and local government workers experienced chemical inhalation injuries in Salem Township when they responded to investigate illegally dumped containers along a roadway. As the employees approached the dumped containers, they noticed an awkward smell and began to feel ill. Many required medical treatment. HAZMAT crews eventually determined that a company, unwilling to dispose of the hazardous waste properly, dumped several barrels of phenol on the roadside, which leaked and caused the exposures.
- Chemicals were spilled along the freeway on the morning of August 8, 2003, when several motorists reported a truck leaking as it drove along westbound I-94 in Pittsfield Township. Within minutes, 8 motorists reported feeling sick after driving

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on that stretch of freeway. Fire and HAZMAT crews determined that the truck was slowly leaking formaldehyde, and that the vapors were making drivers ill after inhalation. The freeway had to be closed during the response and clean-up phase, creating significant traffic congestion on I-94, US-23, and at nearby interchanges.

Extent

The extent of hazardous materials incidents can be defined in terms of amount of material released. According to USDOT PHMSA, the largest hazardous materials incident reported in Ann Arbor is 1,643 liquid gallons released on the roadway in 2019. HAZMAT incident extent can also be measured in terms of damages; the greatest amount of damages recorded from a single incident occurred during this same incident, which reported $90,090 (2022 dollars) in damages. It should be noted that larger events are possible.

Probability of Future Occurrences

With 54 events recorded in 21 years, Ann Arbor has experienced approximately two to three PHSMA-reported HAZMAT incidents per year since 2000. HAZMAT risk is also elevated by the presence of two toxic release inventory sites in the city. However, most events are generally cleaned up and remediated quickly. Therefore, a probability of likely (10 to 90 percent annual chance) was assigned to this hazard. However, a catastrophic event is less likely. City officials are mindful of this possibility and take precautions to prevent such an event from occurring. Furthermore, there are detailed plans in place to respond to an occurrence.

Vulnerability Assessment

Although historical evidence and existing Toxic Release Inventory sites indicate that the city is susceptible to hazardous materials events, there are few reports of damage. Potential annualized loss from hazardous materials releases is estimated at $11,387 (2022 dollars). Most hazardous materials incidents that occur are contained and suppressed before destroying any property or threatening lives. However, they can have a significant negative impact. Such events can cause deaths, completely shut down facilities for a month or more and cause surrounding properties to be destroyed or suffer major damage. During a hazardous materials incident, solid, liquid, and/or gaseous contaminants may be released from fixed or mobile containers. Weather conditions will directly affect how the hazard develops. Certain chemicals may travel through the air or water, affecting a much larger area than the point of the incidence itself. Non-compliance with fire and building codes, as well as failure to maintain existing fire and containment features, can substantially increase the damage from a hazardous materials release. The duration of a hazardous materials incident can range from hours to days. Warning time is minimal to none.

In order to conduct the vulnerability assessment for this hazard, GIS analysis was used for fixed and mobile areas. In both scenarios, two sizes of buffers—500 and 2,500 meters—were used. These areas are assumed to respect the different levels of effect: immediate

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(primary) and secondary. Primary and secondary impact sites were selected based on guidance from FEMA 426, Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings and engineering judgment. For the fixed-site analysis, geo-referenced TRI sites in Ann Arbor, along with buffers, were used for analysis as shown in Figure 4-48. For the mobile analysis, the major roads (Interstate highway, U.S. highway, and state highway) and railroads, where hazardous materials are primarily transported that could adversely impact people and buildings, were used for the GIS buffer analysis. Figure 4-49 shows the areas used for mobile toxic release buffer analysis. The results indicate the approximate number of parcels, improved value, as shown in Table 4-41 (fixed sites) and

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Table 4-42 (transportation analysis). Parcels included in the 500-meter buffer are also included in the 2,500-meter buffer. Therefore, totals were not calculated in the tables below.

Damage to Buildings. The results of the GIS analysis for fixed sites and transportation are presented below. Exposure of parcels, improved parcels (i.e., buildings) and building footprints are assessed.

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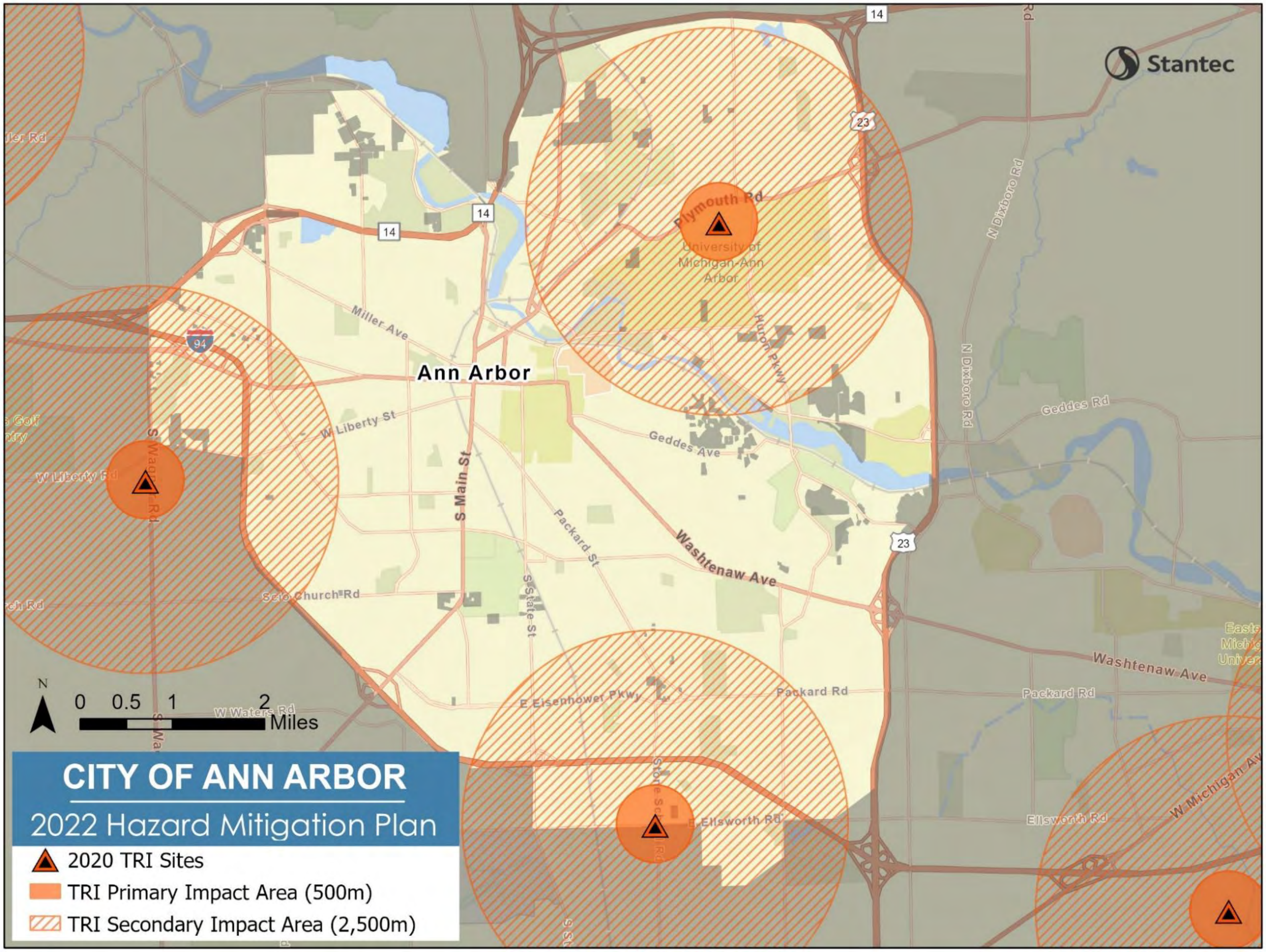

Figure 4-48: TRI Sites with Buffers in Ann Arbor

Table 4-41: Uses of Buildings Potentially At-Risk to HAZMAT Fixed-Sites in Ann Arbor

Impact Area	Commercial	Office	Public	Residential	Total
TRI Primary (500 m buffer)	21	9	39	165	234
TRI Secondary (2500 m buffer)	443	144	385	10,151	11,123

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Table 4-42: Exposure of Parcels, Improved Parcels, and Buildings to HAZMAT Fixed-Sites

Site Type	500-meter Buffer - Fixed Sites							
	Parcels at Risk*	%	Improved Parcels*	%	Value of Improvements (2022 dollars)**	%	Building Footprints***	%
TRI Sites	178	0.6%	172	0.5%	$69,973,566	1.0%	234	0.7%

Site Type	2,500-meter Buffer - Fixed Sites							
	Parcels at Risk	%	Improved Parcels*	%	Value of Improvements (2022 dollars)**	%	Building Footprints***	%
TRI Sites	11,578	36.4%	10,981	36.1%	$2,408,269,420	35.9%	11,110	32.0%

**Parcels completely within, partially within, or touching the buffer were included in this analysis*
***Value of improvements may not include tax-exempt properties*
****Improvement value data was not tied to building footprints*

Many buildings and parcels in Ann Arbor are posed to fixed HAZMAT sites. While less than 1 percent of structures and parcels are exposed in the primary impact area (500 meters), approximately one-third of parcels, buildings, and their associated values are located in TRI site secondary impacts areas (2,500 meters).

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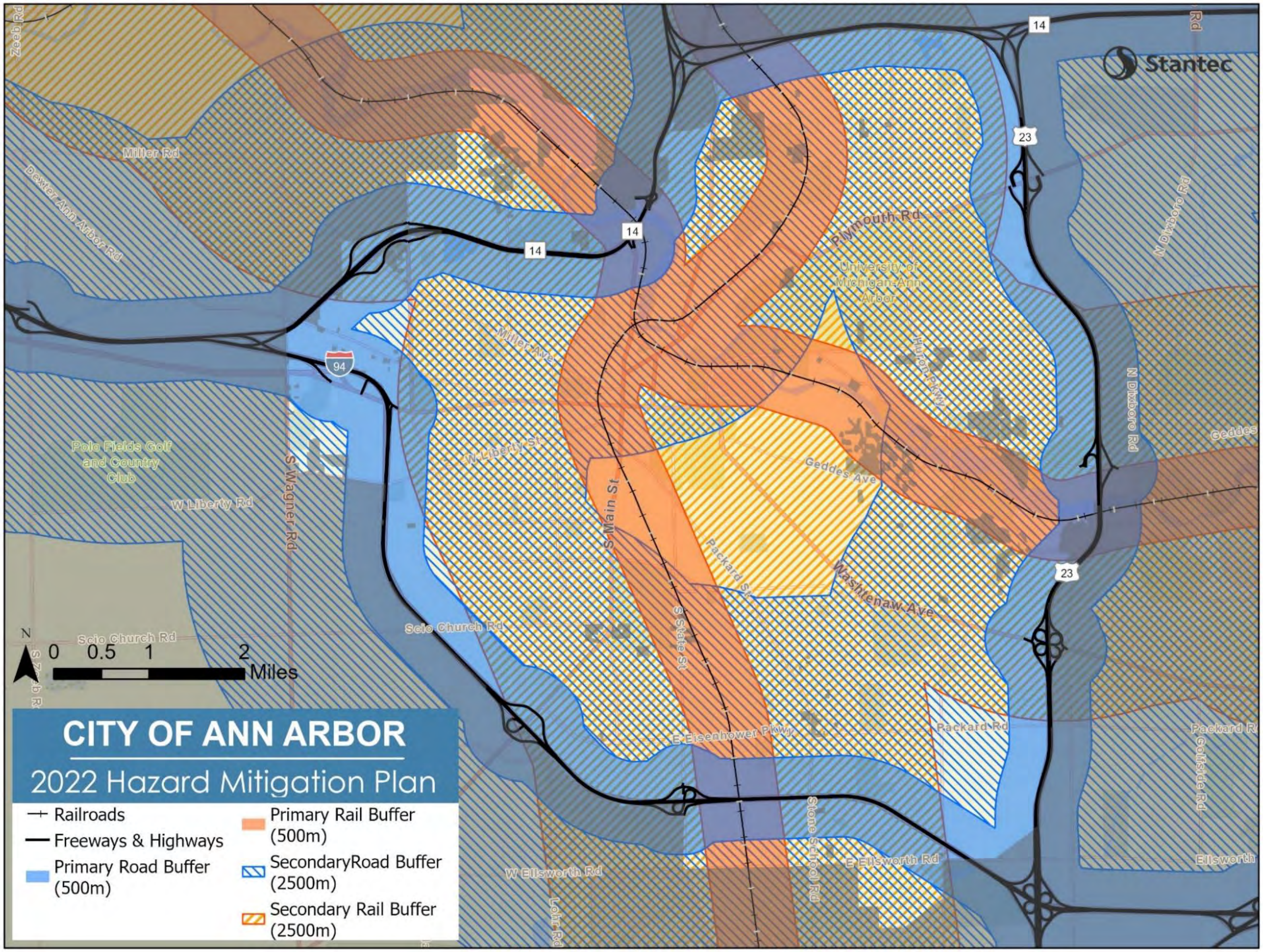

Figure 4-49: Transportation HAZMAT Buffers in Ann Arbor

Table 4-43: Exposure of Parcels, Improved Parcels, and Buildings to HAZMAT Incidents (Transportation Analysis)

Transportation Mode	500-meter Buffer - Transportation							
	Parcels at Risk	%	Improved Parcels*	%	Value of Improvements (2022 dollars)**	%	Building Footprints***	%
Highways/Freeways	7,374	23.2%	7,020	23.1%	$1,586,584,620	23.7%	6,871	19.8%
Rail	6,628	20.9%	6,130	20.1%	$1,738,479,635	25.9%	6,519	18.8%

Transportation Mode	2,500-meter Buffer - Transportation							
	Parcels at Risk	%	Improved Parcels*	%	Value of Improvements (2022 dollars)**	%	Building Footprints***	%
Highways/Freeways	28,114	88.5%	26,905	88.4%	$5,592,320,151	83.4%	29,270	84.3%
Rail	28,575	89.9%	27,356	89.9%	$6,285,935,227	93.8%	30,768	88.6%

**Parcels completely within, partially within, or touching the buffer were included in this analysis*
***Value of improvements may not include tax-exempt properties*
****Improvement value data was not tied to building footprints*

A significant number of buildings and parcels in Ann Arbor are at risk to transportation-related HAZMAT incidents due to their proximity to highways and railroad lines. Around 20 percent of parcels and buildings are in the primary impact area, along with about a quarter of all improvement value. Over 85 percent of improved parcels are in the secondary impact areas for rail and highways, and with 83-94 percent of improvement value (depending on mode) and 84-89 percent of buildings. A summary of building and parcel exposure to mobile HAZMAT incidents are presented in Table 4-43.

Damage to Infrastructure. Although not presented by potential loss values, infrastructure such as roads, bridges, railroad lines, and utilities have the potential to be impacted by hazardous materials incidents, particularly in an incident involving a corrosive material. Often, this infrastructure is being used to transport hazardous materials, making them especially at-risk.

Life Safety, Health, and Warning and Evacuation Procedures. HAZMAT incidents can result in injuries or fatalities when employees, responders, and civilians come in contact with hazardous materials. In certain events, persons may not realize they have been exposed until symptoms are presented. HAZMAT incidents may result in the need for evacuations or sheltering in place.

In the event of a hazardous materials spill that requires protective action, the city's siren warning system will activate. The warning system consists of 22 sirens providing coverage for the entire city as demonstrated in Figure 4-50 under this profile's equivalent in the *Severe Winds* profile.

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Public Health. HAZMAT incidents impact public health when incidents are widespread and/or long-lasting. HAZMAT incidents have the potential to contaminate drinking water sources, or to contaminate air through the release of toxic gases. One such example is Graniteville, South Carolina, where in 2005 a train derailment resulted in approximately nine deaths, 600 people seeking medical care, and the evacuation of over 5,400 people.[lxxvii] In Ann Arbor, railroads are located along the Huron River (the city's drinking water source), including through the densely populated downtown area, which increases risk in the event of a train derailment involving hazardous materials.

Impacts to Socially Vulnerable Populations. Socially vulnerable populations may be disproportionately impacted by hazardous materials releases. Low-income neighborhoods are more likely to be located near facilities with noxious uses or adjacent to railroads or large highways. Illegal dumping of hazardous materials is also more likely to occur in low-income areas relative to high-income neighborhoods. Further, appropriate response measures for hazardous materials releases are not uniform – some events may require evacuations while others may require sheltering in place. Measures may include closing windows, sealing doors, and switching off HVAC intakes. Populations without access to information, such as internet or cellular service, or individuals with limited English proficiency may face challenges acting on response measures issued by the city of county. In addition, the elderly or mobility challenged may struggle to evacuate or shelter in a timely manner. The deaf or hard of hearing may not hear audible evacuation orders or warnings. Once evacuated, deaf individuals or those reliant on medications or medical devices will require additional services and care considerations during response. Special accommodations for these populations must be considered in disaster planning processes. Additionally, those without health insurance may delay seeking out and receiving necessary health care services or emergency care. Neither of the TRI sites identified within Ann Arbor are located in census tracts considered to have low access or opportunity of the Washtenaw County Opportunity Index, nor are they located in tracts ranked as having high social vulnerability on the NRI.

Economic Impact. HAZMAT incidents can result in business disruption or closures, road closures, and property damage, all of which have an economic impact on the community. The permanent loss of a business due to a HAZMAT incident could result in lost tax revenue and jobs for the city.

Climate Change Impacts. Climate change is not expected to have direct impacts on hazardous materials incidents. However, HAZMAT incidents can be triggered by certain natural hazards, such as transportation accidents involving hazardous materials preempted by blinding downpours or severe winds. It is common for hazardous materials incidents (i.e., contamination) to occur as a secondary impact of flooding. Therefore, the projected increase in extreme precipitation events in Ann Arbor may indicate a subsequent increase in HAZMAT incidents. Generally, if the frequency and intensity of natural hazards increases due to climate change, the frequency of HAZMAT incidents may increase as a result.

DRAFT

Nuclear Power Plant Incidents

Description

According to the Nuclear Regulatory Commission (NRC), accidents at nuclear power plants are considered a possibility, and appropriate on-site and off-site emergency planning is conducted. An accident could result in the release of potentially dangerous levels of radioactive materials into the environment and could affect the health and safety of the public living near the nuclear power plant. A nuclear power plant accident might involve both a release of airborne radioactive materials and radioactive contamination of the environment around the plant. The degree and area of environmental contamination could vary greatly, depending on the type and amount of release, and the weather conditions that are present. Response to a nuclear power plant accident requires specialized personnel who have been trained to handle radioactive materials safely, who have specialized equipment to detect and monitor radiation, and who are trained in personal radiation exposure control.

There have been several destructive nuclear powerplant accidents in the past. Perhaps the most notable of these are the Three Mile Island accident, the Chernobyl accident, and the Fukushima accident. The Three Mile Island accident occurred in 1979 when a reactor at a plant near Middletown, PA, melted down and radiation was released. The incident resulted in the need to evacuate vulnerable populations within a 5-mile radius of the site, as well as thousands of subsequent tests of the area's air, water, soil, vegetation, and other resources.[lxxviii] The 1986 accident at the Chernobyl plant in Ukraine was more severe and is the only commercial nuclear power-related incident in which radiation-related fatalities occurred. Twenty-eight people, mainly plant operators and firemen, died within a few weeks of the accident from acute radiation syndrome, and over 230 people were diagnosed with the illness. Additionally, over 330,000 people had to be relocated out of the contaminated area.[lxxix] More recently, the 2011 Fukushima accident in Japan occurred after a tsunami disabled the power supply and cooling of three reactors, resulting in the release of radiation. Evacuations were performed within 20 kilometers (about 12.5 miles) on the site.[lxxx]

After a period of decline following the Three Mile Island and Chernobyl accidents, there is a recent renewed interest in nuclear energy because it could partially address problems of dwindling oil reserves and global warming, with far fewer emissions of greenhouse gases than the use of fossil fuels. However, the use of nuclear power is controversial because of the problems of storing radioactive waste for indefinite periods, the potential for radioactive contamination by accident or sabotage, and the possibility that its use could in some countries lead to the proliferation of nuclear weapons.

The City of Ann Arbor is in the secondary (50-mile) Emergency Planning Zone (EPZ) for the Enrico Fermi II Nuclear Power Plant out of Monroe, MI (Figure 4-50). The Secondary EPZ (also called the ingestion exposure pathway) indicates the area where contamination has the potential to infiltrate the food chain.

- Primary EPZ (Plume Exposure Pathway): The plume exposure pathway EPZ has a radius of about 10 miles from the reactor site. Predetermined protective action plans are in place for this EPZ and are designed to avoid or reduce dose from

DRAFT

potential exposure of radioactive materials. These actions include sheltering, evacuation, and the use of potassium iodide where appropriate.

- Secondary EPZ (Ingestion Exposure Pathway): The ingestion exposure pathway EPZ has a radius of about 50 miles from the reactor site. Predetermined protective action plans are in place for this EPZ and are designed to avoid or reduce dose from potential ingestion of radioactive materials. These actions include a ban of contaminated food and water.

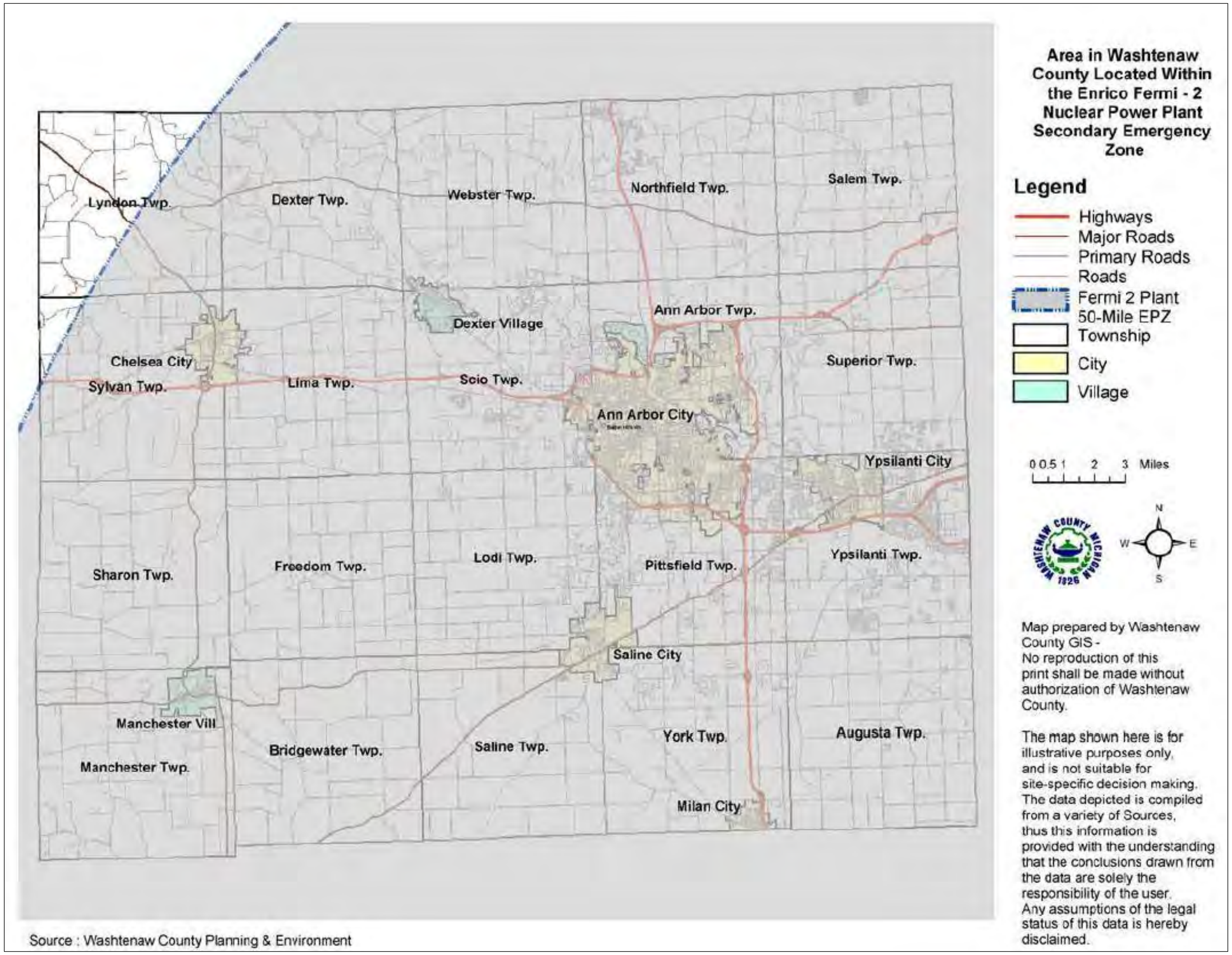

Figure 4-50: Enrico Fermi II Nuclear Power Plant Emergency Planning Zones

Location

The closest nuclear power plant to Ann Arbor is the Enrico Fermi II plant near Monroe, MI. The plant is approximately 28 (linear) miles away from Ann Arbor. Due to its proximity to the plant, the entire city is considered at-risk to a nuclear power plant incident. Figure 4-50 shows the Enrico Fermi II plant relative to the City of Ann Arbor.

Previous Occurrences

Ann Arbor does not have a known history of nuclear power plant incidents. The State of Michigan Hazard Mitigation Plan cites one historic incident that involved the Enrico Fermi II plant's predecessor, the Enrico Fermi I:

October 5, 1966 – Enrico Fermi-1, Monroe County, Michigan. Although Michigan has never experienced a significant nuclear power plant accident that involved an off-site release of radioactive material, on October 5, 1966, a serious incident did occur at Detroit Edison's then-new Enrico Fermi Atomic Power Plant near Monroe (commonly called Fermi-1). Fermi-1 was an experimental breeder reactor designed to demonstrate the feasibility of liquid fast-metal breeder reactor technology. On October 5, a metal flow guide inside the reactor broke off and blocked the flow of sodium coolant in the space below the reactor core. As a result, approximately 1 percent of the fuel melted. The fuel damage caused the release of some radiation into the reactor containment building; however, no off-site release occurred. The plant was eventually repaired, and it operated for a short period until it was permanently shut down in 1972. The fuel and related materials were removed and sent to a federal government facility in the mid-1970s. The Enrico Fermi-2 nuclear power plant opened next door in 1988.

Extent

The extent of a nuclear power plant incident could be measured in terms of property damage, injuries, or loss of life. Given the lack of historic incidents resulting in off-site releases, the extent of a nuclear power plant incident at Ann Arbor is difficult to determine. Considering that Ann Arbor is in the plant's secondary EPZ, it is likely that the extent of an event would be contamination of the food chain and other resources. This could result in the need to ship in food and/or water from outside sources.

Probability of Future Occurrences

Given the lack of historic nuclear power plant incidents impacting Ann Arbor, the probability assigned to the nuclear power plant hazard is unlikely (less than 1 percent annual chance).

DRAFT

Vulnerability Assessment

All current and future buildings, infrastructure, and populations are considered at risk to nuclear power plant accidents. Specific potential impacts to buildings, infrastructure, life safety, public heath, and the economy from the nuclear power plant hazard are described below.

Damage to Buildings. Because of Ann Arbor's location in the secondary EPZ rather than the primary EPZ, it is unlikely that a nuclear power plant incident has the potential to damage buildings.

Damage to Infrastructure. Infrastructure damage due to a nuclear power plant incident Is unlikely, though infrastructure closer to the Monroe located in the EPZ1 may be compromised. This could impact transportation and services in and around the City of Ann Arbor.

Life Safety, Health, and Warning and Evacuation Procedures. A severe nuclear power plant incident could result in the need for evacuation if the city's food, water, or air supply were to become contaminated.

Public Health. Ann Arbor is located in the Enrico Fermi II nuclear power plant's secondary EPZ, an area in which the food chain could be impacted by a severe off-site release incident. If an incident were to occur, the city's public health has the potential to be impacted via radioactive contamination to local food and water supplies.

Impacts to Socially Vulnerable Populations. Certain populations may be more severely impacted by a nuclear power plant incident. A nuclear power plant incident could result in the need for evacuation. Evacuation notices must be released in multiple languages to ensure populations where English is not the primary language receive adequate warning and the message is received. Income constrained households may face challenges with evacuation and relocation and may be more likely to lose income sources in the wake of such an event (e.g., individuals in service sector unable to work remotely if forced to evacuation or if businesses must close). These households may also face difficulty obtaining imported food in water in the event the local supply becomes contaminated.

Economic Impact. Economic impacts stemming from a nuclear power plant incident could include disruption to business, especially for businesses dependent on locally-sourced food. After an event, a significant number of students may choose online education or to go to another university, which would have severe economic impacts for the city.

Climate Change Impacts. Direct impacts to the nuclear power plant hazard from climate change are not anticipated. However, it should be noted that, as temperatures rise and the number of extreme heat events increases, the demand for energy in the region could increase, resulting in an increase in the number of nuclear power plants built to meet demand. If additional power plants are built in close proximity to Ann Arbor, the threat from this hazard could increase.

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Petroleum and Natural Gas Pipeline Accidents

Description

Petroleum and natural gas pipelines pose a real threat in many communities. Pipelines are used to transport petroleum and natural gas products and are often used as an alternative to road and rail transportation. Products typically transported in pipelines include crude oil, fuel oil, propane, or butane (often referred to as liquified petroleum gas, or LPG), and gasoline. Pipelines are used to transport products from wells and production facilities to storage facilities and local distribution systems. The network of pipelines spans the entire country. Petroleum and natural gas pipeline accidents occur when pipelines leak, rupture, or fracture, potentially causing fires, explosions, spills, or the release of poisonous gases resulting in property damages, injuries, and loss of life. For example, the danger of hydrogen sulfide (H_2S) release can occur where the gas or oil has a high sulfur content. Hydrogen sulfide is not only an extremely poisonous gas but is also explosive when mixed with air at temperatures of 500 degrees Fahrenheit or above. Many structures are located right next to pipelines and thus may be at risk. Petroleum and natural gas pipeline accidents are on the rise, due to the aging of the underground infrastructure (much of which was laid over 50 years ago) and an increase in construction excavation. According to the US DOT Pipeline and Hazardous Materials Safety Administration (PHSMA), 12,794 pipeline incidents occurred in the US between 2002 and 2021, resulting in 276 fatalities, 1,147 injuries, and over $10 billion in costs.[lxxxi] Pipelines can also cross through rivers, streams, and wetlands, thus posing the possibility of extensive environmental damage in the event of a major failure.

Increased pipeline safety regulations again came to the forefront in 2000, after deadly pipeline explosions occurred in Bellingham, Washington in June 1999 (three deaths) and Carlsbad, New Mexico in August 2000 (11 deaths). In 2004, the Pipeline and Hazardous Materials Safety Administration (PHMSA) was signed into law. The purpose of the Act was to provide a more focused research organization and establish a separate operating administration for pipeline safety and hazardous materials transportation safety operations. The Pipeline Safety Improvement Act of 2002 mandated significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines. The law applies to natural gas transmission pipeline companies. The law places requirements on each pipeline operator to prepare and implement an "integrity management program" that, among other things, requires operators to identify so-called "high consequence areas" (HCA) on their systems, conduct a risk analysis of these areas, perform baseline integrity assessments of each pipeline segment, and inspect the entire pipeline system. Companies were required to identify all HCAs and submit specific integrity management programs to the Office of Pipeline Safety (OPS), the Research and Special Projects Administration, and the U.S. Department of Transportation. All pipeline segments within HCAs were to be inspected and remediation plans completed by December 17, 2008, while non-HCA segments must be inspected by 2012. All segments must be re-inspected on a 7-year cycle, with certain exceptions.[lxxxii]

Michigan is both a major consumer and producer of natural gas and petroleum products. According to the State of Michigan hazard mitigation plan, Michigan's consumption of petroleum products, particularly LPG, is high; Michigan is the largest residential LPG market in the nation, due mostly to high residential and commercial propane consumption. The state has a single petroleum

DRAFT

refinery but a large network of product pipelines. Michigan has significant underground natural gas storage capacity in the nation and supplies natural gas to neighboring states during high-demand winter months. Driven largely by the residential sector, Michigan's natural gas consumption is high. Nearly four-fifths of Michigan households use natural gas as their primary energy source for home heating.

Large quantities of petroleum and natural gas are extracted from, transported through, and stored in Michigan, making many areas vulnerable to petroleum and natural gas emergencies. The state's major natural gas storage facilities are in the central part of the Lower Peninsula. Natural gas is piped into those storage facilities from Michigan wells, and from large transmission pipelines that originate in Canada, the southwestern United States, and the Gulf of Mexico area. Petroleum pipelines have their heaviest concentrations in southeastern Lower Michigan and between Detroit and Toledo. Many of the refineries, terminals, and storage areas are in urban areas where the potential for extensive damage, and threat to lives and property, is greatest. The largest concentration of these facilities is found in the Detroit metropolitan area. In Michigan, most pipeline accidents that occur are caused by third party damage to the pipeline, often due to construction or some other activity that involves trenching or digging operations.

Location

Areas at or near pipelines are most vulnerable to petroleum and natural gas pipeline accidents. As shown in Figure 4-51, no hazardous liquid pipelines run through Ann Arbor. However, as shown in blue on the map, a gas transmission pipeline does exist along Geddes Road, and a segment of gas transmission pipeline exists along Fuller Road.

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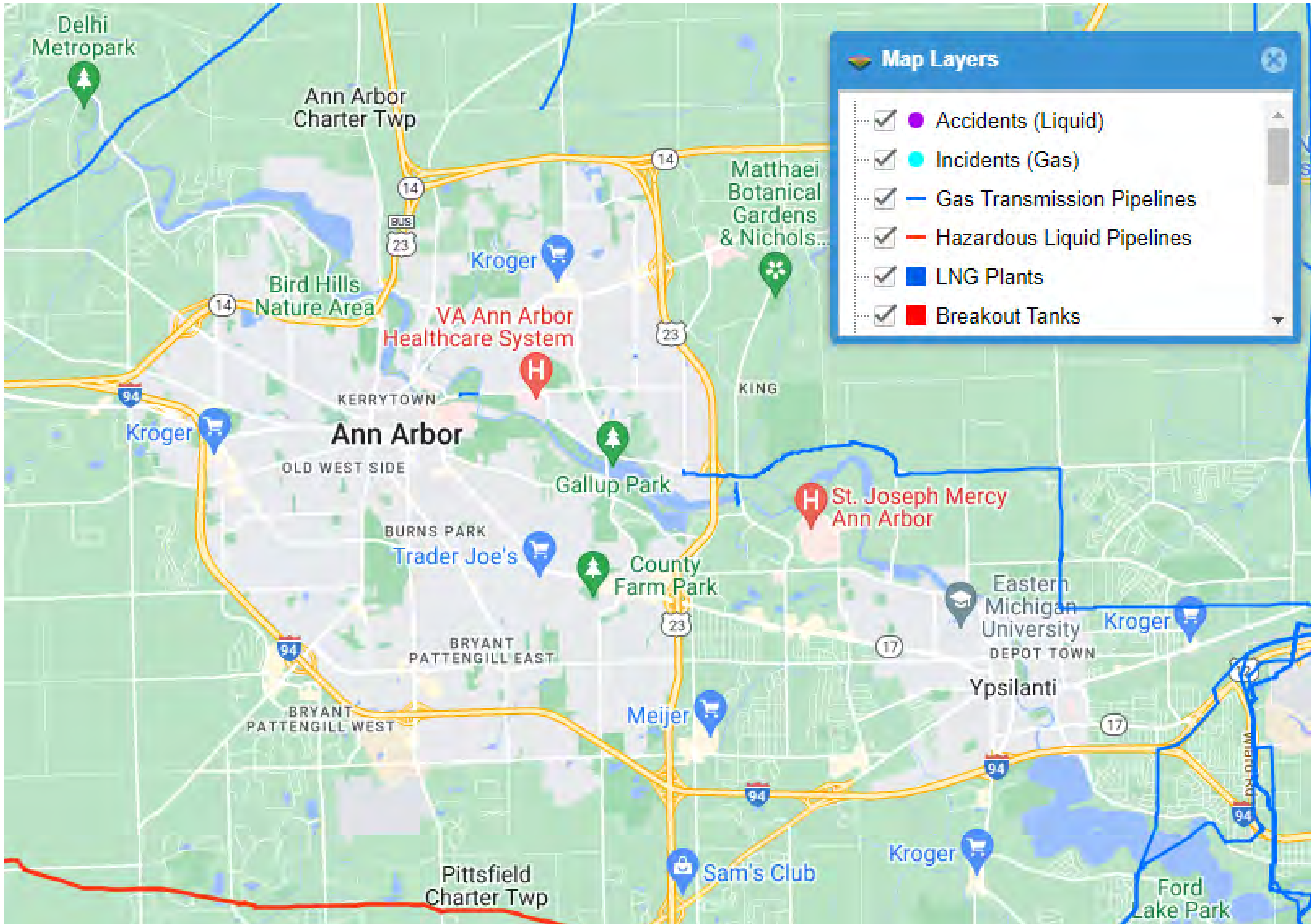

Source: US DOT Pipeline and Hazardous Materials Safety Administration

Figure 4-51: Pipeline Locations and Incidents in Ann Arbor

Previous Occurrences

According to PHSMA, Ann Arbor does not have a history of petroleum or natural gas pipeline incidents. The closest reported pipeline accident to Ann Arbor occurred in the Scio Township, approximately 5.5 miles from Ann Arbor's city limits. That incident, which occurred on January 10, 2008, resulted in $235,624 and no injuries or fatalities.[lxxxiii]

In order to gain an understanding of potential impacts, major pipeline accidents in Michigan were reviewed. According to the State of Michigan hazard mitigation plan, the largest pipeline accident in Michigan was the Enbridge Pipeline Disaster, which occurred in 2010 and resulted in over $1 billion in damages:

On July 26, 2010, an oil spill was discovered by the owners of an oil pipeline, Enbridge Energy Partners L.P., during a maintenance activity at a pumping station located on the south edge of the City of Marshall. The 30-inch pipeline normally transported 190,000 barrels per day from Griffith, Indiana, to Sarnia, Ontario, and passes through Calhoun County and several other Michigan counties. Oil from the pipeline leaked into the Talmadge Creek and then into the Kalamazoo River and began to flow downstream toward Lake Michigan. Enbridge Energy officials shut down the pipeline pumps and closed valves located upstream and downstream from the leak site to stem the flow of additional oil and try to contain the spill. Based on company estimates, up to 19,500 barrels of crude oil had leaked from the pipeline (approximately 800,000 gallons).

Calhoun County declared a local state of emergency and several downstream communities, including Kalamazoo County, took emergency response actions in coordination with Calhoun County. The State Emergency Operations Center in Lansing was activated, and a number of state departments and support organizations convened there to monitor the incident and coordinate state response activities with involved governmental agencies and company officials. Representatives of the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Transportation Safety Board, U.S. Department of Transportation and other federal agencies quickly convened at the incident site and began working with company, local and state officials (under a Unified Command structure) to develop and implement a spill containment, recovery, and clean-up plan and protection strategy for the environment and affected local residents.

A coordination facility was established in the City of Marshall and contractors where brought in for environmental restoration and product recovery. Aggressive product recovery efforts were instituted to expedite oil containment and environmental clean-up. Wildlife rescue and rehabilitation operations were also implemented to aid in protecting animals and aquatic life from harm and saving wildlife that had been adversely impacted by the spill. Health advisories were issued to protect the public from harm, and some of the nearby residents were evacuated for a time until the air quality improved within the area. A number of contracted cleanup crews were brought in to perform clean-up and product recovery work.

On September 27, the repaired oil pipeline was restarted by company officials, with the approval of the U.S. Department of Transportation. New oil again flowed through the pipeline, initially at a reduced pressure level but then at full capacity again. The unified command center remained operational for an extended period of time, due to the long-term nature of product recovery

DRAFT

and environmental clean-up operations. Clean-up and product recovery efforts are still ongoing in 2014, with more than 1.5 million gallons of water treated and huge quantities of material processed off-site to remove and recover the oil.

Although there is no history of pipeline accidents in Ann Arbor, future events are possible given the existence of pipelines in the city. In addition, it should be noted that an incident impacting the Huron River upstream of Ann Arbor could impact the city, especially as the Huron River is the city's drinking water supply.

Extent

The extent of petroleum and natural gas pipeline accidents can be measured in terms of product released. Pipeline accidents can also be measured in terms of deaths, injuries, or property damage. The extent of petroleum and natural gas pipeline accidents in Ann Arbor is difficult to determine given the lack of historic accidents. The largest pipeline accident in Michigan was the Enbridge Pipeline Disaster and resulted in over $1 billion in damages; a similar event in Ann Arbor is possible given the presence of petroleum and natural gas pipelines near the city. It should be noted that a future event is possible, and could potentially result in property damage, environmental damage, injuries, and loss of life.

Probability of Future Occurrences

Given the lack of historic petroleum and natural gas pipeline accidents in Ann Arbor, the probability of future pipeline accidents is unlikely (less than 1 percent annual probability).

Vulnerability Assessment

Petroleum and natural gas pipeline accidents have the potential to impact buildings, infrastructure, life safety, public health, and the economy. All current and future buildings, infrastructure, and populations are considered at risk to petroleum and natural gas pipeline accidents.

Damage to Buildings. Petroleum and natural gas pipeline accidents can result is damage to buildings through fire and explosions caused by released materials. Because buildings in Michigan typically get their heat source from natural gas, distribution lines are present near structures. Accidents can be caused by construction, digging, and excavation occurring at or near distribution lines.

Damage to Infrastructure. Like building damage, infrastructure damage can occur as a result of pipeline fires or explosions. The pipelines themselves can be damaged during incidents, or other utilities and their distribution lines, such as water and sewer pipes or electricity transmission lines, can become damaged. Roads and sidewalks may also become damaged or may need to be dug up to fix a damaged pipeline located underground.

DRAFT

Life Safety, Health, and Warning and Evacuation Procedures. Petroleum and natural gas pipeline accidents can result in injuries or fatalities due to fires, explosions, or releases of poisonous gases. Accidents may result in the need to quickly evacuate buildings, homes, and public spaces near the area of accident occurrence.

Public Health. Petroleum and natural gas pipeline accidents have the potential to impact public health. Poisonous gases may be released during accidents, causing air to be unsafe to breathe. Similarly, pipeline leaks have the potential to pollute ground and surface water, which could contaminate drinking water sources. Leaks or ruptures in natural gas pipelines may result in the need to shut of the natural gas supply until the pipeline can be repaired. In the winter months, this could pose a threat to vulnerable populations without a safe alternative heat source.

Impacts to Socially Vulnerable Populations. Studies have shown a positive correlation between pipeline density and social vulnerability.lxxxiv While there is low likelihood of pipeline incidents in Ann Arbor, an event has the potential to impact certain populations more than others. Individuals living in older buildings, substandard housing, or housing not built to code may be more likely to experience a natural gas leak due to aging or damaged infrastructure.

Economic Impact. Petroleum and natural gas pipeline accidents can result in business disruption due to evacuations or damaged buildings. Severe events may also result in shortages of, or higher prices for, petroleum or other fuels. Higher prices could impact populations with low or fixed incomes disproportionately.

Climate Change Impacts. There are no known direct impacts of climate change on the frequency and severity of petroleum and natural gas pipeline accidents. As Ann Arbor strives to meet the goals of its A2Zero plan to reduce greenhouse gas emissions by switching from natural gas to electricity, the present of active natural gas lines within the local distribution system may decrease, reducing the overall risk of pipeline incidents.

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Power Outages

Description

A reliable and adequate electricity supply is critical to economic and social well-being, and systems within the U.S. have become accustomed to uninterrupted and relatively inexpensive power. Short-term power outages caused by weather damage (e.g., downed power lines) or temporary shortages (e.g., brownouts) can have community-wide impacts especially as society's dependence on technology grows.

There are several types of power outages that have the potential to impact the city of Ann Arbor, including:

- Physical failures of electrical production or distribution facilities due to aged or faulty equipment, poor maintenance, or employee accidents.

- Physical failures due to exogenous factors, such as severe storms, cyber-attacks, or other sabotage. Michigan, including Ann Arbor, experiences storm related disruptions in particular, mostly due to high winds or damage caused by ice.
- Blackouts or brownouts stemming from demand for electricity outpacing supply (generation). These types of outages are typically brief in nature, controlled, and can often be curbed through demand management techniques.
- Other planned outages (i.e., maintenance).

A distinction should be made between routine power outages and more severe outages. During a routine outage, the loss of power is isolated to a small area and power is restored within minutes or hours. Most routine power outages are caused by physical damage to production or distribution facilities, as described above. Most times, routine power outages have a minimal impact. However, substantial impacts can occur when facilities or equipment are impacted by routine outages and do not have a suitable back-up power source. More severe outages may last for days or even weeks and are more likely to happen during or as a result of another hazard, such as a severe storm or heat wave.

Location

It is assumed that all of Ann Arbor is uniformly exposed power outages.

Previous Occurrences

Ann Arbor experiences several routine power outages annually, in which power to parts of the city is temporarily out (e.g., minutes or hours). In addition to these outages, the city has experienced several severe outages in which power was out for a prolonged period. Significant power outage events were sourced from the State of Michigan Hazard Mitigation Plan, local news sources, and city officials, and are described below. It is likely that additional significant power outages have occurred within the city but have gone unreported.

July 1991. A major electrical blackout event due to storms occurred on July 7, 1991, when a powerful windstorm affected a large portion of central North America and knocked out power to over one million customers from Iowa to Ontario. Almost the entire lower half of Michigan’s Lower Peninsula was affected by the intense windstorm, with gusts of 65–85 mph. Electrical power was cut off to around 850,000 customers in Michigan alone, which was the largest number of customers to lose power from a single storm up to that time. (Source: State of Michigan Hazard Mitigation Plan).

May 1998. On May 31, 1998, a derecho (severe, widespread windstorm) with winds averaging 60–90 mph (the highest being 130 mph) raced across lower Michigan, causing about 860,000 customers in Michigan to lose electrical power. The 860,000 customers represented a new record for Michigan, slightly exceeding the number of customers that lost power during the Southern Great Lakes Derecho of 1991. Some residents would not get power back for 10 days. (Source: State of Michigan Hazard Mitigation Plan).

DRAFT

August 2003. This event, dubbed the 2003 Great Northeast Backout, was the largest blackout in the U.S. to date, with over 50 million people losing power. Most essential services were able to remain in operation during the blackout by using back-up generators, but cellular networks failed when transmission towers became overloaded, some water supplies required boil-water notices after losing pumping capabilities, and non-functioning sewer pumps resulted in sewage flowing into rivers in Lansing and Metro Detroit. Isolated portions of Ann Arbor were impacted by this event. Total costs of this blackout are estimated at $4-10 billion. (Source: State of Michigan Hazard Mitigation Plan).

December 2013. A massive ice storm hit Michigan shortly before Christmas, knocking out power to approximately 380,700 homes and businesses, some of whom were then without power for up to a week and a half. The outages came in waves, with the first hitting on the night of the storm and others following later on, as ice weighed down tree branches and power lines which then broke. Consumers Energy, DTE Energy, and the Lansing Board of Water and Light were the hardest hit companies. Additional snow and frigid temperatures continued throughout repairs. (Source: State of Michigan Hazard Mitigation Plan).

February 2016. A severe windstorm caused 117,000 DTE customers to lose power; 75,000 of which did not have power restored for 2-3 days. (Source: NCEI).

March 2017. A severe windstorm on March 8, 2017, left 800,000 customers without power for several days. This storm caused the largest power outage in the state's history to-date (Source: NCEI).

February 2019. On February 23, 2019, a windstorm left 200,000 DTE customers without power for up to two days. (Source NCEI).

July 2019. A severe storm downed over 2,000 lines on July 19, 2019, knocking out power to 600,000 DTE customers. Four days later, on July 23rd, 54,000 customers were still without power, including 24 units in the Green Baxter Court Apartment complex, a subsidized housing complex in Ann Arbor. The impacts of this event were compounded an extreme heat event that occurred during the outage, in which temperatures reached over 100°F. Many residents at the complex reported evacuating to stay with friends and family or sitting in running cars to cool down. Residents also reported perishables going back and having to be thrown out.[lxxxv]

August 2021. A series of violent storms on August 14, 2021, caused over one million residents in Michigan to lose power, including 25 percent of the DTE service area. Some residents were without power for over a week. In Ann Arbor, a relief station was opened at Pioneer High School due to high temperatures.

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Extent

Without detailed records of major outages within the city, the severity of power outages is difficult to determine. Most power outages in Ann Arbor are limited to isolated, short-term power outages caused by severe weather. However, major, prolonged disruptions, such as those lasting several days to a week, have occurred, and more severe events are possible. In the future, as severe thunderstorm become more intense and more frequent, there is a greater potential for severe power outages within the city.

Probability of Future Occurrences

Routine power outages caused by severe weather or maintenance issues occur multiple times a year in Ann Arbor, as they do in most places. A prolonged, devasting power outage that surpasses the ability of back-up power supplies to keep facilities running are less frequent. With nine events reported in 30 years, it is assumed the city experiences such an outage every three years, on average. However, several factors may increase the likelihood of power outage events in the future. Increased storm activity may cause more frequent outages. Further, increased demand for electricity may strain the grid, resulting in more frequent blackouts or brownouts. For example, in May 2022, the electric grid operator MISO (Midcontinent Independent System Operator), which includes Michigan, warned that controlled outages may be required over the summer as demand was projected to exceed capacity.[lxxxvi] Increased future demand for electricity is expected to increase in Ann Arbor for several reasons:

- An increase in the number high heat days and heat wave events is expected to increase energy demand for cooling;
- Population and economic growth are expected to increase energy demand; and,
- Electrification (e.g., switch from fuel electricity) of buildings and cars (EVs) is projected to increase in Ann Arbor. According to the A^{2}Zero Plan, by 2030: 330 – 459 additional megawatts (MW) of electricity will be needed for the planned fuel switch and 60 – 84 additional MW will be needed for EV charging.

Considering past events and projected future impacts, the probability assigned to this hazard (a multi-day power outage) is likely (10 to 90 percent annual chance).

Vulnerability Assessment

All current and future buildings and infrastructure reliant on electricity to operate, and populations are potentially at risk to power outages. Electricity is supplied to the City of Ann Arbor by DTE Energy and is part of the MISO grid, which supplies energy to 15 states and the Canadian province of Manitoba. The University of Michigan, located within Ann Arbor, generates its own electricity through its Central Power Plant and North Campus Research Complex Energy Plant.

In Ann Arbor, most power outages are caused by severe thunderstorm and windstorm events when power lines or poles are downed. Tree and tree limbs are often a cause of downed power lines. DTE has a robust tree trimming program in place as a prevention measure against outages, but there are still a large number of trees in the city in need of pruning.

Damage to Buildings. Typically, power outages cause minimal damages to buildings, especially if equipped with a backup generator. In extreme cases, surges associated with power outages can cause fires and/or damage electrical systems, includes computers, TVs, and appliances. In addition, prolonged outages during periods of high heat and humidity can cause loss of cooling, during which buildings may retain moisture (e.g., swelling of drywall, wood flooring or trim, etc.) resulting in minor damages.

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Damage to Infrastructure. Typically, power outages cause minimal damages to infrastructure. Infrastructure that is reliant on electricity, such as water or wastewater treatment and pumping, traffic signals, communications networks, and monitoring system may be temporarily inoperable, which could have wider impacts for the city, as described in the sections below. In extreme cases, surges associated with power outages can cause fires and/or damage electrical systems. Further, as infrastructure continues to incorporate "smart" technology in the future, the impacts of a power outage may have wider consequences, such as data loss and loss of automated functionality.

Life Safety, Health, and Warning and Evacuation Procedures. Prolonged power outages may have substantial impacts on life safety, warning, and evacuation procedures. Power outages that coincide with extreme heat events may result in heat-related illnesses (see Extreme Heat hazard profile) when cooling capabilities are lost. In recent years, City of Ann Arbor has developed processes in place to open relief centers when such cases occur, as demonstrated by the opening of Pioneer High School as a relief center during the 2021 power outage. In addition, outages that cause traffic signals to lose functionality may increase the likelihood of vehicle crashes and complicate evacuation processes. In addition, emergency alert sirens that do not have backup power may not be functional during a power outage.

Medical, fire, and EMS facilities impacted by power outages may lose or experience limited functionality, which in turn may impact life safety within the community, such as access to medical services and emergency response times.

Public Health. Public health impacts from power outages are not common but can occur in extreme cases. For instance, during prolonged outages in which fuel cannot be supplied for backup power to water treatment and/or pumping, a boil water advisory may be required. Similarly, loss of pumping capacity within wastewater systems may result in sewage overflows. In addition, the need to open relief centers may increase the potential for infectious disease to spread, such as COVID-19, if social distancing cannot be observed.

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Impacts to Socially Vulnerable Populations. Certain populations are more likely to experience disproportionate impacts from power outages. The elderly and very young are more susceptible to heat-related illnesses, and therefore may be more vulnerable to power outages that occur during extreme heat events. Individuals reliant on medical equipment, such as oxygen pumps, motorized stairlifts, or C-PAP machines, may experience a medical emergency during a power outage, especially if backup power is not available to them. Income-constrained households may experience loss of refrigeration and food spoilage more acutely than non-constrained households. In addition, households without an English-speaker may face challenges with reporting outages or receiving information regarding outage notifications and services.

Economic Impact. Power outages, especially those lasting several days or more, may have substantial economic impacts. Businesses may have to close for several days or more, and some, such as grocery stores, pharmacies, and restaurants, may lose thousands of dollars' worth of products. Major events, such as concerts, festivals, or sporting events may have to be cancelled, resulting in loss of revenue.

Climate Change Impacts. Climate change is expected to have indirect impacts on power outages. Changing climatic conditions are expected to increase severe storm activity and tornadic activity, which could increase the frequency of power outages in Ann Arbor. As power outages often occur during summer months when thunderstorms are more common, the increase in extreme heat days may also increase the impact of power outage events (e.g., increase the likelihood of heat-related illness during an outage). Further, warmer temperatures are expected to increase future demand for cooling, which may contribute to controlled outages or blackouts.

Structure Fires

Description

Structural fires are defined as the uncontrolled burning of any building—residential, agricultural, recreational, institutional, commercial, or industrial (MSP/EMHSD). Structural fires can originate from a number of sources, including faulty electric systems, natural gas leaks, arson, and improperly discarded cigarettes, candles, and incense. Structural fires are a common occurrence in Ann Arbor, but a catastrophic structural fire has not occurred in Ann Arbor in recent years (MSP/EMHSD; Washtenaw County Emergency Management). Within a city, it can sometimes be difficult to limit the spread of a major fire to surrounding buildings. Large population centers, like dormitories, apartment buildings, senior housing or special care facilities, schools, large churches, and other buildings that house large numbers of people, tend to be regularly inspected, built with masonry, and have emergency evacuation procedures, reducing the potential for injury and death. Of greater concern are densely populated areas, such as student housing sections in urban areas, where people live in over-crowded wood-built homes in close proximity to other over-crowded and wood-built homes. Preventing the spread of a fire in this situation could be extremely challenging.

In the U.S., over 491,000 structure fires were reported between 2015 and 2019, resulting in over 2,800 deaths, 12,000 injuries, and over $10.9 billion in property losses.[lxxxvii] Michigan has higher rates of fatalities and injuries from structure fire when compared to the national average. While potential reasons for state-to-state variations are many, a September 2019 Analysis conducted by the National Fire Protection Association (NFPA) found that higher state fire death rates are positively correlated with a larger percentage of people within a state who:

- Have a disability
- Have incomes below the poverty line
- Are current smokers
- Live in rural areas
- Are either African American/Black or are Native American or Alaskan Native

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Location

It is assumed that all of Ann Arbor is exposed to structure fires. Areas with clusters of wood-built structures or densely developed areas may be at higher risk.

Previous Occurrences

Based on the 2021 City of Ann Arbor Fire Department (AAFD) Annual Report, the AAFD responded to 80 structure fires. In addition, the report states that fires in Ann Arbor resulted in 42 civilian injuries and 2 civilian fatalities from 2012 to 2021.[lxxxviii] No additional serious structure fire occurrences were provided by the city. The following lists provides a brief description of past events for serious structure fires:

- Multiple Structure Fires in 1940: On March 26, 1940, four fires broke out throughout the day, starting in the morning and continuing through the afternoon. The two worst fires were at a parts supply store located at 209 N. Main St. and a private home located at 521 N. Fifth Ave. In total the four fires caused over $141,541 in damages.[lxxxix]
- Buildings Destroyed by Fire in 2003: On July 24, 2003, four buildings were destroyed by a fire within the city resulting in a significant effort by firefighters.
- Apartment Complex Fire in 2006: On March 3, 2006, an apartment complex was heavily damaged by fire. There was one fatality and two others injured. Over 100 people were evacuated by the responding fire fighters.
- Senior Citizen High Rise Fire, August 2008: One Senior citizen was killed and over 50 seniors were displaced when a fire started in an occupied apartment complex for the elderly.
- Historic Ypsilanti Building Destroyed in 2009: A historic building that was under renovation in Ann Arbor's neighboring city of Ypsilanti was destroyed by a large fire on the early morning of September 23, 2009. The building originally housed soldiers during the Civil War and was located in the downtown area known as Depot Town. The fire started on the second floor of the vacant three-story building. Firefighters from several Ann Arbor area departments including Ann Arbor, Ypsilanti Township, Pittsfield Township, and Superior Township were at the scene for hours. There were no injuries reported. The fire appeared to be suspicious and was called a setback for plans to revitalize the neighborhood.
- Building Fire in 2009: On the night of October 25, 2009, a large fire broke out near the University of Michigan campus near restaurants and bars along a crowded street. Fire crews immediately rushed to the scene and there were up to 55 firefighters actively fighting the fire. The fire became so large that an adjacent apartment building was evacuated due to fear of it spreading, resulting in approximately 600 students being temporarily displaced. Even though police officers had attempted to blockade the sidewalk, the crowds outside remained and onlookers were able to make their way to the scene through a passageway, between buildings across the street. While the fire burned on the west side of the street, the east side of the street remained a bustling night scene.

DRAFT

- Fatal House Fire November 2009: Three people were killed in a residential house fire on the city's Westside. The house collapsed and was completely destroyed.
- Student Housing Fire, April 2010: One student was killed, and another seriously burned. Pittsfield Fire Department was called through Mutual Aid to assist with RIT (Rapid Intervention Team, a team of two or more firefighters dedicated solely to search and rescue of other firefighters in distress) and overhaul.
- House Fire January 2011: On January 29, 2011, a house was destroyed by fire. There were two fatalities, both of whom were trapped inside. Firefighters tried to rescue the victims using thermal imaging cameras.
- House Fire in 2014: One woman was killed, and a man was hospitalized following a structure fire in the 2900 block of Shady Lane, on the south side of Ann Arbor. The fire started in the living room and was likely accidentally started by the residents. One firefighter suffered a sprained ankle while responding to the fire because of the large amount of belongings being kept inside the home. The Ann Arbor Fire Department Investigator stated that the heavy content load within the home made responded to the fire difficult and likely added fuel to the fire, causing more damage.[xc]
- House Fire in 2019: One man was killed, and a firefighter was seriously injured as a result of a structure fire in the 3500 block of Paisley Court. The firefighter was injured when he or she fell through the floor of the second story while searching for the resident of the home. Shortly after, the resident of the home was located but, unfortunately, was pronounced dead at the scene.[xci]

Extent

The extent of structure fires is difficult to determine. In Ann Arbor, perhaps the greatest impact event was the 2009 University of Michigan fire, in which 600 students were displaced and 55 fire fighters were at the scene. However, more severe events are possible, especially given increasing density in Ann Arbor, along with the University of Michigan campus, and the large influx of people on game days.

Probability of Future Occurrences

The probability of structure fires is difficult to determine without detailed yearly data. Structure fires are normal occurrence in most cities. In 2021, Ann Arbor reported responding to 80 structure fires. Therefore, the probability assigned to this hazard is highly likely (greater than 90 percent annual chance). However, events resulting in multiple fatalities or catastrophic damages are less likely.

Vulnerability Assessment

Potential impacts to buildings, infrastructure, life safety, public heath, socially vulnerable populations, and the economy from the structure fire hazard are described below. All current and future buildings, infrastructure, and populations are considered at risk to structure fires.

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Damage to Buildings. Structure fires can cause significant damage to structures, ranging from smoke and water damage to the total loss of one or multiple structures. Wooden buildings or densely developed areas may be at a higher risk, as fire may spread more quickly. Compliance with building and fire codes will greatly reduce buildings' vulnerability to structure fires. Hoarding, or storing a large quantity of materials, within a home was highlighted as an issue in a number of local news articles reporting on structure fires. A heavy content load within the structure can add fuel to a fire, as well as hinder any rescue or fire suppression efforts.

Damage to Infrastructure. Structure fires that spread outward from their originating structure can damage infrastructure, such as utilities and bridges. Fires burning adjacent to infrastructure may damage structural integrity.

Life Safety, Health, and Warning and Evacuation Procedures. Structure fires present a serious hazard to life safety. People trapped in structures on fire may sustain injuries due to smoke inhalation or burns. Fatalities can occur during structure fire events. Buildings should follow building codes and requirements for smoke detectors to result in early detection and evacuation of structures on fire. Large population centers, like dormitories, apartment buildings, senior housing or special care facilities, schools, large churches, and other buildings that house large numbers of people, tend to be regularly inspected, built with masonry, and have emergency evacuation procedures, reducing the potential for injury and death. Practicing fire drills can reduce impacts to life safety by speeding up the evacuation process in the event of a structure fire.

Subsequently, displacement of individuals impacted by a structure fire is a concern, especially if the structure housed a large population. Having established emergency shelters and a plan for providing basic necessities to displaced individuals can mitigate issues arising from a structure fire.

Public Health. Structure fires have a limited impact on overall public health. A large structure fire may result in reduced air quality due to smoke.

Impacts to Socially Vulnerable Populations. Socially vulnerable populations are more likely to be negatively impacted by structure fires. The U.S. Fire Administration (USFA) acknowledges that socioeconomic factors are a good predictor of fire rates at a neighborhood level. Furthermore, the USFA also highlights children under the age of 14 and adults over the age of 65 as vulnerable populations, as these populations may have difficulty evacuating a building in a timely manner.[xcii] A 1992 congressional hearing cited in a recent FEMA publication states that children from low-income families are five times more likely to die in a fire.[xciii] Although more recent research is limited, available research indicates that housing characteristics play a key role in the likelihood of a structure fire. This includes the age of a residence, the density of vacant buildings in a neighborhood, and the installation and upkeep of smoke detectors in a residence. Other factors include a parental presence in the home and household income. The easiest and most effective method for reducing the risk of structure fires is ensuring that smoke detectors are installed and maintained. The State of Michigan hazard mitigation plan indicated that 50 percent of fire related deaths occur in homes without working smoke detectors. Renters may have less control over the testing the replacing of smoke detectors, and those with negligent landlords may be more likely to live in housing without functioning smoke detectors.

DRAFT

Economic Impact. Structure fires can have a severe economic impact due to building damages and business interruptions. Damages to certain structures, such as historic buildings and entertainment centers (such as the University of Michigan Stadium), could have a farther-reaching economic impact on the community. Damages to public buildings from structure fires could result in a large expense for the city. In addition, structure fires that result in the closure of nearby businesses and roads could result in a reduction to the city's tax base.

Climate Change Impacts. Direct impacts to the structure fire hazard from climate change are not anticipated.

Water Contamination

Description

An adequate supply of clean drinking water is vital to a functioning community. Basic needs, such as hydration, cooking, and sanitation, require an adequate water supply. Water is also often essential for firefighting, medical services, electricity generation, industrial processes, and operations for many businesses. Water contamination occurs when water delivered to customers becomes unsafe for consumption or other uses, and therefore has the potential to result in life-threating illness, as well as limiting water availability.

There are several sources of water contamination with the potential to impact Ann Arbor, such as:

- Water main breaks or loss of pressure: Water mains that deliver treated, or finished, water to customers are typically pressurized, which keeps outside water and substances from seeping into pipes. However, loss of pressure within the water distribution system, due to main breaks or loss of pumping capacity, has the potential to introduce bacteria or other contaminants into the finished water supply. In addition, contaminants may also enter a drinking water system at the site of a water main break.
- Aging pipes: Aging water pipes have the potential to leach contaminants from the pipes themselves into finished water when appropriate measures, such as the use of anti-corrosives or pipe upgrades, are not employed. Many parts of the U.S., including Michigan, have aging water distribution systems with pipes that are prone to leaks, breaks, and corrosion. For example, in Flint, MI, lead from aging pipes leached lead into the water supply in 2014 after the supply was switched, exposing 100,000 residents to elevated levels of lead exposure. This incident resulted in a federally declared state of emergency, and the long-term health implications of the event, especially on exposed children, is still unknown.
- Groundwater and surface water pollution: Groundwater and surface water supplies have the potential to become contaminated through the release of hazardous materials. Releases may have been lawful and/or planned at the time of release or have been released unintentionally through negligence or an accident (e.g., during a flood). Other releases may be a result of an intentional, illegal discharge. Discharge into waterways is typically regulated by the EPA through permitting. Certain chemicals may not dilute or break down over time, and therefore chemicals that were released into

DRAFT

water systems decades prior can have a lasting impact. Michigan has a history of industrial uses and manufacturing, which increased the potential for water contamination across the state.

- Sewage overflows: Sewage overflows have the potential to contaminate water when untreated sewage is released from the sewer conveyance system and flows into surface water supplies. Sewage overflows typically occur during heavy rainfall events; unlike drinking water systems, sewer systems are not pressurized, which allows storm water to seep into the sewer system, especially when sewer and stormwater systems are combined. During heavy rainfall events, the sewer system may become overwhelmed, resulting in the flow of sewage out of the system and onto nearby lands or into waterways. In addition to heavy rainfall events, sewage overflows may occur when loss of pumping capacity is experienced (e.g., during a power outage) and backed-up sewage is released.
- Sabotage/intentional contamination: Sabotage, or the intentional contamination of water supplies, occurs when water supplies are compromised by an actor using biological, chemical, nuclear, or radiological contaminants. Such contamination may occur as part of a terrorist act or similar criminal activity.

Location

All of areas of Ann Arbor have the potential to be impacted by water contamination.

Previous Occurrences

Previous instances of water contamination incidents and/or close calls in Ann Arbor were gleaned from the TAC, interviews with local stakeholders, news articles, and the State of Michigan hazard mitigation plan, and are included below. It is likely that minor contamination incidents, such as additional boil water advisories, have not been reported.

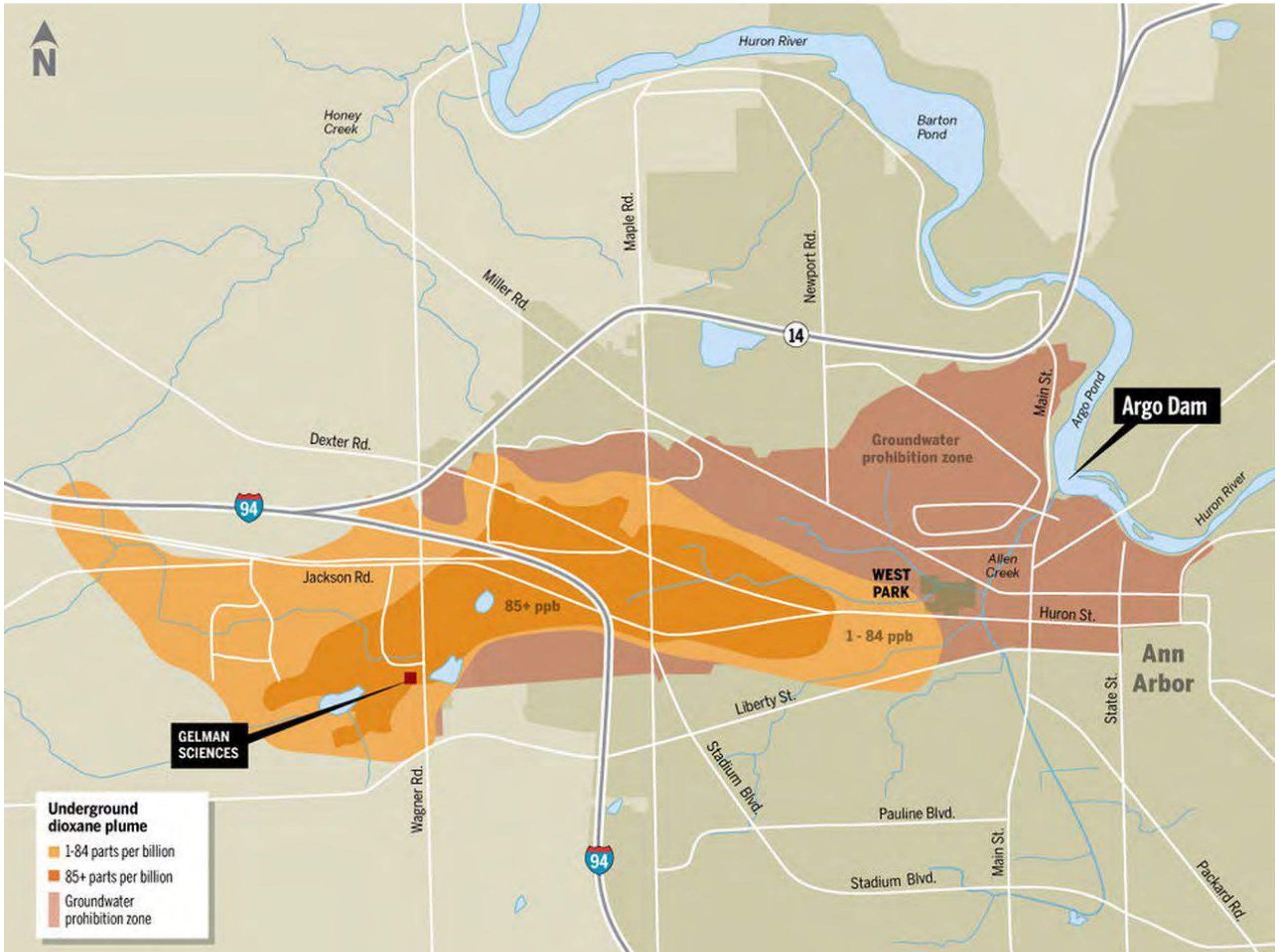
June 22, 2021, Water Main Break. On June 22, 2021, a water main at Jackson and Maple collapsed, causing significant road damage, shown in Figure 4-52. A boil water advisory was issued for the impacted area (approximately 600 residents) for approximately two days, until 9am on June 24, 2022. The advisory was issued as a precautionary measure, and no contamination was detected.

DRAFT

Figure 4-52: June 2021 Water Main Break

June 2021 Sewage Overflow. An estimated 25,000 gallons of sewage overflowed to the ground surface near Hogback Road. The overflow occurred during the June 25-26th extreme rainfall event, which was documented as a 100-year storm event. No evidence was found that the sewage entered a storm sewer or waterway.[xciv]

Gelman Dioxane Plume. In addition to the incidents listed above, Ann Arbor also has a slow-moving threat that continues to impact the city despite the original use being inactive. Decades ago, a plant manufacturing medical filters released an industrial solvent, dioxane, into the groundwater. Dioxane is a carcinogen. The result has been a slowly moving plume of dioxane in the aquifer under the west side of the city. Clean-up is ongoing, but the city can no longer use the aquifer as a drinking water source. There are concerns that the plume will eventually pollute the City's main drinking water source, the Huron River, which is regularly tested for dioxane.[xcv] In the last several years, trace levels of dioxane (between 0.03 and 0.08 parts per billion) were detected in raw intake water from Barton Pond. These levels are about 10 times lower than the EPA's lifetime risk level of 0.35 parts per billion.[xcvi] Figure 4-53 shows the location of the dioxane plume in Ann Arbor.



Source: Stanton, MLive.com

Figure 4-53: **Ann Arbor's Underground Dioxane Plume**

PFAS (per- and polyfluoroalkyl substances). PFAS is a long-standing chemical contaminant that began to gain statewide attention when it was detected at significant levels in drinking water in 2010. It is a broad term for a variety of related chemicals with unique properties useful in non-stick applications, as stain removers, water repellants, and in firefighting foams. Generally available beginning in the 1940s, ongoing studies of this environmentally persistent chemical have shown harmful health effects in chronically exposed individuals. This is especially true with drinking water contamination or in persons showing high levels that have increased over time (many people in Michigan exhibit at least some level of accumulation). PFAS has been found to significantly alter immune and inflammatory responses.

Extent

The extent of water contamination is difficult to determine without detailed historical records. Contamination could be measured in terms of amount of contaminant or geographic extent of contaminated water. In Ann Arbor, a "worst case" scenario for water contamination would be one in which the city's primary water supply, Barton Pond, becomes contaminated and must be abandoned as a water source. Such an event would be rare and has not occurred historically but is possible.

Probability of Future Occurrences

The probability of water contamination is difficult to determine without complete data. Some contamination issues, such as PFAS and the dioxane plume, are chronic issues. Considering Michigan's industrial history, it is likely that other water contamination events have occurred in the past. Therefore, the probability assigned to this hazard is likely (10 to 90 percent annual chance). However, devasting water contamination events, such as those resulting in acute fatalities/injuries, or a loss of the water supply are far less likely.

Vulnerability Assessment

All current and future populations within Ann Arbor are considered at risk to water contamination. The city's water utility performs regular water quality checks in order to ensure contaminants are within levels permitted through EPA.

Damage to Buildings. Damage to buildings due to water contamination is not typical, although buildings may lose potable water service.

Damage to Infrastructure. While infrastructure is unlikely to be damaged by water contamination, water treatment infrastructure or processes may have to be modified in order to treat potential contamination. Drinking water conveyance systems may have to be flushed following a contamination event, which can be costly and result in a temporary loss of service. In extreme cases, source water infrastructure, such as wells or reservoirs, may have to be abandoned.

Life Safety, Health, and Warning and Evacuation Procedures. Water contamination is unlikely to impact warning and evacuation procedures, however water contamination may necessitate activation of warning and notification systems, such as Everbridge, during instances such as boil water advisories.

Public Health. Water contamination has the potential to severely impact public health. Undetected water contamination may result is illness, lifelong impairments, or even fatalities, depending on the contaminant and levels of exposure. Public health impacts

DRAFT

from water contamination may be acute, such as contamination introduces during water main breaks, or chronic, such as those from long-term exposure to chemicals.

Water contamination may impact populations through microorganisms, causing waterborne illness. This may include exposure to bacteria, such as E. Coli, Listeria, and Legionella, or parasites such as Giardia. Ingestion of these types of contaminants may cause individuals to fall ill (often gastrointestinal) or die. It is also possible to contract certain viruses through contaminated water, such as Hepatitis A or norovirus (see Public Health Emergencies profile).

Aside from microorganisms, water contamination from inorganic compounds may also severely impact public health. Compounds such as arsenic, hexavalent chromium, and lead can have dangerous health side effects. For instance, hexavalent chromium is a carcinogen (cancer-causing), and unsafe lead exposure can cause neurological damage.

Impacts to Socially Vulnerable Populations. Certain populations may be disproportionately impacted by water contamination. The very young, elderly, or immunocompromised may be less able to rebound from exposure to contaminants. For instance, children and babies are more likely to experience developmental issues associated with lead exposure. Income constrained households may struggle to purchase bottled water in the event the drinking water supply is contamination and may also be less able to pay for at-home testing of their water supply. Historically, communities of color have been more likely to be exposure to unsafe drinking water. A study by the National Resources Defense Council found that water systems with chronic noncompliance were 40 percent more likely to be in counties with the highest racial, ethnic, and language vulnerability than those with the lowest.[xcvii]

Economic Impact. Water contamination could have catastrophic economic impacts. Waterborne illnesses may result in closure of restaurants, schools, industrial centers, and other businesses. Cancellation of events, such as festivals or sporting events, may be required. Furthermore, long-term contamination may cause populations to move away from the city or to choose not to live in Ann Arbor (e.g., incoming student populations may be curtailed). In order to combat contamination, large sections of the water distribution system could have to be replaced (as occurred in Flint, MI), or specialized treatment facilities may be required.

Climate Change Impacts. Warmer temperatures associated with climate change may result in certain bacteria or viral contaminants being able to thrive if surface water temperatures increase.

DRAFT

Human-Caused Hazards

Civil Disturbances

Description

Civil disturbances are events that involve a gathering of many people collectively engaging in unlawful behavior, such as rioting, looting, vandalism, or arson. Civil disturbances can escalate from a public event, like a sporting event, or lawful political rallies, protests, and demonstrations. Civil disturbances can be both planned or unplanned, organized or unorganized. The State of Michigan hazard mitigation plan classifies civil disturbances into four broad categories:

1. Protests that become unlawful. Protests are only considered civil disturbances if they become threatening, disruptive, and even deliberately destructive or malicious (on the part of at least some of those involved either in the protest itself or in reaction to the protest). The destruction of property, interruption of services, interference with lawful behaviors of ordinary citizens and/or emergency responders, the use of intimidation or civil rights violations, and threats or actual acts of physical violence may all occur during civil disturbances. Michigan events have included the willful destruction of property and impeded property access during labor strikes, and heated conflicts between opposing participants at political rallies or issue-driven demonstrations.

2. Hooliganism, which is relatively unorganized and involves individual or collective acts of deviance inspired by the presence of crowds, in which the means (and responsibility) for ordinary levels of social control are perceived to have slackened or broken down. Certain types of events, such as sporting events, "block parties," or concerts, become widely publicized and, in addition to normal citizens who merely seek entertainment, tend to also attract persons who seek situations in which anonymity, confusion, and a degree of social disorder may allow them to behave in unlawful, victimizing, or unusually expressive ways that would normally be considered unacceptable by most ordinary people. Examples include the disorder that has followed various sporting events and college parties. Although the majority of persons present are ordinary citizens (although many may have some level of intoxication), a minority of persons begins making itself known through unlawful or extreme acts of deviance, and it is from this part of the crowd that the hazard primarily stems. Common problems include the widespread destruction of property, numerous types of assault and disorderly conduct, and criminal victimization. It should also be noted that many persons who are normally law-abiding may temporarily behave in unusually aggressive ways during these events, often prompted by an understandably defensive anxiety about the disorder and behavior exhibited by the deviant minority, but also possibly exacerbated by a level of alcoholic intoxication, as well as the temptation by some to engage in deviant behaviors that, under normal circumstances of social control, would not be selected.

DRAFT

3. Riots may stem from motivations of protest but lack the organization that formal protests include. Although legitimate and peaceful protests may spontaneously form when people gather publicly with the perception that they already share certain values and beliefs, riots tend to involve violent gatherings of persons whose level of shared values and goals is not sufficiently similar to allow their collective concerns or efforts to coalesce in a relatively organized manner. This may lead to assaults, intimidation, and unlawfully destructive expressions of discontent, possibly including the victimization of innocent citizens or businesses. In addition to the sentiments of discontent that may have sparked the initial activities, elements of hooliganism may emerge and even come to predominate, as certain persons may attempt to exploit the social disorder for their own individual ends.
4. Insurrection involves a deliberate collective effort to disrupt or replace the established authority of a government or its representatives by persons within a society or under its authority. Some prison uprisings may fall into this category, although others may more properly be classified as riots or protests, depending upon the presence and extent of specific goals and organization, and the type of action used in achieving such goals. An insurrection has the deliberate goal of either replacing established authorities with a new distribution of power, or with the destruction of established power structures in favor of (usually temporary) anarchy or a smaller-scale set of recognized criminals (gang), ethnic, political, or other group networks and power-structures.

The City of Ann Arbor has many aspects that make it a prospective location for a civil disturbance to occur. Ann Arbor is home to a large university, The University of Michigan. At universities, political or social demonstrations and sporting events have the potential to ignite a riot. Riots inspired by demonstrations or football and basketball games have the potential to involve active participants as well as people and property in the surrounding area. Ann Arbor also has the largest population center in the area, and therefore is likely to be selected by demonstrators.

Recent years have seen an increase in violent protests and riots across the U.S., often as protestors and counter-protestors clash. Notable recent events of civil disturbance at the national level include:

- 2017 Charlottesville, VA White Nationalist Rally: In Charlotteville, VA, home to University of Virginia, white nationalists clashed with counter-protestors, erupting in skirmishes. A man from Ohio drove a car into a group of counter-protestors, killing one woman and wounding others.
- April 2020 Michigan State Capitol COVID-19 Protest: During this event, armed individuals protesting COVID-19 emergency measures entered the Michigan State Capitol.
- **Summer 2020 “100 days of violence”:** Across the nation, protests stemming from police brutality and COVID-19 became widespread. While most demonstrations were peaceful, some turned violent, to include looting, arson, property damage, and assault. A study from the University of Connecticut found that of over 7,300 events nationwide, 3.7 percent included property damage (approximately 270 events) and 2.3 percent (approximately 168 events) reported injuries.[xcviii]
- January 6, 2021, Attack on the U.S. Capitol: On January 6, 2021, a group of armed individuals stormed the US Capitol building in an attempt to block the certification of the 2020 election results. During the attack, rioters broke into Senate chambers,

DRAFT

destroyed and stole property, and attacked Capitol police. Four people in the crowd died during the attack, and five officers died in the days of weeks following the event.

Location

All of Ann Arbor is considered at-risk for civil disturbances. However, urban areas, particularly those including public meeting spaces, government buildings, or areas near or on the University of Michigan campus and its stadium, are considered at a higher risk.

Previous Occurrences

As a university community, Ann Arbor is the site of regular protests, but most are peaceful, lawful events. In recent years, protests and counter protests have seen an uptick across the country, Ann Arbor included, to call attention to issues such as police brutality, women's rights, and climate change. While most events would not be classified as a civil disturbance, Ann Arbor has experienced several civil disturbances in the past, including:

- Civil Disturbance of 1969: The night of June 17, 1969, ranks as one of the most contentious and frightening moments in Ann Arbor's existence, from the violence of the South University Avenue riot. Police from five agencies used tear gas and night sticks to twice clear the street of more than 1,000 people making 47 arrests in the process. The conflict began the night before partly out of an interest in creating a pedestrian mall or People's Park on the street, which some called "the liberation" of South University Avenue. The unruly crowd blocked cars, threw rocks, and yelled obscenities at police who braced for a confrontation as the University of Michigan President Robben Fleming pleaded for restraint on both sides.
- General civil unrest within the student population in the 1960s and 1970s.[xcix]
- Civil unrest resulting from the Gus Macker basketball tournament in the 1980s.
- On January 18, 2016, about 60 protesters calling for then-Governor Rick Snyder's arrest for his role in the Flint drinking water crisis marched from the University of Michigan's campus to Snyder's voting address.[c]
- On May 30, 2019, trespassing charges were requested for 10 protesters who participated in a sit-in in the University of Michigan's administration building. The demonstration, which consisted of around 50 people, was part of a global "Climate Strike." Those that were charged had remained in the building after an established 8pm deadline.[ci]

Extent

The extent of civil disturbance is difficult to measure. Civil disturbances can be measured in terms of crowd-size, arrests, injuries, or property damage. The most severe event of civil disturbance in Ann Arbor's history is that of the Civil Disturbance of 1969, in which resulted in over 1,000 people in attendance and 47 arrests. More recent events in Ann Arbor, while potentially unlawful (e.g., no permit acquired for a protest, or exceeding curfews), have not been violent. However, more devastating events are possible, including ones that could result in vandalism, business closures, loss of life, and loss of economic income.

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Probability of Future Occurrences

Given the limited history and documentation of civil disturbances in Ann Arbor, combined with the characteristics that make it prone to such events, the probability assigned to the civil disturbance hazard is possible (between 1 and 10 percent annual probability).

Vulnerability Assessment

Civil disturbances have the potential to impact buildings, infrastructure, life safety, public health, and the economy. All current and future buildings, infrastructure, and populations are considered at risk to civil disturbances.

Damage to Buildings. All current and future buildings in Ann Arbor are considered at-risk to civil disturbances. Civil disturbances can include in vandalism and arson, which may result in damages to public and private property. Damages to buildings may include, but are not limited to, fire and smoke damage, broken windows and doors, and spray painting.

Damage to Infrastructure. Civil disturbances can include in vandalism and arson, which may result in damages to infrastructure like roads, bridges, and utilities.

Life Safety, Health, and Warning and Evacuation Procedures. All current and future populations in Ann Arbor are considered at-risk to civil disturbances. Civil disturbances can have severe impacts on life safety. Physical violence to participants, bystanders, and responders is possible. Dangers resulting from explosions, fire, smoke inhalation, and tear gas is also possible. Civil disturbances may result in the need to evacuate a building, structure, or public space.

Public Health. Civil disturbances impact public health and safety when those not actively participating in the disturbance are put at risk. During severe and/or long-lasting events, residents living or working near the disturbance may not have safe access to essential goods and services. For example, during a civil unrest event in Baltimore, Maryland in April 2015, senior residents reported rationing medications due to inadequate safe access to pharmacies. Residents also reported a shortage of food and basic supplies and required assistance from the Baltimore Health Department.[cii]

Impacts to Socially Vulnerable Populations. Certain socially vulnerable populations may be disproportionately impacted by civil disturbance events. Those living in dense urban areas, where disturbance events are more likely to occur, may be at a higher risk to having homes or property damaged or roads blocked during events. In addition, racial inequities may occur during arrests at protests and civil disturbances. For example, one analysis found that black people were nearly twice as likely to be arrested as whites a Portland, OR protests.[ciii] Populations with limited access to information, such as those without telephone service or access

DRAFT

to the internet may experience delays in receiving and acting upon hazard information related civil disturbances in their community. Additionally, those who do not speak English well may not comprehend event information to the extent that enables them to make timely decisions and take appropriate actions. A civil disturbance event may cause disruptions to public transportation. Populations with limited vehicle access or transportation routes are more likely to experience mobility challenges and have difficulty accessing needed supplies or commuting to work.

Economic Impact. Civil disturbance events can result in business disruption. Some disturbances may be planned and organized with the intent to disrupt normal business operations or traffic flows, while others may indirectly impact nearby businesses by creating unsafe conditions for employees and customers to access nearby businesses. In extreme cases, some businesses may need to close down to repair or rebuild following damages from a civil disturbance.

Climate Change Impacts. It is possible that warmer days may lead to greater numbers of civil disturbance, as studies show a positive correlation between warmer temperatures and crime.[civ] Further, given the political nature of climate change policy, it is possible that civil disturbances may occur as a result of policy changes, new information, or general activism.

Cyber-attacks

Description

Cyber-attacks typically involve the use of computers and electronic devices over the Internet to attack other computers and network systems. Examples of cyber-attacks include:

- Computer viruses, which can damage infected computers;
- Denial-of-service attacks, which can shut down a targeted website; and
- Hacking, in which sensitive information can be compromised or held for ransom.

There are many different motives for cyber-attacks, including undermining public confidence in cyber security, vandalism, and obtaining or altering information in order to commit fraud, identity theft, extortion, or sabotage. For instance, confidential personal information, such as birth dates and Social Security numbers, can be sold by hackers in order to be used in identity theft activities. Additionally, ransomware restricts a user's access to their data or system and requires a user to pay the attacker prior to regaining access.

An increasing prevalent type of cyber-attack capability is the ability to impair or destroy machinery by taking over the software that controls the machines. Cyber-attacks such as these could be used to damage or inhibit the functionality of critical infrastructure such as electrical grids, water treatment systems, and fuel pipelines.

DRAFT

Cyber-attacks can be ad-hoc or planned in advance. Similarly, perpetrators of cyber-attacks can range from individual, amateur hackers to organized, highly skilled groups of "professional" criminals, such as those associated with organized crime or nation-state operators. Further, cyber-attacks can be committed by parties operating globally through the internet, making prevention, enforcement, and response all the more challenging.

Ultimately, cyber-attacks cause harm to critical cyber functions and Internet services by impairing the confidentiality, integrity, and availability of electronic information, services, and networks. This hazard will continue to grow as the Internet of Things (IoT) expands, with cybersecurity concerns moving beyond desktop and laptop computers, as cars, phones, infrastructure, and other devices not previously connected to the Internet become more widely adopted.[cv]

The State of Michigan Hazard Mitigation Plan contains the following definition associated with cyber-attacks:

- Adware: A form of software that displays advertising content in a manner that is potentially unexpected and unwanted by users, and which may also include various user-tracking functions (similar to spyware).
- Backdoor: An Internet method used for bypassing normal authentication or encryption in a computer or network device. Backdoors have legitimate purposes and are often used for securing remote access to a computer or restoring user passwords. Many computer users are unaware of the backdoors that exist on their system, and unauthorized access due to poor vendor management or weak security can be exploited. Some backdoors may be secretly installed.
- Botnet: The word BOTNET is short for the combination of the word robot and network. The term often applies to groups of computer systems that have had malicious software installed by worms, Trojan horses or other malicious software that allows the "botnet herder" or botnet's originator to control the group remotely.
- Cookie: A small text file that is placed on a computer's hard drive by a web site, in order to allow that site to retain and use information about the user (and the user's activities) at a later time.
- Deep web: The content of the World Wide Web that is not generally public nor indexed (made searchable) by search engines. Typically used for web mail, online banking, restricted access social-media pages, and content protected by paywalls (video on demand, some online newspapers).
- Internet of Things (IoT): The interconnection, via the Internet, of everyday devices, such as eyeglasses, watches, pacemakers, house doors, automobiles, and other items that historically did not have computer components that allowed for the wireless transfer of electronic data or remote operation.
- Keystroke logger: Any method that allows the recording or interpretation of which keys have been pressed by a user on the person's computer keyboard, typically without the person's awareness or consent. The methods may include software or hardware that records all typed information, possibly including the analysis of video and acoustic information about the user's behavior, but often accomplished by means that make use of the computer itself to relay information to a remote person or machine, for later use.

DRAFT

- Malware: A broad term for software, often installed on a user's computer without their consent, which performs unwanted actions. These may be relatively benign and used for targeted advertising, but may also result in poor computer performance, data corruption, or system crashes. Some can be used to send email through another person's account or used for surveillance purposes (see spyware).
- Pharming: Arranging for a web site's traffic to be redirected to a different, fraudulent site, either through a vulnerability in an agency's server software or through the use of malware on a user's computer system.
- Phishing: the attempt to trick someone into providing confidential information or doing something that normally wouldn't or shouldn't be done. For example, phishing could involve sending an e-mail that falsely claims to be from an established legitimate enterprise, in an attempt to scam the user into surrendering private information that will be used for identity theft.
- Ransomware: An attack where a hacker encrypts or otherwise locks the legitimate user out of portions of their computer system. Sensitive or necessary data is reenabled only after the computer's owner pays the hacker money (frequently in cryptocurrency such as bitcoin).
- Social engineering: In the context of cyber-security, this refers to an effort to psychologically manipulate a person, especially through misrepresentation or deception (as in a con game), to gain access to information. The manipulation often relies on the trusting nature of most individuals or makes use of many persons' natural reluctance to offend others or to appear too mistrustful. The ruse may involve creating impressions that make things appear more benevolent, trustworthy, and reliable than they actually are. Some schemes are very complex and involve several stages of manipulation over a substantial period of time.
- Spear phishing: A form of phishing that targets a specific individual, company, or agency, usually relying on an accumulation of information to make subsequent ruses more effective when further probing the target, until a successful security breach finally becomes possible.
- Spoofing: (1) Attempting to gain access to a system by posing as an authorized user. Synonymous with impersonating, masquerading, or mimicking. (2) Attempting to fool a network user into believing that a particular site was reached, when actually the user has been led to access a false site that has been designed to appear authentic, usually for the purpose of gaining valuable information, tricking the user into downloading harmful software, or providing funds to the fraudsters.
- Spyware: Software that allows others to gain private information about a user, without that person's knowledge or consent, such as passwords, credit card numbers, social security numbers, or account information.
- Trojan (or Trojan Horse): A program that, although neither replicating nor copying itself, performs some illicit activity when it is run. It stays in the computer doing its damage or allows somebody from a remote site to take control of the computer.
- Virus: A program or code that attaches itself to a legitimate, executable program, and then reproduces itself when that program is run.
- Worm: A self-contained program (or set of programs) that is able to spread copies of itself to other computer systems—usually through network connections or e-mail attachments

DRAFT

Location

Cyber-attacks are not constrained by geography. Government or private IT nodes, servers, and databases that store personal or sensitive information, especially those with financial, critical infrastructure, or healthcare information, may be more likely to be targeted for a cyber-attack.

Previous Occurrences

According to city officials, the majority of cybersecurity incidents in Ann Arbor are vendor related, in which a third-party vendor serving the city experiences a breach. Officials also noted occasional phishing schemes and past ransomware breaches. These instances were reported and stopped promptly, with no significant impacts. No incidents impacting vital infrastructure (e.g., dams, drinking water, wastewater, electricity) have been reported in Ann Arbor.

In addition to incidents impacting the city, according to the 2018 University of Michigan hazard mitigation plan, the University experienced a data breach in 2012. Further, the Michigan Department of Technology, Management, and Budget (DTMB) reports over 5 million intrusion attempts annually within state government.[cvi] The Michigan Cyber Command Center (MC3) has led the investigation of several cyber incidents, resulting in at least 13 criminal prosecutions.[cvii] Nationally, Michigan ranked eighth for most internet crime losses in the U.S. in 2021, with over $181 million in losses.[cviii]

Extent

The severity of cyber-attacks can be measured in terms of records breached or data compromised. The 2012 University of Michigan data breach was the most severe local event. Although this event did not impact the city's system, such an attack could happen to the city. It should be noted that cyber-attacks affecting more individuals are possible, as are those with the potential to compromise infrastructure and public safety.

Probability of Future Occurrences

The probability of cyber-attacks is difficult to predict, as trends show increasing instances of cybercrime, and the success of attacks in highly dependent upon controls in place and hackers' ability to overcome such controls. The FBI's 2021 Internet Crime Report shows a continued increase in the number of cybercrime complaints and losses over the last five years, with an average of 552,000 complaints per year.[cix] Considering the various controls the city has in place to reduce the likelihood of a successful cyber-attack, along with the upward trend in cyber-attacks and the potential for attacks that have not yet been discovered or reported, the probability of a successful cyber-attack on the City of Ann Arbor was assigned as likely (10 to 90 percent annual chance).

DRAFT

Vulnerability Assessment

All current and future buildings, infrastructure, and populations are potentially at risk, directly and indirectly, to cyber-attacks. Government, healthcare, and higher education facilities are especially vulnerable to cyber-attacks due to the large number of users on personal devices and use of open networks. Cyber-attacks can occur on an individual- (i.e., viruses and malware) or large-scale basis (i.e., hacking of university databases, taking control of facilities).

Damage to Buildings. Any software used for building or facility access control, or automated messaging may be at risk to cyber-attacks. Additionally, databases containing sensitive personal information, such as those associated with financial or healthcare industries, as well as servers storing, or backing-up valuable or confidential personal data are vulnerable to cyber-attacks.

Damage to Infrastructure. Infrastructure, including critical assets, have the potential to be targeted for cyber-attacks, with the aim of harming life and property or causing disruptions to critical community lifeline systems. Cyber-attacks may be designed to cause physical damage to property (and population impacts) stemming from losing control of software associated with the city's critical infrastructure. There have been documented instances on cyber-attacks on community water systems, in which adversaries have illegally monitored activity and even attempted to block or tamper with operations. For example, in 2021, hackers remotely accessed the water treatment facility in Pinellas County, FL, and changed the chemical levels of the water, in a failed attempt to make the water unsafe to drink.[cx]

Cyber-attacks may also be executed with the intention of financial gain. A March 2018 cyber-attack on Atlanta's computer networks impacted the municipal courts and online services, such as payment systems used for traffic violations and water bills. The attackers, later determined to be two Iranian citizens, were demanding $51,000 in Bitcoin as a ransom payment to unlock the computer system. The city did not cooperate with the attackers, which typical in these situations; however, recovery efforts over the next year ended up costing upwards of $17 million. Other ransomware attacks have occurred in Baltimore (MD), St. Lucie (FL), New Bedford (MA), and New Orleans (LA).[cxi]

Life Safety, Health, and Warning and Evacuation Procedures. A potential cyber-attack could have the ability to impact life safety and warning procedures within Ann Arbor. A successful cyber-attack on the power grid, water treatment and delivery system, or dam network could have substantial life safety implications. In addition, a cyber-attack on police or fire, or on the city's siren warning system, could increase risk to life safety during an incident in which these services are needed.

Public Health. Direct impacts to public health from cyber-attacks are not anticipated. However, cyber-attacks that affect public water supplies, transportation, fuel supplies, or medical facilities have the potential to impede individuals' access essential items, such as food, water, and medicine. For instance, a cyber-attack on the city's water system could introduce high levels of chemicals into the public drinking water system or reduce chemical levels in a manner that allows bacteria to thrive within finished water.

Impacts to Socially Vulnerable Populations. Certain populations have the potential to be disproportionately impacted by cyber-attacks relative to the general population. For example, the elderly may be more likely to be impacted by cyber-attacks on

DRAFT

individuals, as the highest losses from internet crime were reported by individuals over 60 years old, accounting for almost a quarter of total losses nationally.cxii Further, households or individuals struggling financially may be unable to purchase protective services (such as credit monitoring) after experiencing a breach or to access services to counter a breach.

Economic Impact. Cyber-attacks have the potential to cause direct and indirect economic impacts. The city may incur significant expenses in the wake of a cyber-attack (e.g., paying ransomware requests, lawsuits, paying for monitoring services in the event sensitive personal information is compromised). In addition, cybercrime prevention measures (e.g., staff training, testing, monitoring, and third-party services) can be costly. According to the FBI, the economic impact of cyber-attacks is increasing; total losses from internet crimes have increased annually for the last five years, growing from $1.4 billion in 2017 to $6.9 billion in 2021. A data breach typically cost a U.S. company nearly $8 million.[cxiii]

Climate Change Impacts. Impacts to the cyber-attacks hazard from climate change are not anticipated.

Public Health Emergencies

Description

Public health risks, such as those presented by infectious diseases, vector-borne illnesses, water-borne illnesses, and chronic diseases, are present within every community. They include commonly occurring illnesses like the common cold and influenza, as well as less common inflictions such as bacteria-caused Escherichia coli ("E. coli") and mosquito-transmitted Zika virus.

The degree to which communities are susceptible to or actively experiencing public health issues can impact a community's vulnerability to natural hazards, as well as its ability to respond to disasters. For instance, an infectious disease outbreak may complicate evacuations or/and mass sheltering required due to a natural hazard. Similarly, high incidents of chronic diseases may decrease mobility within a community, and natural disasters may reduce access to vital healthcare services needed by the ill.

History reveals that in the absence of information about a public threat, treatments, and vaccines, infectious diseases can be extremely deadly. For example, the 14th-century bubonic plague killed about 50 million people in Europe at a time well before modern medicine or an understanding of contagion existed. The plague did not submit for nearly 10 years, and even then, continued to reemerge every decade or so for nearly 400 years.[cxiv] The plague was largely managed through trial and error and ultimately controlled through quarantine measures, the first use of it in history. Tuberculous is considered the world's deadliest infectious disease today despite available vaccines and treatments. Although it is nearly eliminated from the U.S., less developed areas of the world such as Southeast Asia and Africa see high infection rates and have limited capacity to manage the disease.

While major outbreaks are uncommon, public health emergencies can become stand-alone disasters that compound the threat of other natural hazards and exceed local and state capacity. There is precedent for federal assistance due to public health emergencies including West Nile Virus (2000), a mosquito-borne disease, for which a federal emergency declaration was made in

DRAFT

New York and New Jersey, and the COVID-19 pandemic, which resulted in a major disaster declaration in all states, territories, and the District of Columbia.[cxv]

Location

The entirety of Ann Arbor is considered to be uniformly exposed to public health risks. However, university settings are considered at a higher risk to certain public health risks, such as infectious illness outbreaks, as students live, learn, and socialize within close proximity to one another. Therefore, the University of Michigan Campus may be at a higher risk to public health risks than other parts of the city. While the University maintains its own hazard mitigation plan, public health emergencies initiating on campus can spread to the wider community.

Previous Occurrences

The city deals with a range of public health risks on a regular basis, and most are managed, but occasionally a disease outbreak becomes an emergency. The following presents a summary of previous occurrences of health risks in Ann Arbor, with notable outbreaks bolded:

- Aseptic Meningitis (Viral): Viral meningitis is the most common type of meningitis, and most people can get over the infection without treatment. However, those displaying symptoms should still see a doctor immediately to ensure the correct diagnosis and proper treatment can be prescribed. Babies younger than 1 month old or individuals with a weakened immune system are more likely to have severe illness from viral meningitis.[cxvi] Washtenaw County had 343 cases of aseptic meningitis between 2012 and 2021, with the most cases (60) being recorded in 2012.
- Campylobacter: Campylobacter is an infection commonly caused by eating raw or undercooked poultry or something that touched it. It can also be contracted from eating other foods, by contact with animals, or by drinking untreated water.[cxvii] Campylobacteriosis is the leading cause of bacterial diarrheal illness in the US and is the most identified cause of Guillan-Barré syndrome. Washtenaw County had 589 cases of campylobacter from 2012 to 2021.
- COVID-19: On March 27, 2020, a major disaster declaration was declared for the COVID-19 Pandemic response. The incident period began on January 20,2020 and is ongoing.[cxviii] The COVID-19 pandemic (caused by the novel coronavirus SARS-CoV-2S) has become the most significant disease threat of the modern era, with broad public health, social, and economic consequences. As of June 3, 2022, 74,435 cases of COVID-19 have been reported in Washtenaw County, with 496 deaths.[cxix] The COVID-19 pandemic has the potential to continue to some degree over the next several years and will likely become endemic (i.e., around but not causing significant disruptions). The COVID-19 vaccine, released in 2021, was instrumental in reducing the disease's severity and preventing spread.
- Hepatitis A Outbreaks: Hepatitis A is a foodborne illness that infects the liver. In 1997, 300 cases of hepatitis A were reported across four Michigan school districts and were traced back to frozen strawberries. In 2016, southeast Michigan experienced

DRAFT

a hepatitis A outbreak that is considered one of the largest in the country. As of February 2020, there were 920 cases reported with 30 deaths. No specific cause was traced.

- Hepatitis C: Hepatitis C is a liver infection cause by the hepatitis C virus. The disease is spread through contact with infected blood. Most people become infected with the virus by sharing needles or other equipment used for injecting drugs.[cxx] Washtenaw County has had 1,696 cases of hepatitis C from 2012 to 2021, with the most cases (224) being reported in 2017.[cxxi]
- Influenza (flu): Michigan experiences an average of 1,200 deaths per year from the flu. A normal flu season begins in November and ends in May. In November 2021, a flu outbreak at the University of Michigan saw 313 cases within one week, and a 37 percent rate of positive testing. The outbreak was considered severe enough that a team from the CDC was deployed to Ann Arbor.[cxxii]
- Lyme Disease: Washtenaw County is a confirmed area where Lyme disease can be transmitted. There were 169 cases of Lyme disease in Washtenaw County between 2012 and 2021, with the most cases (52) occurring in 2021.[cxxiii]
- Norovirus Outbreak of 2016: In February 2016, over 100 students contracted a norovirus on the University of Michigan campus within one week (*source: University of Michigan hazard mitigation plan)*.
- Pertussis (Whooping Cough): The Washtenaw County Health Department has noted that pertussis, or "whooping cough," continues to be diagnosed in the county. The disease is vaccine preventable, and it is recommended that all eligible persons receive the vaccination. It is highly recommended that infants receive the Tdap or another pertussis containing vaccine.[cxxiv] There were 681 cases of pertussis from 2012 to 2021, with the most cases (199) occurring in 2013.[cxxv]
- Rabies: Rabies is a viral disease that is usually spread from animal to animal but can also infect humans. The disease is typically transmitted to a human from an animal via a bite from the infected animal. In the last 15 years there have been 65 animals that tested positive for rabies in Washtenaw County.[cxxvi] Of those, all but 9 have been bats.
- Tuberculosis (TB): Washtenaw County has had 121 active TB cases in the last 16 years. The highest number of active cases in a year during that timeframe was 10 cases, which has occurred three times (2005, 2008, and 2016).[cxxvii]
- West Nile Virus: West Nile virus is transmitted by mosquitoes and can cause encephalitis (inflammation of the brain) and meningitis in humans. It was first detected in Michigan in 2001 and peaked in 2002 with 644 cases and 51 deaths. The virus is present throughout the state, including Ann Arbor.

Extent

The severity of public health risks is difficult to determine given the varying impacts associated with different events. COVID-19 has likely had the largest overall impact on Ann Arbor in recent history when considering number of cases, deaths, business disruptions, and societal impacts. However, more severe events are possible.

DRAFT

Probability of Future Occurrences

Probability of public health emergencies in Ann Arbor is variable, with a mix of chronic public health risks and acute outbreaks. Many public health risks occur seasonally and are ongoing, such as the common cold and influenza. Major outbreaks, such as the current COVID-19 pandemic, are less common. Based on the information available regarding historic or current events, and the risk posed to the city as a university community, this hazard was assigned a probability of likely (10 percent to 90 percent annual chance).

Vulnerability Assessment

All current and future populations and infrastructure in Ann Arbor are considered at risk to public health emergencies. The COVID-19 pandemic has shown the far-reaching impacts a public health emergency can have. In Ann Arbor, the COVID-19 pandemic resulted in illness and death. Business closures and a switch to online learning for the university have had long-term consequences on the local economy. As the severity of public health risks is difficult to determine given the varying impacts associated with different health risks. COVID-19 has likely had the largest overall impact on Ann Arbor in recent history when considering number of cases, deaths, and societal impacts. Potential impacts from public health emergencies are detailed below.

Damage to Buildings. Buildings are not typically impacted by health risks but may need to be sterilized or decontaminated in some cases. During outbreaks hospitals and healthcare facilities may be overwhelmed.

Damage to Infrastructure. Infrastructure is not typically impacted by health risks but may need to be sterilized or decontaminated in some cases.

Life Safety, Health, and Warning and Evacuation Procedures. Public health emergencies directly impact life safety through deaths or injuries stemming from disease outbreaks or substance abuse (e.g., overdoses). Health risks are unlikely to result in an evacuation, but may result in quarantining, stay-at-home orders, or social distancing measures. Warnings may be issued by the Ann Arbor Office of Emergency Management, the Washtenaw County Health Department, or the Michigan Department of Health regarding measures needed to combat health risks.

Infectious diseases, such as COVID-19, create added complexity to emergency response including evacuation, sheltering, and managing events from typically crowded Emergency Operations Centers (EOC). Ann Arbor has developed a virtual EOC to curb such issues. Public health emergencies may strain capacity of emergency personnel time and budgets to manage multiple disasters.

Public Health. Health risks have direct impacts on public health through the spread of infectious diseases or rise in substance abuse. Health risks often require action from local, state, and federal public health agencies to curb the spread of disease, prevent substance abuse, or treat affected individuals. Major outbreaks may overwhelm local healthcare capabilities.

DRAFT

Impacts to Socially Vulnerable Populations. Socially vulnerable populations may experience the impacts of public health risks at higher levels compared to less vulnerable populations. The elderly and immunocompromised may be more susceptible to contracted diseases, and may experience disproportionate impacts in terms of illness, missed work or school, required isolation, and/or medical costs. Economically stressed households, such as those living below the poverty line, may have troubling paying for preventative measures and medical care or taking needed time off to recover from an illness. Those who are mobility impaired or living in isolated areas without access to transportation may have issues accessing medical supplies, equipment, or care. Further, those living in crowded households may have difficulty quarantining when a member of the household is ill, leading to an increased likelihood or spreading disease. Single-parent households may face increased challenges with childcare during a public health emergency, for instance if daycares or schools are closed.

Economic Impact. Public health emergencies can have devasting economic impacts. Localized disease outbreaks may impact tourism, both through direct business interruptions and through the perceived danger of visiting the city. Or, in the case of a global pandemic such as COVID-19, mandatory closures and stay at home orders cause business interruptions, school closures, lost tourism and lay-offs. Further, the city may lose revenues from sales and hospitality taxes, while at the same time having to increase spending and divert resources to managing the spread of disease.

Climate Change Impacts. Increases in temperature, precipitation, and humidity all have impacts on public health. The impacts are dependent on each type of public health risk. For instance, warmer and wetter conditions create a more favorable environment for the growth and spread of some vector-borne infectious diseases, such as mosquito-borne viruses. Insects also have a limited range of temperatures where they can live, which may bring new insects to the area or lead to the decline of others. Conversely, warmer and more humid weather generally weakens the spread of certain respiratory illnesses, such as influenza. Changing climate conditions may also lead to virus mutations and adaptation leading to a rise in emerging diseases.[cxxviii] It will also shift habitats for wildlife and livestock, which may bring animals, and their diseases, closer to humans. Beyond disease, more extreme heat days and more precipitation may also deter people from outdoor exercise which may increase NCDs, such as diabetes.

Terrorism and Similar Criminal Activities

Description

Terrorism and similar criminal activities are categorized as non-natural and human-caused hazards.

Terrorism is the use of violence to achieve political goals by creating fear. Terrorism can be distinguished from other violent crimes because it is politically motivated. Terrorism is carried out for a cause and is not used for the sole purpose of financial gain, personal revenge, or a desire for fame. While terrorist acts can be carried out by individuals, terrorists generally work in groups or networks. Terrorism is practiced by many different groups worldwide. The United States is threated by international terrorist groups, such as the Islamic State (ISIS), and by domestic or "home-grown" terrorist groups, such as groups using violence to advance racist, ecological,

DRAFT

anti-abortion, and anti-government causes. Terrorists often seek the greatest amount of media exposure, as the goal of terrorists is to frighten as many people as possible rather than to inflict the greatest amount of damage possible, and media exposure allows terrorists to reach more people than those who are directly involved in an attack.

Non-Terrorist Criminal Activities may resemble terrorist attacks but lack a political motive. These do not include routine crimes committed daily, but rather crimes that impact a large number of people. Such attacks may require resources beyond those available at the local level. Non-Terrorist Criminal Activities may be motivated by mental illness, financial gain, a desire for fame or revenge, or a combination of the above. Non-terrorist criminal activities can be committed by groups but are often carried out by a single criminal. The range of motives and lack of a formal network that characterizes many non-terrorist criminal activities makes them difficult to predict. Universities and colleges may be more likely to be targeted by terrorists and criminals than other types of institutions.[cxxix]

Below is a non-comprehensive list of crimes that may be perpetrated by terrorists or criminals carrying out similar activities, especially on a university campus:

- Arson/use of incendiaries: arson is the act of deliberately setting fire to property. Incendiaries are used to start fires. This tactic is typically used to harm property rather than to directly injure people and is therefore popular with animal rights terrorists or ecological terrorists looking to minimize casualties.
- Bomb threat: a bomb threat is a threat, communicated by telephone, electronically, verbally, or in writing, to detonate an explosive device to cause property damage or casualties whether or not such a device exists. Bomb threats can occur annually at schools and universities can require the evacuation of the threatened building or area.
- Chemical/biological weapons: chemical weapons involve the use of poisonous materials, usually toxic gases. The impacts of a chemical attack are similar to those from a hazardous materials incident. Chemical attacks are rare in practice. Biological weapons involve the intentional release of disease organisms to cause illness and death. Biological agents can be released into air, food, or potable water sources. Biological weapons can also be used to contaminate crops or livestock, resulting in economic damages. It may be difficult to distinguish a biological weapons attack from a naturally occurring disease outbreak, as impacts may be similar. Therefore, biological weapons are not popular amongst terrorists looking to advance political motives. Further, deadly biological agents such as smallpox or anthrax are difficult to obtain, transport, and control. Therefore, use of biological weapons is considered rare.
- Cyber-attack (covered separately, see profile).
- Explosions: explosives are the most common tool used by terrorists to carry out attacks. Commercial explosives, such as those used by mines, farms, and businesses can be easily obtained; alternatively, explosive devices can be built at home with commonly purchased materials. Explosive devices can be delivered to a site in a wide variety of ways, including car bombs, suicide vests, and packages left in an area or sent by mail. One especially detrimental tactic

DRAFT

used by terrorists is a secondary device, in which a second explosive is detonated after emergency personnel and bystanders have gathered at the site of an initial explosion.

One notable incident involving an explosive device is the Northwest Airlines Flight 253 Bombing Attempt (2009) On Christmas Day 2009. A terrorist with ties to al-Qaeda attempted to destroy Northwest Airlines Flight 253 as it approached Detroit Metropolitan Airport. The terrorist had concealed an explosive device in his underwear that failed to properly detonate. This attack demonstrates the potential effectiveness of even small bombs when used against vulnerable targets such as aircraft. It also demonstrates that international terrorism may be directed at targets in Michigan.

- Infrastructure sabotage: deliberate harm to or destruction of infrastructure can have wide-spanning consequences. Basic functionality of everyday systems and processes are dependent upon critical infrastructure such as highways, rail systems, airports, dams, bridges, power plants, and network communications systems. Further, these systems are often interconnected, meaning the failure of one can impact the ability of another to serve its purpose. Infrastructure sabotage is the deliberate act of targeting critical infrastructure. Infrastructure sabotage can result in significant economic damages (both physical and those stemming from disruption) and well as deaths and injuries.
- Mass shooting/active shooter: Shooting attacks are popular among both terrorists and criminals, and usually involve the use of firearms to target a crowded area and/or a specific individual or group of individuals. Firearms such as rifles, pistols, and shotguns, including semi-automatic weapons with high magazine capacities, are easily available in the United States. Schools, universities, and workplaces are common places for mass shootings to occur, as are crowded venues with limited options for evacuation, such as theaters, auditoriums, and concert venues.
    - Although there is no universal definition for a mass shooting, the Congressional Research Service defines a mass shooting as one in which the gunman:
    - Kills four or more people;
    - Selects victims randomly (rules out gang-related shooting and domestic violence)
    - Attack occurs in a public place

Mass shooting incidents have risen exponentially in the United States in recent decades. From 1916 to 1966, 25 mass shootings were recorded, compared with over 150 mass shootings in the next 51 years (including some of the deadliest shootings recorded).[cxxx] Data from the FBI, released in 2018, found that even since 2000, mass shootings in the U.S. had risen exponentially, from 6.4 shootings annually between 2000 and 2006 to 22.1 shootings annually from 2012 to 2018.[cxxxi] Figure 4-54 shows the magnitude and frequency of mass shooting occurrences in the U.S. since 1966.

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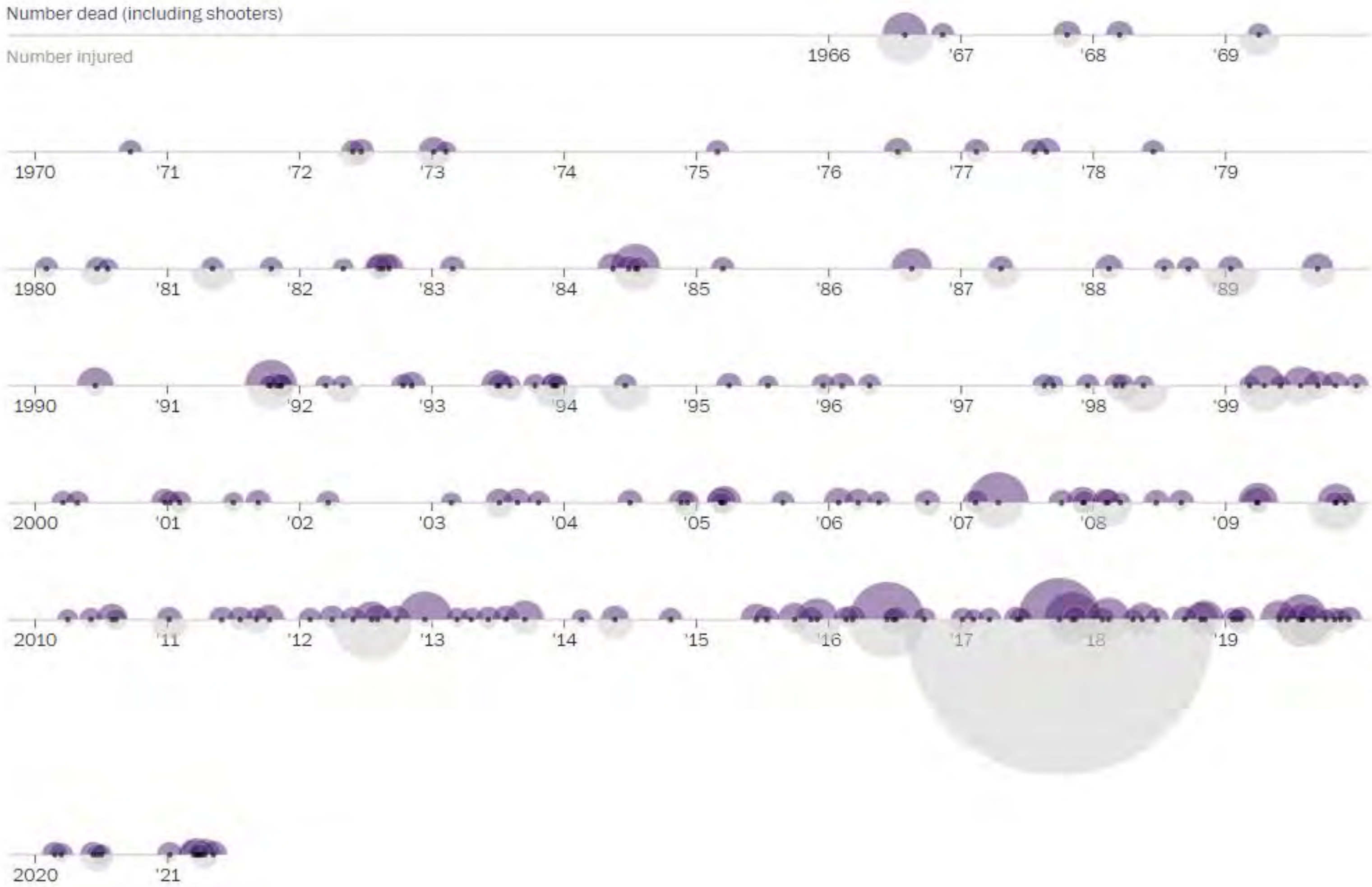

Figure 4-54: Mass Shootings in the U.S. Since 1966

- Radiological Weapons: Radiological weapons, sometimes referenced to as radiological dispersal devices or "dirty bombs," are weapons designed to spread hazardous radiological materials. These devices no not create a nuclear explosion, but rather expose victims to radiation. Hospitals, food-processing centers, and research facilities possess radiological materials and may be targeted by terrorists looking to create a radiological weapon. There are no records of a radiological weapon being used in an attack but plans for radiological devices have been found in the possession of foreign and domestic terrorists.

- Special Event Disruption: special event disruptions can include one or more of the other criminal activities described here, such as a vehicle ramming or detonation of an explosive device but require special consideration and planning as they involve a large number of people coming together for a specific reason (e.g., a sporting event, concert, parade, graduation ceremony). Special events draw above average crowds of people, often concentrated into a small area, making them especially vulnerable to a terrorist attack or similar criminal activity. Further, during such an attack there is potential for injuries or deaths due to trampling while people rush to evacuate the venue.

  One such example of a special event disruption is the 2016 Bastille Day attack in Nice, France. During the attack, a driver drove a lorry into a crowd watching a fireworks display, killing 86 people, and injuring 303.[cv]

  Vehicle-born attack/vehicle ramming: like the event described above, a vehicle-born attack is characterized by a terrorist or criminal using a vehicle as a weapon, typically by driving it into a crowd of people. Another example of a vehicle-born attack was an attack at the University of Virginia in 2017, in which a driver drove a car into a crowd of counter-protesters, killing a woman.

Location

All of Ann Arbor is considered at-risk to terrorism and similar criminal activities. However, urban areas, particularly those including public meeting spaces, government buildings, or areas near or on the University of Michigan campus and its stadium, are considered at a higher risk. Local schools and other education institutions have the potential to be targeted for terrorist or criminal acts. Of the 277 active shooter incidents in the U.S. from 2000 to 2018, over 20 percent took place at an education facility (pre-kindergarten to twelfth grade schools and institutions of higher education).

Previous Occurrences

There are no historic occurrences of terrorism or similar criminal activities in Ann Arbor. Although there is no history of these incidents in Ann Arbor, future events are possible. One incident, noted in the UM hazard mitigation plan, describes when the Michigan State Police Bomb Squad was called in to investigate a package left on South State Street, which was as found to not be a threat.

Mass shootings (defined as four or more individuals, not including the shooter, were killed) in Michigan have risen since 2018. Figure 4-55 shows the number of mass shootings in Michigan since 2014. On November 30, 2021, there was a mass shooting at Oxford High School, located approximately 45 miles away from Ann Arbor. Four victims were killed, and seven others were injured during the shooting.[cxxxii]

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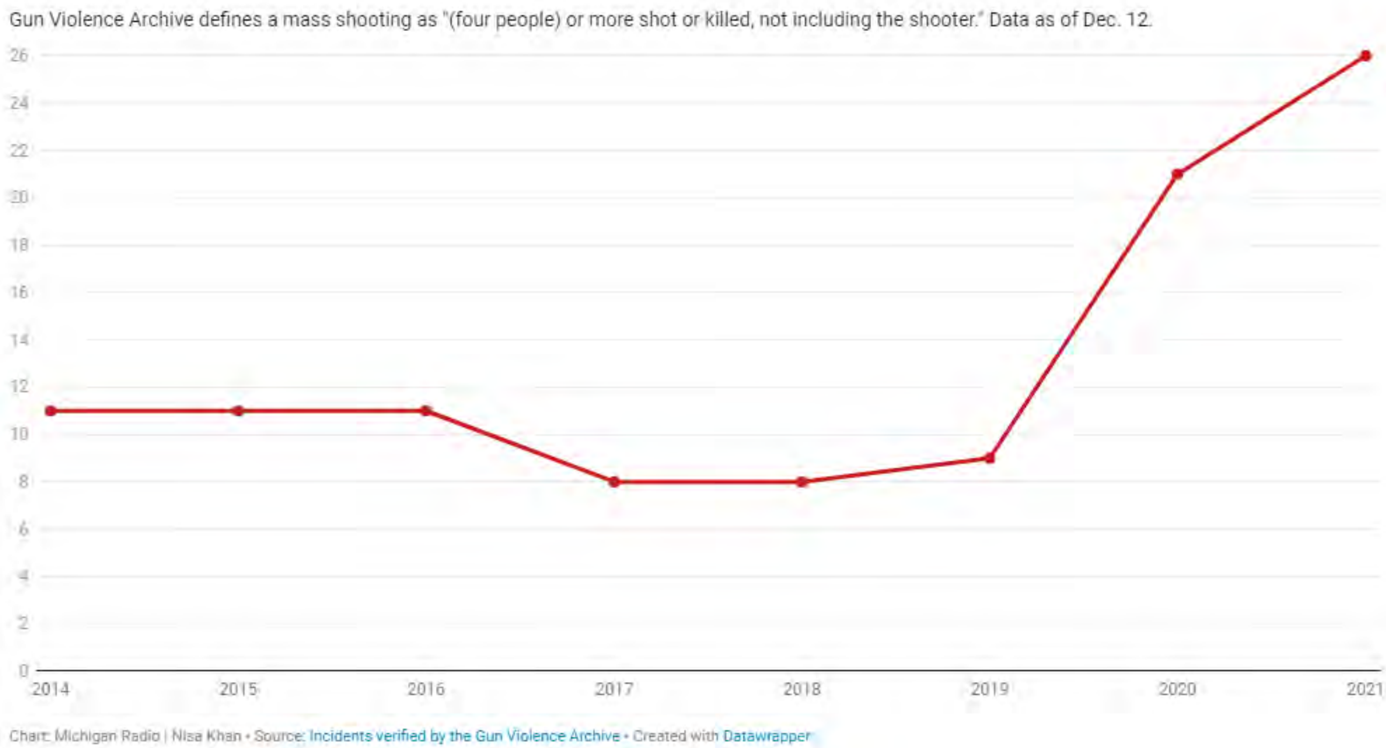

Figure 4-55: Mass Shootings in Michigan since 2014

Extent

The extent of terrorism or similar criminal activities is difficult to measure with limited data regarding previous occurrences. These events can be measured in terms of injuries, deaths, or property damage. Although there are no historic occurrences reported for Ann Arbor, a large-scale, devastating event is possible.

Probability of Future Occurrences

Although Ann Arbor has not experienced a large-scale event, data shows an upward trend in terrorism/criminal activity occurrences. Given the lack of historic events in Ann Arbor along with national trends, the probability assigned for terrorism and similar criminal activities is unlikely (less than 1 percent annual chance).

Vulnerability Assessment

If an incidence of terrorism or a similar criminal activity were to occur, the impacts could be devastating. All current and future buildings, infrastructure, and populations are considered at risk to terrorism and similar criminal activities. Potential impacts specific to buildings, infrastructure, life safety, public heath, socially vulnerable populations, the economy, and climate change are described below.

Damage to Buildings. All current and future buildings are considered at-risk to terrorism and similar criminal activities. Damages to buildings could result from fire, smoke, vandalism, or explosions related to terrorist activities. Certain facilities, such as schools, hospitals, large venues, and government buildings have an elevated risk to be targeted for terrorist and criminal activities given larger concentrations of people. Institutions that could be viewed as potentially controversial, such as research facilities, abortion clinics, or places of worship, may have increased likelihood of an event.

Damage to Infrastructure. All infrastructure is considered at-risk to terrorism and similar criminal activities. Key infrastructure, such as roads, bridges, dams, water/water treatment systems, electrical substations, and computer networks have the potential to be targeted for terrorist and criminal activities.

Life Safety, Health, and Warning and Evacuation Procedures. Terrorism and similar criminal activities can have severe impacts on life safety. All current and future populations are considered at risk to terrorism. Physical harm to participants, bystanders, and responders is possible and often the intention of such activities. Dangers resulting from gunfire, explosions, fire, smoke inhalation, chemical weapons, and moving vehicles (such as car, trucks, or aircraft) is possible. Terrorism and similar activities may result in the need to evacuate a building, structure, or public space. Lockdowns, or sheltering-in-place, may also be necessary when safe evacuation is not possible.

In the event of a national or imminent threat alert from the Department of Homeland Security, the city's siren warning system will activate. The warning system consists of 22 sirens providing coverage for the entire city as demonstrated in Figure 4-12 under this profile's equivalent in the Severe Winds profile.

Public Health. Public health has the potential to be impacted by terrorism. If biological weapons are used, a large number of people or livestock could be infected with a bacterium, virus, or parasite. Contamination of the food and/or water supply is possible. An intentional spread of an infectious disease may be difficult to control.

In addition, a terrorist or similar activity could have community-wide impacts to mental health in the aftermath of a devastating event.

Impacts to Socially Vulnerable Populations. Additionally, terrorism and similar criminal activities have the potential to be targeted at socially vulnerable populations. Nationally, events have targeted specific races, classes, or genders. For example, a mass

DRAFT

shooting, which resulted in 10 fatalities and 3 injured, on May 14, 2022, in Buffalo, NY was racially motivated, and the location was chosen by the shooter because it was in a predominantly Black community.[cxxxiii]

Furthermore, socially vulnerable populations may lack trust or confidence in law enforcement and may be reluctant to call for help. Community members who have experienced police discrimination or brutality are less likely to rely on law enforcement for protection. For example, a 2016 study examining the impact of the highly publicized beating of an unarmed Black man in Milwaukee, WI, by police found that there was a dramatic drop in the number of 911 calls received the following year.[cxxxiv]

Economic Impact. Terrorism and similar criminal activities has the potential to impact major economic impacts. Damages to buildings and infrastructure have the potential to disrupt business operations for extended periods of time. In addition, entities that rely on tourism or enrollment could see numbers decline significantly in the wake of such an event.

Climate Change Impacts. As mentioned in the *Civil Disturbances* hazard profile, given the political nature of climate change policy, it is possible that civil disturbances may occur as a result of policy changes, new information, or general activism.

Summary of Overall Vulnerability

This section summarizes overall vulnerability by looking at several measures including the priority risk index, ranking of hazards, key areas of vulnerability, and key points on vulnerability. A brief summary of the hazards that impact the City of Ann Arbor is provided below. The table lists impacts, number of occurrences and associated timeframe, spatial extent, probability, and estimated losses to date. The impacts of potential climate migration on Ann Arbor are also described in this section.

Priority Risk Index Results

The PRI results are presented in the following table by the order they are presented in the plan (Table 4-44). This information was used to rank hazards.

DRAFT

Table 4-44: PRI Results

Summary of PRI Results for Ann Arbor						
Hazard	Category/Degree of Risk					
	Probability	Impact	Spatial Extent	Warning Time	Duration	PRI Score
Extreme Cold/Wind Chill	Highly Likely	Critical	Large	More than 24 Hours	Less than one week	3.3
Extreme Heat	Highly Likely	Critical	Large	More than 24 Hours	Less than one week	3.3
Fog	Highly Likely	Minor	Small	Less than 6 Hours	Less than 6 hours	2.4
Hail	Likely	Limited	Moderate	Less than 6 Hours	Less than 6 hours	2.6
Lightning	Highly Likely	Critical	Negligible	Less than 6 Hours	Less than 6 hours	2.8
Severe Winter Weather	Highly Likely	Critical	Large	More than 24 Hours	Less than one week	3.3
Severe Wind	Highly Likely	Catastrophic	Moderate	12 to 24 Hours	Less than 24 hours	3.5
Tornado	Possible	Catastrophic	Small	Less than 6 Hours	Less than 6 hours	2.7
Dam Failure	Unlikely	Catastrophic	Moderate	More than 24 Hours	Less than 24 hours	2.4
Drought	Highly Likely	Minor	Large	More than 24 Hours	More than one week	2.6
Flood (including Extreme Precipitation)	Likely	Critical	Moderate	Less than 6 hours	Less than one week	3.1
Invasive Species	Highly Likely	Minor	Large	More than 24 Hours	More than one week	2.6
Earthquake	Unlikely	Limited	Moderate	Less than 6 Hours	Less than 6 hours	2.0
Hazardous Materials Incident	Likely	Limited	Small	Less than 6 Hours	Less than 24 hours	2.5
Nuclear Power Plant	Unlikely	Minor	Large	More than 24 Hours	More than one week	1.9

DRAFT

Summary of PRI Results for Ann Arbor						
Hazard	Category/Degree of Risk					
	Probability	Impact	Spatial Extent	Warning Time	Duration	PRI Score
Petroleum and Natural Gas Pipeline Accidents	Unlikely	Limited	Small	Less than 6 Hours	Less than 24 hours	1.9
Power Outages	Likely	Critical	Moderate	Less than 6 Hours	Less than one week	3.1
Structure Fire	Highly Likely	Limited	Negligible	Less than 6 Hours	Less than 6 hours	2.5
Water Contamination	Likely	Limited	Moderate	Less than 25 hours	Less than one week	2.6
Civil Disturbances	Possible	Limited	Small	6 to 12 hours	Less than 24 hours	2.1
Cyber-attacks	Likely	Limited	Small	Less than 6 hours	More than one week	2.7
Public Health Emergencies	Likely	Critical	Small	More than 24 hours	More than one week	2.7
Terrorism and Similar Criminal Activities	Unlikely	Critical	Moderate	Less than 6 Hours	Less than 24 hours	2.4

Hazard Ranking

Hazards were ranked based on PRI results and knowledge of the area. The rankings were reviewed and confirmed by the TAC. Rankings within each category (high, moderate, or low) are presented in alphabetical order in Table 4-45.

DRAFT

Table 4-45: Hazard Ranking Results

Ranking	Hazard
HIGH	Extreme Cold/Wind Chill Extreme Heat Flood (including Extreme Precipitation) Power Outages Severe Wind Severe Winter Weather
MODERATE	Civil Disturbances Cyber-attacks Dam Failure Hazardous Materials Incident Lightning Public Health Emergencies Structure Fire Terrorism and Similar Criminal Activities Tornado Water Contamination
LOW	Drought Earthquake Fog Hail Invasive Species Nuclear Power Plant Petroleum and Natural Gas Pipeline Accidents

Key Areas of Vulnerability

Key areas of vulnerability were identified to show areas where at risk buildings are clustered (especially those in multiple hazard areas), and/or where high concentrations of at-risk properties are located in census tracts identified as having low access to opportunity or relatively high/moderate social vulnerability according to the NRI. Information from the TAC and city officials was also used in determining key areas of vulnerability. The following areas have been identified, along with descriptions of why each

DRAFT

area was selected, provided below. These areas are shown in

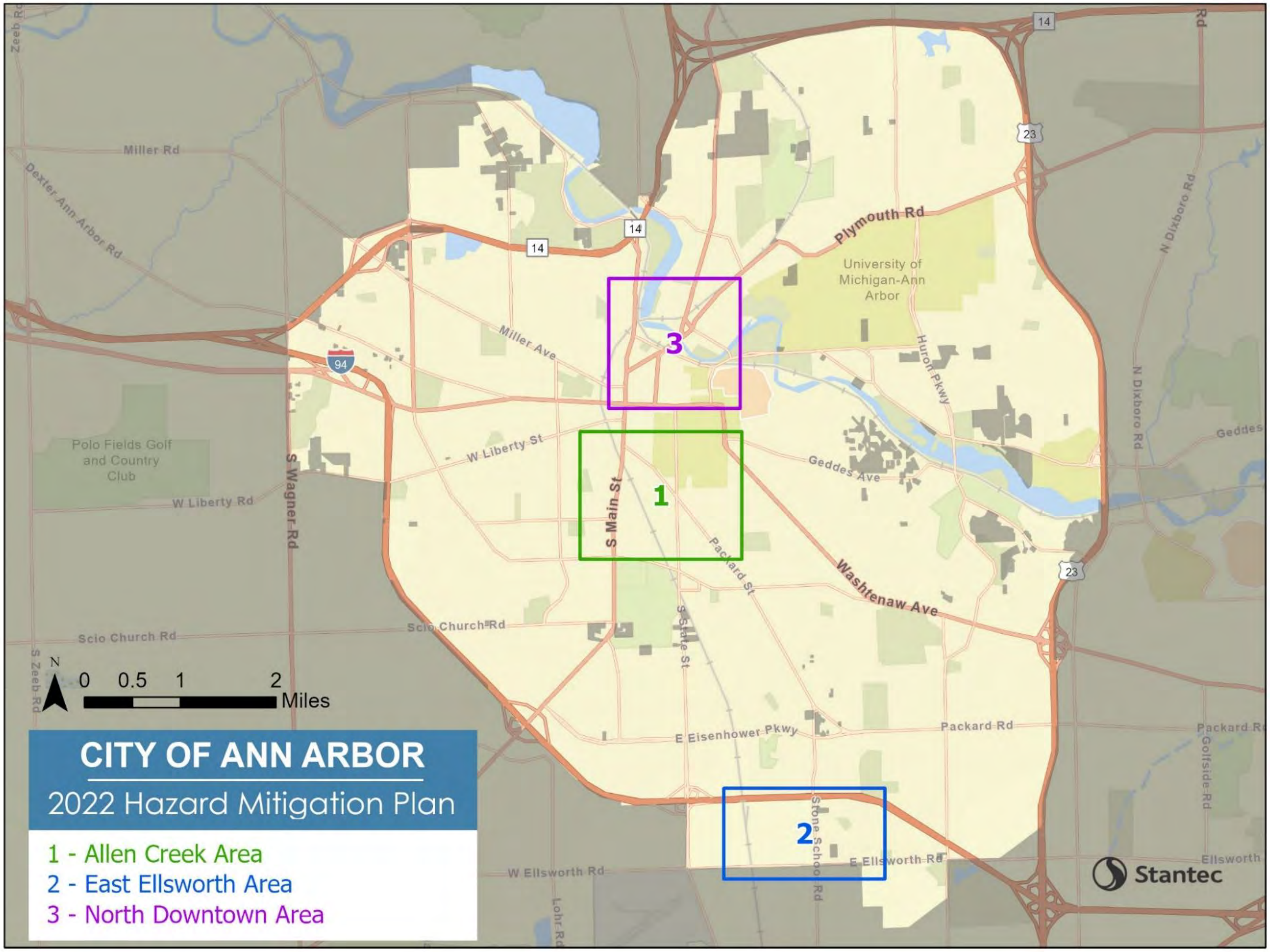

Figure 4-56.

The Allen Creek area east of Main Street and west of Packard

- High concentration of buildings in flood hazard areas (FEMA and local/InfoSWMM);
- Area of low access to opportunity (Washtenaw County Opportunity Index); and,
- Several storm peak stage recorders located in this area, indicating flooding during extreme rain events.

This area is shown in Figure 4-57 below.

Area south of I-94 and north of East Ellsworth Road

- Adjacent to railroad track and major highway (vulnerability to hazardous materials incidents);
- Area of relatively moderate social vulnerability (NRI);
- Area of low access to opportunity (Washtenaw County Opportunity Index);
- Within both FEMA and local (InfoSWMM) 1.0 percent annual chance flood areas;
- Within or partially within TRI primary buffer area;

This area is shown in Figure 4-58 below.

Area North of Downtown (southeast of Plymouth Road and north of Fuller Street and area east of North Main and Northeast of Beakes Street)

- Adjacent to/bounded by railroad tracks (vulnerability to hazardous materials incidents);
- Within Barton Dam failure inundation area;
- High concentration of buildings in flood hazard areas (FEMA and local/InfoWMM);
- Partially within/adjacent to area with low access to opportunity (Washtenaw County Opportunity Index).

This area is shown in Figure 4-59 below.

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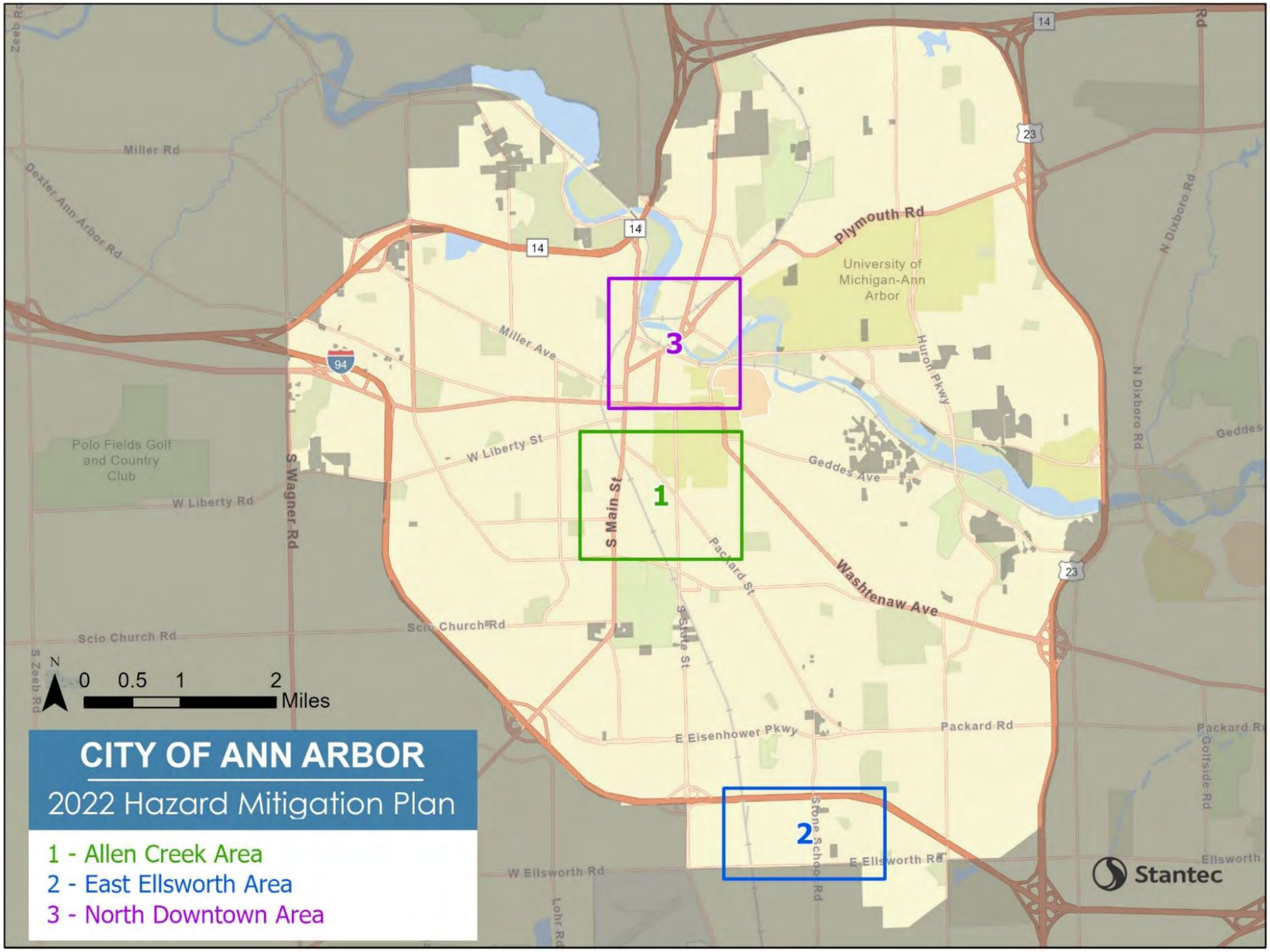

Figure 4-56: Key Areas of Vulnerability in Ann Arbor

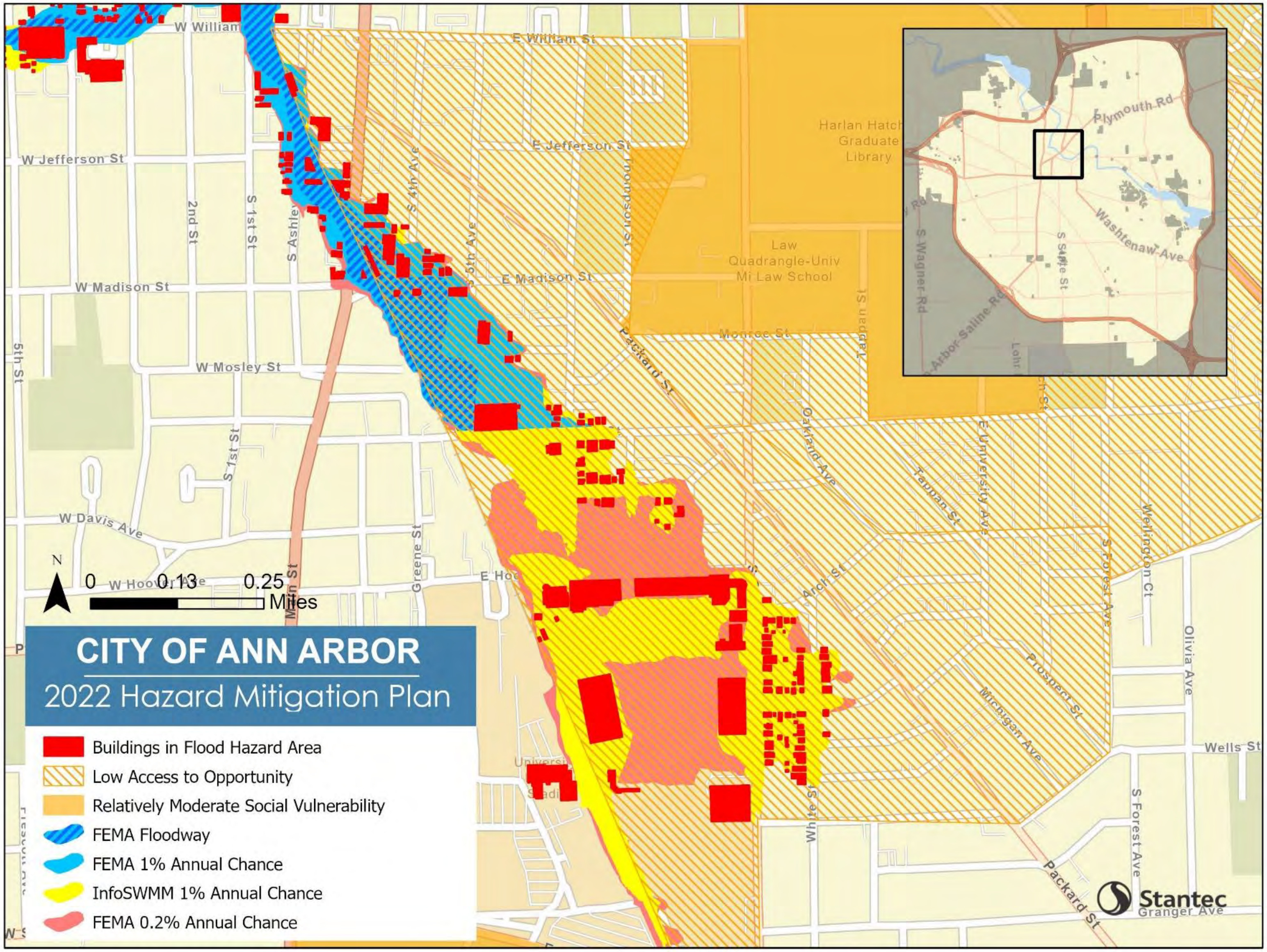

Figure 4-57: Allen Creek Area of Key Vulnerability

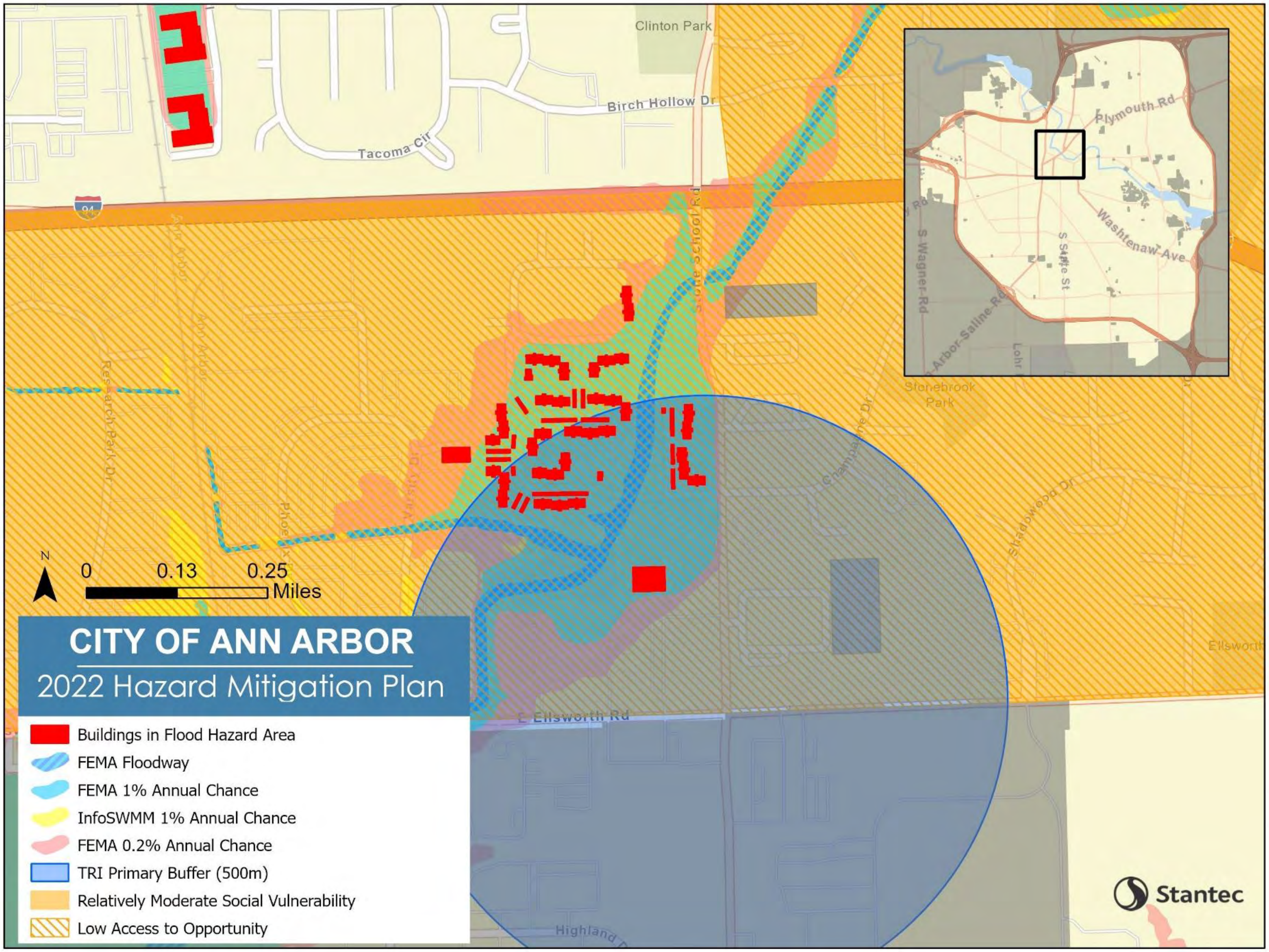

Figure 4-58: East Ellsworth Road Area of Key Vulnerability

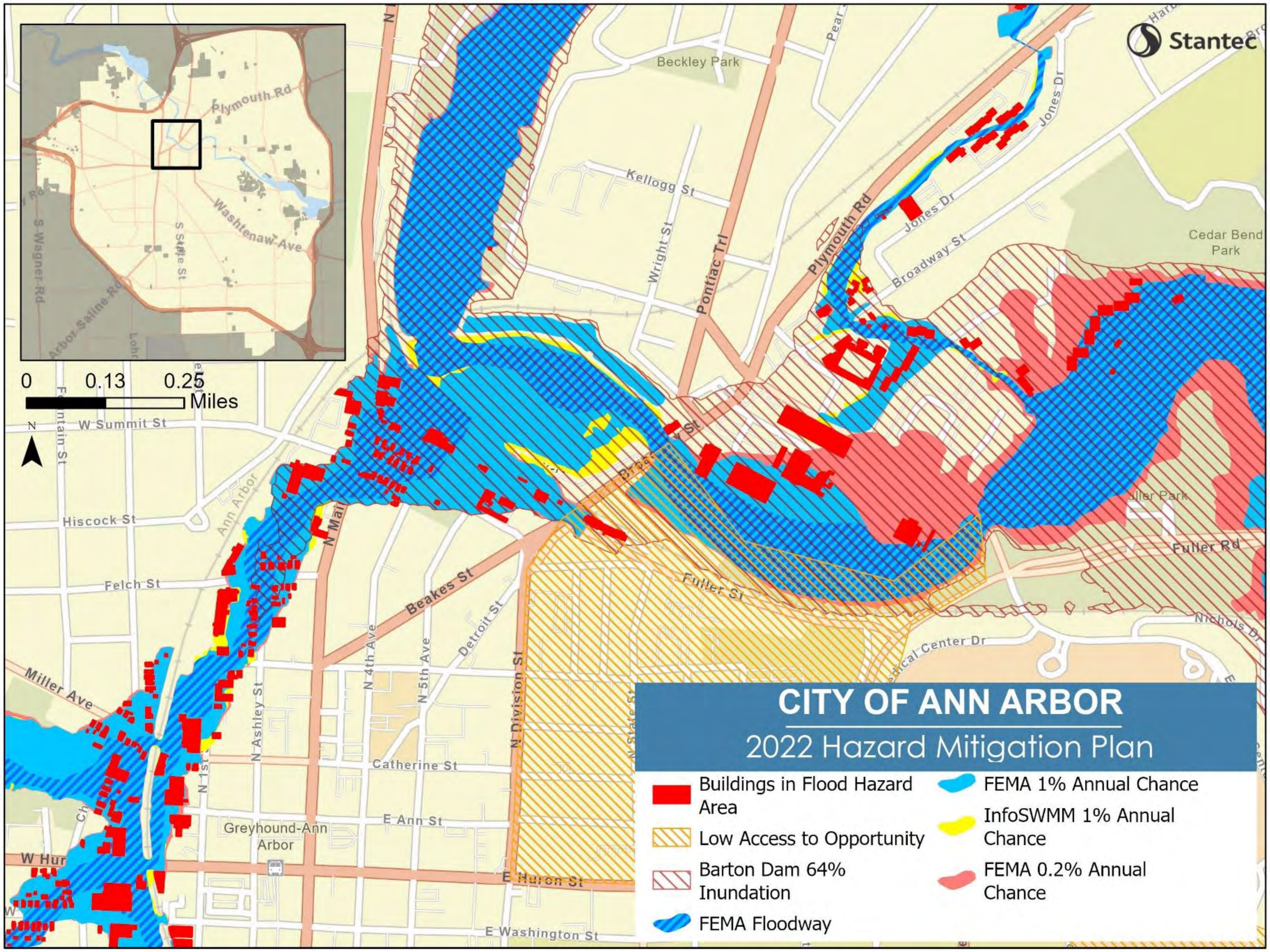

Figure 4-59: North of Downtown Area of Key Vulnerability

Key Points on Vulnerability

In summary, all of the hazards addressed in this plan pose a threat to the City of Ann Arbor, including the assets and population within. There are several factors that influence vulnerability including building construction type, date of construction, social factors, time of occurrence, and capacity to respond, for example. The greatest hazards of concern in Ann Arbor are severe wind, severe winter weather, extreme temperatures (heat and cold), flooding, and lightning.

Based on the risk and vulnerability assessment analysis and input from the community, here are some key points on vulnerability:

- Extreme heat events in Ann Arbor are projected to increase with climate change. Ann Arbor is projected to have as many as 80 days above 90°F (22 percent of the year), and as many as eight waves per year by the end of the century. Additionally, extreme heat is exacerbated in urbanized areas due to heat islands. Ann Arbor is experiencing growth and redevelopment, and is almost built-out, making it vulnerable to urban heat island effects. Extreme heat has resulted in more recorded injuries in Ann Arbor than any other hazard.
- Extreme Cold/Wind Chill events may become less severe in the future due to a changing climate.
- An increase in storm activity is projected for Ann Arbor, including an increase in the frequency of severe storms and a longer thunderstorm season as temperatures increase. Ann Arbor has a substantial vulnerability to thunderstorm related-hazards, as there is potential for multiple hazards to occur at once as a result of a severe thunderstorm (including severe wind, tornadoes, hail, lightning, and flooding due to heavy precipitation are all potential outcomes of severe thunderstorms).
- Tornado Alley is shifting east, indicating greatest tornado risk for Ann Arbor. Observed trends show an increase in tornado frequency in the southeast and Midwest over the last 40 years, and this trend is expected to continue into the future.
- Facilities within dam inundation areas (in particular, the city's wastewater treatment plant) increases vulnerability to contaminated floodwaters and decreased functionality of the treatment plant if it were to become inundated in a dam failure event. However, the city's wastewater treatment plant currently protected to the 500-year flood event.
- Long-term droughts may become less common in Ann Arbor as annual precipitation increases. However, seasonal summer drought may become more common due to higher temperatures resulting in insufficient soil moisture.
- Flooding may become more frequent due to 1) increased precipitation that is more concentrated into heavy precipitation events, and 2) increased development and impervious cover. The floodplain associated with Allen Creek is particularly vulnerable, as it is in one of Ann Arbor's most populated areas and development within the floodplain is ongoing. The city's storm sewer is not designed to handle stormwater volumes for 100-year precipitation events, several of which have occurred in recent years.
- Climate change is likely to create conditions where some non-native or invasive species will thrive and out-compete native species. Similarly, some native species may struggle under new climate conditions. In particular, Ann Arbor is seeing a shift

DRAFT

from native maple, beech, and birch canopy cover to hickory and oak trees. Heat-stressed trees in Ann Arbor may be more susceptible to invasive pests.

- HAZMAT incidents are an annual occurrence in Ann Arbor. Almost the entire city is within the 2,500-meter buffer for transportation-related HAZMAT incidents, resulting in widespread vulnerability. HAZMAT incidents aggravated by flooding are likely to increase throughout the city with climate change.
- Ann Arbor has increasing susceptibility to power outages due to 1) projections for increased storm activity and 2) increasing demand stemming from electrification, increased demand for cooling as temperatures warm, and demand due to population and economic growth. A recent power outage lasted several days and coincided with an extreme heat event.
- Potential causes of water contamination within the city include water main breaks, sewage overflows, and water pollution. A recent water main break caused a 2-day boil water advisory. Sewage overflows may become more common in the future as extreme precipitation events increase in frequency. Lastly, the dioxane plume in the city's groundwater would have devasting impacts if it were to reach the city's water supply, Barton Pond.
- The strong presence of the University of Michigan in the city makes Ann Arbor vulnerable to political, social, and sports-related civil disturbances.
- The COVID-19 pandemic has demonstrated that public health emergencies can have catastrophic impacts including widespread illness and death, as well as severe social and economic impacts due to business, education, and supply-chain disruptions.

Additional Considerations – Climate Migration

As the impacts of climate change, such as extreme heat, sea level rise, and wildfires, as well as subsequent impacts such as food and water shortages, supply chain disruptions, and political instability, are realized globally, people in areas with severe impacts may seek to relocate to places where such impacts are less acute. People migrating due to climate-related causes are referred to as "climate migrants." The World Bank estimates that by 2050, 30 to 200 million climate migrants worldwide may be forced from their homes due to climate impacts. Events such as drought, sea level rise, and sudden extreme weather events were cited as reasons for migration. Further, humanitarian crises exacerbated by the cascading impacts on climate change are also cited as a causes of climate migration.[cxxxv]

Ann Arbor is considered a place with a high quality of life, due to the presence of the University of Michigan, exceptional health and medical facilities, recreation and green space, and a healthy local economy. Further, the city has made commitments to affordable housing, sustainability, and walkability. Ann Arbor is also located in the Great lakes Region, meaning it is in close proximity to the world's largest source of fresh water. In addition, while Ann Arbor will experience impacts from climate change, such as extreme precipitation and extreme heat, the city is not expected to experience extreme climate impacts such as devastating wildfires, long-term droughts and water shortages, hurricanes, or sea level rise. The high quality of life, combined with less acute climate impacts and access to fresh water may make the city attractive to climate migrants. A study completed by the city and

DRAFT

Florida State University through a resilience grant found that as many as 50,000 individuals may more to southeast Michigan once 3 feet of sea level rise has been experienced in the U.S. – this estimate doesn't account for higher rates of sea level rise, or climate migration due to other climate impacts.[cxxxvi]

In its current state, the city's infrastructure and social systems are not prepared for an influx of individuals. Ann Arbor is currently working to further understand the potential influx of climate migrants to city in the future, and to identify what actions the city may need to take to adequately prepare for such an influx of people.

In the following section, a mitigation strategy to reduce the risks to current and future populations and structures will be presented.

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Section 5 – Capability Assessment

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Introduction

The purpose of conducting a capability assessment is to determine the ability of a local jurisdiction to implement a comprehensive mitigation strategy and to identify potential opportunities for establishing or enhancing specific mitigation policies, programs, or projects[i]. As in any planning process, it is important to try to establish which goals, objectives, and/or actions are feasible based on an understanding of the organizational capacity of those agencies or departments tasked with their implementation. A capability assessment helps to determine which mitigation actions are practical, and likely to be implemented over time, given a local government's planning and regulatory framework, level of administrative and technical support, amount of fiscal resources, and current political climate.

A capability assessment has two components: 1) an inventory of a local jurisdiction's relevant plans, ordinances, or programs already in place and 2) an analysis of its capacity to carry them out. Careful examination of local capabilities will detect any existing gaps, shortfalls, or weaknesses with ongoing government activities that could hinder proposed mitigation activities and possibly exacerbate community hazard vulnerability. A capability assessment also highlights the positive mitigation measures already in place or being implemented at the local government level, which should continue to be supported and enhanced through future mitigation efforts.

The Capability Assessment completed for the *2022 City of Ann Arbor Hazard Mitigation Plan* update serves as a critical planning step and an integral part of an effective hazard mitigation strategy. Coupled with the Risk Assessment, the Capability Assessment helps identify and target meaningful mitigation actions for incorporation in the Mitigation Strategy portion of this plan. Any potential shortcomings in the ability of the city to implement hazard mitigation is tied to the mitigation strategy in the form of actions selected by the planning team. It not only helps establish the goals and objectives for the region to pursue under this plan, but it also ensures that those goals and objectives are realistically achievable under local conditions. Specific recommendations for actions that will improve Ann Arbor's ability to implement the hazard mitigation plan and increase resilience are offered at the conclusion of this section.

Conducting the Capability Assessment

The Capability Assessment began with completion of a Capability Assessment Review Form by the plan's Steering Committee (See Appendix B). The assessment form compiled information on a variety of "capability indicators" such as existing local plans, policies, programs, or ordinances that contribute to and/or hinder the city's ability to implement hazard mitigation and climate adaptation.[ii] Other indicators in the form are related to the city's financial, administrative and technical, education and outreach, and political capabilities, such as access to local budgetary and personnel resources for mitigation purposes. Evaluating the current political climate is an important consideration with respect to hazard mitigation and climate adaptation. Information gathered from the Capability Assessment Review Form was supplemented with information found in reviewing plans and local government websites as well as through a series of interviews with city and county departments and key stakeholders. The following Interviews were

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completed, because of the critical role participating departments play in community resilience, including hazard mitigation and climate adaptation:

- Floodplain Management – Ann Arbor Systems Planning and Emergency Management
- Stormwater Management – Ann Arbor Systems Planning, Washtenaw County Water Resources, and Ann Arbor Emergency Management
- Dam Operations – Ann Arbor Water Treatment Services and Emergency Management
- Sustainability/Climate Action – Ann Arbor Office of Sustainability and Innovations
- Emergency Management – Ann Arbor Emergency Management and UM Emergency Management
- Housing – Avalon Housing and Ann Arbor Housing Commission
- Information Technology – Ann Arbor Information Technology Services and Emergency Management

At a minimum, results of this capability assessment provide an extensive inventory of existing local plans, ordinances, programs, and resources that are in place or under development in addition to their overall effect on hazard loss reduction. However, the information can also serve to identify gaps, weaknesses, or conflicts that Ann Arbor can recast as opportunities for specific actions to be proposed as part of the hazard mitigation strategy. The results of this Capability Assessment provide critical information for developing an effective and meaningful mitigation strategy.

Capability Assessment Findings

The findings of the Capability Assessment are summarized in this Plan to provide insight into the relevant capacity of Ann Arbor to implement hazard mitigation activities. All information is based upon the review of existing plans, ordinances, and programs identified through the assessment form and review of the city's website.

Emergency Management

Hazard mitigation is widely recognized as one of the four primary phases of emergency management. The three other phases include preparedness, response, and recovery. Each phase is interconnected, as Figure 5-1 illustrates. Opportunities to build community resilience through mitigation practices are often implemented before a disaster event strikes, such as elevation of flood prone structures or enforcement of policies that prevent and regulate development that is vulnerable to hazards. Mitigation opportunities will also be presented during immediate preparedness or response activities, such as installing storm shutters in advance of a hurricane, and certainly during the long-term recovery and redevelopment process following a hazard event.

Planning for each phase is a critical part of a comprehensive emergency management program and a key to the successful implementation of hazard mitigation actions. As a result, the Capability Assessment Review Form evaluated a range of emergency management plans in order to assess Ann Arbor's willingness to plan and their level of technical planning proficiency.

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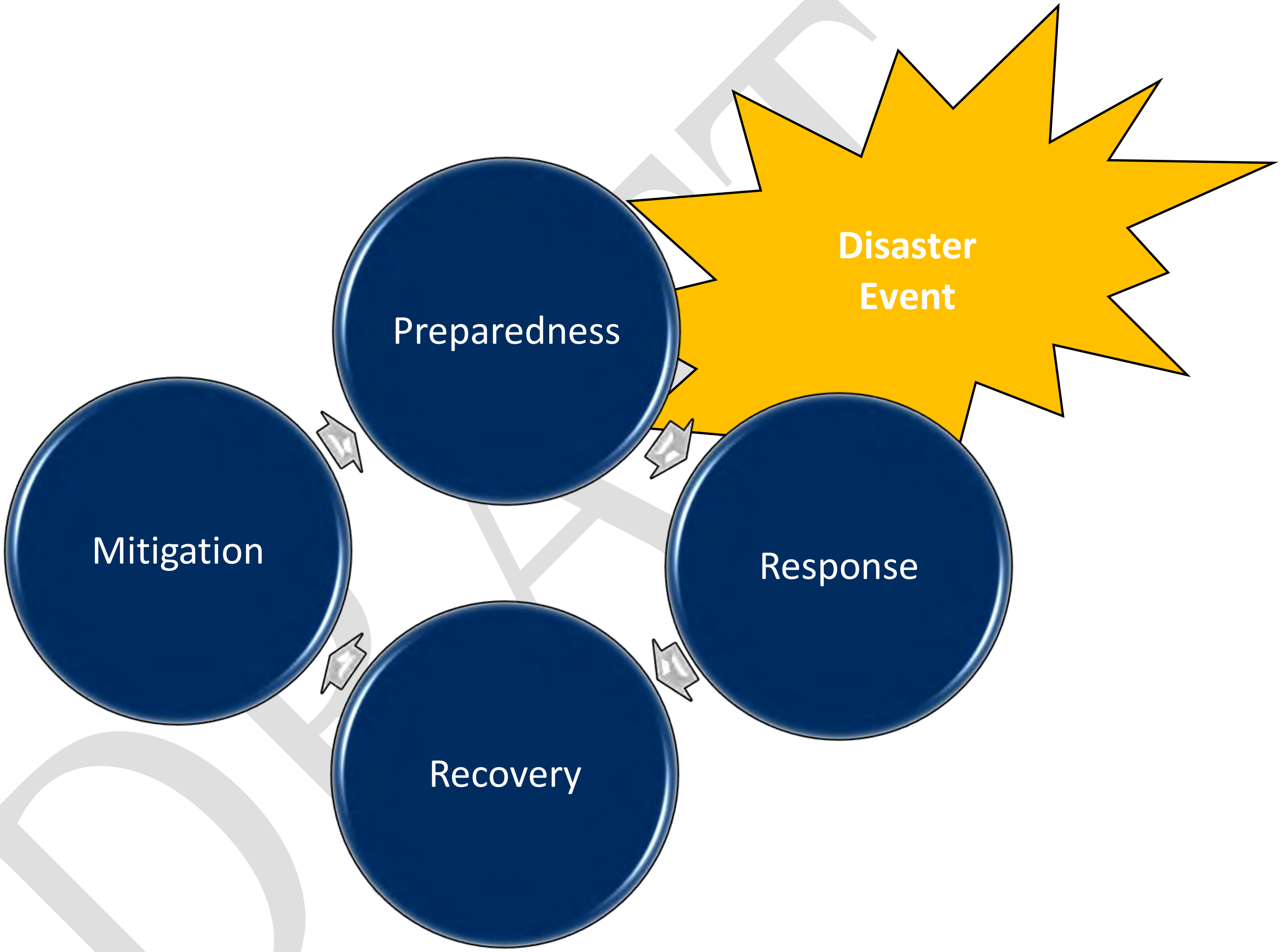

Figure 5-1: The Four Phases of Emergency Management

Hazard Mitigation Plan

A hazard mitigation plan represents a community's blueprint for how it intends to reduce the impact of natural and human-caused hazards on people and the built environment. The essential elements of a hazard mitigation plan include a Risk Assessment, Capability Assessment, and Mitigation Strategy.

In 2012 Ann Arbor adopted its first stand-alone Hazard Mitigation Plan. This plan replaced the Ann Arbor subsection of the Washtenaw County Hazard Mitigation Plan and integrated the 2007 City of Ann Arbor Flood Mitigation Plan. The 2007 plan recognized the many hazards shared with the county, while highlighting several hazards unique to the City of Ann Arbor. The Flood Mitigation Plan was Ann Arbor's first hazard mitigation plan and was an outcome of the city's subsection of the Washtenaw County Plan. The planning process included a much more detailed flood analysis than had been included in the Washtenaw County hazard mitigation plan and was heavily focused on implementation. The flood plan's strategies addressed the following areas: Mapping & Technology, Education and Outreach, Planning and Zoning, Regulation and Development Standards, Corrective Actions, Infrastructure, and Emergency Services.

The 2012 Ann Arbor Hazard Mitigation Plan was updated in 2017 and will be updated again through this planning process. The 2017 Plan is a FEMA approved mitigation plan that served the city well in acquiring funds and implementing mitigation projects. Some of the projects Ann Arbor completed since 2017 include:

- $3.7 million in FEMA funding for the Allen Creek Railroad Berm
- Improved from a Class 7 to a Class 6 in the Community Rating System (CRS)
- Developed and adopted a Dam Evacuation Plan
- Updated the Floodplain Management Overlay ordinance

Disaster Recovery Plan

A disaster recovery plan serves to guide the physical, social, environmental, and economic recovery and reconstruction process following a disaster. In many instances, hazard mitigation principles and practices are incorporated into local disaster recovery plans with the intent of capitalizing on opportunities to break the cycle of repetitive disaster losses. Disaster recovery plans can also lead to the preparation of disaster redevelopment policies and ordinances to be enacted following a hazard event. Ann Arbor has not yet adopted a disaster recovery plan. A Disaster Recovery Plan will also earn CRS points, if it addresses post-disaster redevelopment and mitigation policies and procedures. These policies and procedures should account for the expected damage from a base flood or other disaster.

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Emergency Operations Plan

An emergency operations plan (EOP) outlines responsibilities and the means by which resources are deployed during and following an emergency or disaster. Ann Arbor completed a new EOP and an exercise in 2017. The EOP was submitted for state approval in August 2017. The new EOP is NIMS and ICS compliant, following the structure of the National Response Framework. The City's EOP will be updated again in 2023 and will include lessons learned from the COVID-19 pandemic and a cybersecurity plan.

Ann Arbor has four high hazard dams (Barton, Argo, Geddes, & Superior) and an emergency action plan (EAP) is required for each one. All four EAP's are being updated in 2022. Because Barton Dam and Superior Dam are hydroelectric dams, they are subject to Federal Energy Regulatory Commission (FERC) requirements of holding a drill or tabletop exercise annually and a functional or full-scale exercise every five years. Ann Arbor is scheduled to conduct a functional exercise in November 2022.

Ann Arbor Emergency Management helped establish the Washtenaw County Joint Information System and Center. This team is comprised of Public Information Officer's and key communicators across the county. The Washtenaw County JIC meets on a recurring quarterly basis and is activated in the event of an emergency to develop consistent community messaging. The group activated for a severe winter weather storm that impacted the County and Southeast Michigan in February 2022.

Ann Arbor Emergency Management chairs the Washtenaw County Emergency Management Coalition. The coalition consists of the emergency managers throughout the county (Washtenaw County, U-M, Michigan Medicine, Trinity Health, VA Hospital, State of Michigan Emergency Management Homeland Security Division, Ann Arbor Public Schools, The American Red Cross). This group meets quarterly and was established to share information and maintain situational awareness in the event of an emergency.

Continuity of Operations Plan

A continuity of operations plan (COOP) establishes a chain of command, line of succession, and plans for backup or alternate emergency facilities in case of an extreme emergency or disaster event. Many continuity-related policy decisions were created and implemented during the COVID-19 pandemic. These policy decisions and the lessons learned throughout the COVID-19 pandemic provide an opportunity for the City to further develop department-specific COOP plans that support a citywide COOP. Ann Arbor Emergency Management will lead this effort as part of the 2023 EOP update.

Evacuation Plan

An evacuation plan provides an evacuation strategy for all or part(s) of a jurisdiction in the event that a life safety threat or hazard occurs or is projected to occur. The evacuation plan is meant to facilitate the safe, timely, and efficient evacuation of an area. An evacuation plan provides a general outline of the expected roles, responsibilities, and evacuation-related response activities during an evacuation. Ann Arbor offers evacuation guidance for the areas below Barton Dam. The city recognizes the need for a dam failure inundation map and an evacuation plan.

DRAFT

Resilience Hubs

The City identified the need to further develop a community network of resilience hubs. The Northside Community Center became the City's first resilience hub in September 2020 and Bryant Community Center and the Senior Center are slated to become the second and third in 2022-2023. Resilience Hubs are community-serving facilities augmented to support residents during disaster events by providing things like resilient power supplies, flood mitigation services, coordinated communication systems, and resource distribution, all while reducing climate pollution and enhancing quality of life every single day. These are trusted community locations that provide services all year long however, can be "activated" in the event of an emergency to provide additional support.

Planning and Regulatory Capability

Planning and regulatory capability is based on the implementation of plans, ordinances, and programs that demonstrate a local jurisdiction's commitment to guiding and managing growth, development, and redevelopment while maintaining the general welfare of the community. It includes emergency response and mitigation planning, comprehensive land use planning, and transportation planning; enforcement of zoning or subdivision ordinances and building codes and protection of environmental, historic, and cultural resources in the community. Although conflicts can arise, these planning initiatives present significant opportunities to integrate hazard mitigation principles into the local decision-making process.

This assessment is designed to provide a general overview of key planning and regulatory tools and programs in Ann Arbor along with their potential effect on hazard mitigation and climate adaptation. This information will help identify opportunities to address existing gaps, weaknesses, or conflicts with other initiatives in addition to integrating the implementation of this Plan with existing planning mechanisms where appropriate.

Table 5-1 provides a summary of relevant local plans, ordinances, and programs in place or under development in Ann Arbor. A checkmark (✓) indicates that the given item is currently in place and being implemented. Each of these local plans, ordinances, and programs should be considered available mechanisms for incorporating the requirements of the Ann Arbor Mitigation Plan.

DRAFT

Table 5-1: Relevant Plans, Ordinances, and Programs

Planning / Regulatory Tools	Ann Arbor
Hazard Mitigation Plan – 2022 Update	✓
Comprehensive Land Use Plan	✓
Floodplain Management Plan	✓
Open Space Management Plan (or Parks & Rec/Greenway Plan)	✓
Stormwater Management Plan/Ordinance	✓
Natural Resource Protection Plan	✓
Flood Response Plan	
Climate Adaptation Plan (Hazard Mitigation Plan + A2 Zero)	✓
Sustainability Plan	✓
Greenhouse Gas Reduction Plan (or Climate Action Plan)	✓
Emergency Operations Plan	✓
Continuity of Operations Plan	
Evacuation Plan	
Disaster Recovery Plan	
Capital Improvements Plan	✓
Economic Development Plan	
Historic Preservation Plan	
Flood Damage Prevention Ordinance	✓
Green or Complete Streets Policy	✓
Zoning Ordinance	✓
Subdivision Ordinance	✓
Tree Removal/Replacement Ordinance	✓
Building Energy Efficiency Ordinance	
Unified Development Ordinance	✓
Post-Disaster Redevelopment Ordinance	
Building Code	✓
Fire Code	✓
National Flood Insurance Program (NFIP)	✓
NFIP Community Rating System	✓

DRAFT

General Planning

The implementation of hazard mitigation activities often involves agencies and individuals beyond the emergency management profession. Stakeholders may include local planners, public works officials, economic development specialists, and others. In many instances, concurrent local planning efforts will help to achieve or complement hazard mitigation goals, even though they are not designed as such. Therefore, the Capability Assessment Review Form also asked questions regarding general planning capabilities and how they impact hazard and climate adaptation.

Comprehensive Land Use Plan

A comprehensive land use plan (master plan) establishes the overall vision for what a community wants to be and serves as a guide for future governmental decision making. Typically, a comprehensive plan contains sections on demographic conditions, land use, transportation elements, and community facilities. Given the broad nature of the plan and its regulatory standing in many communities, the integration of hazard mitigation measures into the comprehensive plan can enhance the likelihood of achieving risk reduction goals, objectives, and actions. The following documents constitute Ann Arbor's Comprehensive Plan, which are described in more detail in the text that follows:

- Sustainability Framework (2013)
- Land Use Element (2009)
- South State Street Corridor Plan (2013)
- Downtown Plan (2009)
- Parks and Recreation Open Space Plan (2016)
- Natural Features Master Plan (2004)
- The Treeline Allen Creek Urban Trail Master Plan (2017)
- Comprehensive Transportation Plan (2021)

Several additional planning documents are to be used by the Planning Commission and Planning Staff as resource information in support of the City Master Plan. Plans with direct relationship to hazard mitigation and climate adaptation include:

- A^{2}ZeroClimate Action Plan (2020)
- Capital Improvements Plan (2018-2023)
- Huron River and Impoundment Management Plan (2009)
- Allen Creek Greenway Task Force Report (2007)
- North Main Street/Huron River Corridor Vision for the Future Report (2013)

DRAFT

Ann Arbor's Planning Department intends to initiate an update to the City's comprehensive plan in 2022 or 2023.

Sustainability Framework (2013)

Ann Arbor's sustainability framework is a reorganization of 20 years of planning into one organized document that recognizes the broad spectrum of Ann Arbor's city plans, goals, and resolutions. Ann Arbor's sustainability framework lays out a set of 16 overarching goals that will help create a more sustainable Ann Arbor. These sustainability goals build on goals already developed through a variety of public processes - from city plans, council resolutions, and the council-approved ten environmental goals. These sustainability goals also include the three key aspects of sustainability – environment, economy, and equity and are organized into four theme areas: 1) climate and energy, 2) community, 3) land use and access, and 4) resource management. Ann Arbor staff indicated that the Framework has morphed and been integrated into the City's more up to date A2ZERO Climate and Equity Plan.

Land Use Element (2009)

The purpose of the Land Use Element of the City Master Plan is to provide information and guidance to city residents, decision-makers, developers, and property owners about land use planning issues that face the City of Ann Arbor. The land use element presents a series of goals, objectives, and actions in two broad categories, Natural Systems and the Environment and Land Use. The element also includes sections devoted to specific areas of the city. The preservation and enhancement of natural systems is a theme throughout the element with several actions that specifically address protecting natural floodplain functions and improving stormwater infiltration. These actions include developing incentives to encourage the enhancement of natural features by developers and modifying city codes to restrict development in the floodway and floodplain. In the section devoted to Lower Town, the element states that, "No new buildings should be allowed in the Huron River flood plain/flood way that negatively impact flood storage capacity."

South State Street Corridor Plan (2013)

The State Street Corridor Plan proposes ideas and strategies that can be used to build upon existing strengths and address current challenges to enhance the image, economic vitality, and sustainability of the corridor. The vision for the South State Street Corridor is for the area to be interconnected, diverse, sustainable, attractive, and invigorated. The plan specifically recommends integrating better stormwater management and drainage, protecting high quality natural systems, and converting concrete/asphalt medians to rain gardens.

Downtown Plan (2009)

This plan recognized the impact of storm water in the downtown area and the important role of street trees in helping manage runoff. One key component of the plan is the development of the Allen Creek Greenway. Several vacant parcels and potential

DRAFT

redevelopment sites create the opportunity for the development of a greenway on the western edge of downtown. This plan includes an action from the Flood Mitigation Plan to reduce the potential for damage of streets, utilities, and buildings in the Allen Creek floodplain. The plan also calls for a reduction in the use of non-renewable energy and to increase the amount of renewable energy sources in public infrastructure systems.

Parks and Recreation Open Space Plan (2016)

The Parks and Recreation Open Space Plan (PROS) Plan is the city's vision for parks and recreation in Ann Arbor. The PROS Plan provides an inventory of existing parks and facilities, describes the relationship between the parks and recreation system and surrounding municipalities and recreation providers, identifies parks and recreation needs and deficiencies, and proposes major capital park projects for existing and new parks. One of the plan's goals is to foster environmental stewardship and sustainability, however the plan does not directly address hazards or climate change. Instead, the plan references the city's Natural Features Master Plan and the protection measures included in that plan. The PROS was in the process of being updated in 2022 at the same time as the hazard mitigation plan update.

Natural Features Master Plan (2004)

The Natural Features Master Plan describes Ann Arbor's natural features, both publicly and privately owned, and sets forth policies to protect, restore and sustain them. This plan specifically addresses flooding along the Huron River, calling for adding flood storage capacity through acquisitions and native plantings, modifying codes to ensure best management practices are implemented in the floodplain and floodway, and restoring floodplains and wetlands. The plan also advocates for protecting steep slopes through code modifications, policy changes to improve groundwater recharge, and a variety of activities to help manage the impacts of climate change. Some implementation strategies from the Natural Features Master Plan will be incorporated into the mitigation strategy presented later in this plan.

The Treeline Allen Creek Urban Trail Master Plan (2017)

The Treeline Allen Creek Urban Trail Master Plan lays out a plan to connect City-owned properties, neighborhoods, and downtown businesses while linking to the Huron River and the regional Border-to-Border trail (B2B Trail). One of the plan's focus areas is stormwater management in the Allen Creek floodplain. The plan calls for green infrastructure solutions to better manage stormwater and acquisition of properties in the floodplain.

Comprehensive Transportation Plan (2021)

Ann Arbor: Moving Together builds on the city's success over the past decade in creating a safer, more sustainable, accessible, and equitable transportation system for everyone. By bringing together diverse perspectives from across the city and the wider region, this plan defines the city's mobility values and goals and details our strategy for managing, operating, upgrading, and

DRAFT

maintaining our transportation system today and into the future. The plan supports the development of neighborhood resilience hubs and meeting the City's climate goals outlined in the A²Zero Plan.

Capital Improvements Plan (2022-2027)

This Capital Improvements Plan (CIP) outlines a schedule of public service expenditures over the ensuing six-year period (fiscal years 2022–2027). The CIP does not address all of the capital expenditures for the city, but provides for large, physical improvements that are permanent in nature, including the basic facilities, services, and installations needed for the functioning of the community. These include transportation systems, utilities, municipal facilities, and other miscellaneous projects. The recently completed Stormwater Modelling project resulted in the identification of several needed capital projects. The CIP identifies 55 projects related to stormwater management with nearly $80 million in estimated funding need. In addition to the long list of stormwater projects, other hazard and climate related projects in the CIP include:

- Fire Station 3, 4, and 5 replacements
- Demolition and site stabilization of 721 N Main
- Open Space and Park Acquisitions
- Northside Methane Collection System Upgrades
- Northside Methane Collection System Upgrades

Huron River and Impoundment Management Plan (2009)

The Huron River and Impoundment Management Plan was developed to better understand the complex interrelationships among the Huron river ecology, community recreation preferences, the effect of dams on river processes, and the economic implications of different recommendations. Plan objectives that are directly related to hazards and climate change include:

- Ensure a healthy and sustainable aquatic ecosystem, including the river and its floodplain and watershed;
- Maintain an adequate drinking water supply;
- Minimize stormwater runoff and maximize infiltration;
- Management of the Shoreline and Riparian Corridor;
- Identify, protect, and enhance natural features, including native forest fragments, scenic vistas, greenways, and designated natural areas; and

DRAFT

- Anticipate and plan for the impact of large-scale forces such as climate change, development pressures and population changes.

The plan included a recommendation to remove the Argo Dam. One of the many identified benefits of removing the dam is the resulting reduction of the floodplain between Argo and Barton dams.

A^{2}Zero Carbon Neutrality Plan (2020)

A2ZERO was created with input from thousands of Ann Arborites over the course of an intensive four month planning process and outlines the path needed to achieve a just transition to carbon neutrality, community-wide, by the year 2030. The process identified forty-four actions, organized around 7 strategies, that if fully implemented, could eliminate 2.1 million metric tons of carbon dioxide equivalent emissions annually. While all of the actions in A2ZERO address climate change, many also address climate adaptation and hazard mitigation locally, including:

- Develop Community Solar Program;
- Launch Landfill Solar Project
- Invest in Resilience Hubs;
- Preserve and Enhance the Local Tree Canopy;
- Update Building Codes;
- Net Zero Energy Affordable Housing;
- Develop Aging in Place Efficiently Program;
- Expand Weatherization Services;
- Mixed-Use Zoning;
- Neighborhood and Youth Ambassador Program;
- Conduct Asset and Needs Mapping of Neighborhoods;
- Assist In Assembling and Distributing Emergency Preparedness Kits; and
- Implement Sensors to Monitor Heat, Air Quality, Waterways, and Flooding.

Allen Creek Greenway Task Force Report (2007)

The Allen Creek Greenway Task Force determined in 2007 that there can and should be an Allen Creek Greenway, and that, at a minimum, it should occupy the floodway portion of the city's sites in the Creek's floodplain. The vision for the Allen Creek Greenway is a path in a continuous, green open space following the floor of the Allen Creek valley along its length and joining the Huron River

DRAFT

Greenway. The task force's report presents detailed recommendations for three city-owned sites in the Allen Creek floodplain. They include an urban garden, art and performance park, and a community green. The recommendations in this report resulted in the Treeline Allen Creek Urban Trail Master and the North Main Street/Huron River Corridor Vision for the Future Report.

North Main Street/Huron River Corridor Vision for the Future Report (2013)

The City of Ann Arbor's North Main-Huron River Corridor Vision Task Force (the "Task Force") developed a vision for the improvement of one of Ann Arbor's northern gateways and surrounding areas: to make the Corridor an identifiable, vibrant, and unique destination that is connected to the community. One of the reports primary recommendations was that area of the 721 N. Main site within the floodway be included in the Allen Creek Greenway.

Economic Development Plan

An economic development plan provides a comprehensive overview of a community's economy. An economic development plan can set policies for a community's economic growth and identify strategies, programs, and projects to improve and maintain a community's economy. Economic development plans can also identify strategies to make the local economy more resilient, such as diversification and support for local businesses and local investment. Ann Arbor does not have a current economic development plan.

Historic Preservation Plan

A historic preservation plan is intended to preserve historic structures or districts within a community. An often-overlooked aspect of the historic preservation plan is the assessment of buildings and sites located in areas subject to natural hazards and the identification of ways to reduce future damages. This may involve retrofitting or relocation techniques that account for the need to protect buildings that do not meet current building standards or are within a historic district that cannot easily be relocated out of harm's way. Ann Arbor maintains an Historic Preservation Ordinance, but it does not specifically reference climate adaptation or hazard mitigation or related issues.

Unified Development Ordinance (UDO)

A unified development ordinance is a local tool that combines traditional zoning and subdivision ordinances, along with other local regulations (e.g., design guidelines, sign regulation, stormwater management), into one document. UDOs can be used to improve efficiency and clarity in the land development process and to eliminate conflicting regulations. Zoning is the primary means by which land use is controlled by local governments. As part of a community's police power, zoning protects the public health, safety, and welfare throughout the jurisdiction. Since zoning regulations enable municipal governments to limit the type and density of development, a zoning ordinance can serve as a powerful tool when applied in identified hazard areas. Ann Arbor's municipal code includes the Unified Development ordinance, which includes zoning and several additional policies and ordinances that directly address hazards and climate change, including:

DRAFT

- Landscaping, Screening, and Buffering. This section has several focus areas, however the two related to hazards and climate adaptation are: to promote the public health, safety, and general welfare by reducing noise and air pollution, glare, soil erosion, and thermal heating of the environment; and to reduce the negative impacts of storm water runoff by reducing Impervious surface area and retaining greater amounts of storm water on site.
- Natural Features. This section establishes how Natural Features shall be identified, evaluated, protected, and mitigated, and to require minimum buffers adjacent to Natural Features, as defined herein, and to regulate property within such buffer in order to prevent physical harm, impairment, or destruction of or to a Natural Feature. It has been determined that, in the absence of such minimum buffers, intrusions in or on to Natural Features would occur, resulting in harm, impairment and/or destruction of Natural Features contrary to the public health, safety and general welfare. Seven Natural Features are protected and regulated in the City, Endangered Species Habitats, Floodplains, Woodlands, Landmark Trees, Steep Slopes, Watercourses and Wetlands.
- Storm Water Management and Soil Erosion. The purpose of this Section is to control soil erosion and the resulting sediment; and to control the impact on water quality and quantity resulting from development and impervious surfaces within the City by requiring proper provisions for water disposal and the protection of soil surfaces during and after construction, in order to promote the safety, public health, convenience and general welfare of the community.
- Flood Management Overlay Zoning District. This tool is described in more detail in the Floodplain Management section below.

Stormwater System

This ordinance establishes a stormwater utility for the purpose of conducting the city's stormwater management program to protect public health, safety, and welfare; provides for the proportional allocation to property owners of the necessary costs of the stormwater utility; permits the establishment and collection of just and equitable rates and charges to fund the stormwater utility; provides for credits, adjustments, exemptions and appeals; establishes regulations for the use of the stormwater system, and prescribes the powers and duties of certain municipal agencies, departments and officials.

Open Space and Parkland Preservation

Ann Arbor's Open Space and Parkland Preservation Ordinance helps the city preserve and protect open space, natural habitats, parkland, and the city's source waters inside and outside the city limits for benefit of residents of the City of Ann Arbor and in cooperation with the greater Ann Arbor community.

Trees and Other Vegetation

DRAFT

The City Administrator shall have the sole authority over the planting, maintenance, and removal of trees in the street right-of-way and other city property. No person without written permission of the City Administrator shall plant, remove, break, spray or take any action which will injure or destroy any tree or shrub, the base of which is located in the street right-of-way or other city land.

Building Codes, Fire Codes, Permitting, and Inspections

Building codes regulate construction standards. In many communities, permits, and inspections are required for new construction. Decisions regarding the adoption of building codes (that account for hazard risk), the type of permitting process required both before and after a disaster, and the enforcement of inspection protocols all affect the level of hazard risk faced by a community. Ann Arbor enforces the State of Michigan building code under the authority of the Stille-DeRossett-Hale Single State Construction Code Act PA 230 of 1972. The latest edition of the Michigan Construction Code is based on the 2015 International Building Code (effective 04/20/2017) and the 2018 International Residential Code (effective 10/04/2021) and is mandatory statewide. Ann Arbor has adopted by reference the Washtenaw County Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMS) for the purposes of administration of the building code and to provide the content of the "Flood Hazards" section of Table R301.2(1) of the Michigan Residential Code.

The adoption and enforcement of building codes by local jurisdictions is routinely assessed through the Building Code Effectiveness Grading Schedule (BCEGS) program developed by the Insurance Services Office, Inc. (ISO).[iii] The results of BCEGS assessments are routinely provided to ISO's member private insurance companies, which in turn may offer ratings credits for new buildings constructed in communities with strong BCEGS classifications. The concept is that communities with well-enforced, up-to-date codes should experience fewer disaster-related losses and, as a result, should have lower insurance rates.

In conducting the assessment, ISO collects information related to personnel qualification and continuing education, as well as the number of inspections performed per day. This type of information combined with local building codes is used to determine a grade for that jurisdiction. The grades range from 1 to 10 with a BCEGS grade of 1 representing exemplary commitment to building code enforcement and a grade of 10 indicating less than minimum recognized protection. Ann Arbor's current BCEGS ratings are 4 for residential and 3 for commercial, both exceeding the threshold for achieving CRS Class 6.

Floodplain Management

Flooding represents the greatest natural hazard facing the nation. At the same time, the tools available to reduce the impacts associated with flooding are among the most developed when compared to other hazard-specific mitigation techniques. In addition to approaches that cut across hazards such as education, outreach, and the training of local officials, the *National Flood Insurance Program* (NFIP) contains specific regulatory measures that enable government officials to determine where and how growth occurs relative to flood hazards. Participation in the NFIP is voluntary for local governments; however, program participation is strongly encouraged by FEMA as a first step for implementing and sustaining an effective hazard mitigation program. It is therefore used as part of this assessment as a key indicator for measuring local capability. For a county or municipality to participate in the NFIP, they must adopt a local flood damage prevention ordinance or resolution that requires jurisdictions to follow established minimum building standards in the floodplain. These standards require that all new buildings and substantial improvements to existing buildings will be protected from damage by a 1% annual chance (100 year) flood event and that new development in the floodplain will not exacerbate existing flood problems or increase damage to other properties.

In January 2021, Ann Arbor adopted a Flood Management Overlay Zoning District to add to Chapter 55 of the City's Unified Development Code. The new overlay district replaced the Resolution to Manage Floodplain Development (2012) for participation in the National Flood Insurance Program (NFIP). Table 5-2 provides NFIP policy and claim information for Ann Arbor. In addition to the overlay district, Ann Arbor's successful floodplain management efforts include:

- Allen Creek Railroad Berm[iv]
- Improved from a Class 7 to a Class 6 in the Community Rating System (CRS), increasing flood insurance premium discount from 15% to 20%
- Stormwater Model Calibration and Analysis Project (2015)
- Urban and Community Forestry Management Plan (2014)
- Huron River and Impoundment Management Plan (2009)
- Allen Creek Greenway Task Force Report (2007)
- North Main Street/Huron River Corridor Vision for the Future Report (2013)

A key service provided by the NFIP is the mapping of identified flood hazard areas. Once completed, the Flood Insurance Rate Maps (FIRMs) are used to assess flood hazard risk, regulate construction practices, and set flood insurance rates. FIRMs are an important source of information to educate residents, government officials, and the private sector about the likelihood of flooding in their community.

Table 5-2: NFIP Policy and Claim Information

	Number of NFIP Policies in Force	Insurance in Force ($)	Total Number of Flood Losses (Closed) Incurred	Total Claims Payments ($)	Average Payment ($)
City of Ann Arbor	317	$80,787,200	58	$281,600	$4,855

Source: NFIP Community Information System, 4/28/2022;

Community Rating System

An additional indicator of floodplain management capability is the active participation of local jurisdictions in the Community Rating System (CRS). The CRS is an incentive-based program that encourages counties and municipalities to undertake defined flood mitigation activities that go beyond the minimum requirements of the NFIP by adding extra local measures to provide protection from flooding. All of the 18 creditable CRS mitigation activities are assigned a range of point values. As points are accumulated and reach identified thresholds, communities can apply for an improved CRS class rating. Class ratings, which range from 10 to 1, are tied to flood insurance premium reductions as shown in Table 5-3. As class rating improves (the lower the number the better), the percent reduction in flood insurance premiums for NFIP policyholders in that community increases. Community participation in the CRS is voluntary. Any community that is in full compliance with the rules and regulations of the NFIP may apply to FEMA for a CRS classification better than class 10.

DRAFT

Table 5-3: CRS Premium Discounts, By Class

CRS Class	Premium Reduction
1	45%
2	40%
3	35%
4	30%
5	25%
6	20%
7	15%
8	10%
9	5%
10	0

Source: *FEMA*

Continued Compliance with the NFIP

The City of Ann Arbor is in good standing with the NFIP and joined the CRS in May 2017 as a Class 7 and improved to a Class 6 in 2018. The following plans and tools demonstrate a jurisdiction's commitment to ongoing NFIP compliance (based on Table 5.2 results).

Flood Damage Prevention Ordinance

A flood damage prevention ordinance establishes minimum building standards in the floodplain with the intent to minimize public and private losses due to flood conditions. Ann Arbor adopted a Floodplain Management Overlay Zoning District in 2021 to implement higher standards that go above and beyond the minimum NFIP requirements. Highlights of the new overlay include requiring first floor elevations in new residential and new non-residential structures to be1 foot above the 0.2% annual chance (500 year) floodplain, requiring substantial improvements to existing structures in the floodplain to meet the new requirements, and prohibiting new development in the floodway.

Floodplain Management Plan

A floodplain management plan (or a flood mitigation plan) provides a framework for action regarding corrective and preventative measures to reduce flood-related impacts. This hazard mitigation plan update serves as the floodplain management plan and will comply with CRS requirements.

Natural Resource Protection Plan

A natural resource protection plan identifies the lands containing natural resources (e.g., forests, streams, wildlife habitat) within a jurisdiction, and provides policies for protecting those resources. These plans can also include regulations or guidelines for altering or developing land containing natural resources. Both the Parks Recreation and Open Space Plan (2016) and the Natural Features Master Plan (2004) deal with the identification and protection of natural resources.

Open Space Management Plan

An open space management plan is designed to preserve, protect, and restore largely undeveloped lands in their natural state and to expand or connect areas in the public domain such as parks, greenways, and other outdoor recreation areas. In many instances, open space management practices are consistent with the goals of reducing hazard losses, such as the preservation of wetlands or other flood-prone areas in their natural state in perpetuity. Ann Arbor's Parks Natural Features Master Plan fills this role. The Plan addresses flooding along the Huron River, calling for adding flood storage capacity through acquisitions and native plantings, modifying codes to ensure best management practices are implemented in the floodplain and floodway, and restoring floodplains and wetlands. The plan also advocates for protecting steep slopes through code modifications, policy changes to improve groundwater recharge, and a variety of activities to help manage the impacts of climate change.

Stormwater Management Plan

A stormwater management plan is designed to address flooding associated with stormwater runoff. The stormwater management plan is typically focused on design and construction measures that are intended to reduce the impact of more frequently occurring minor urban flooding. Ann Arbor does not have an official stormwater management plan; however, the city has several ordinances and programs that help the City manage stormwater. The Systems Planning Department recognizes the need for a comprehensive stormwater management plan that includes updating the stormwater model, floodplain map, dam failure inundation area areas that flood not included in the floodplain and recommends necessary policy, funding, and infrastructure improvements.

Urban and Community Forestry Management Plan (2014)

The overarching goal of the Urban and Community Forestry Management Plan is to sustainably protect, preserve, maintain, and expand Ann Arbor's tree canopy and urban and community forest. The plan includes 17 recommendations that will help increase the quality and size of the urban and community forest, which is an adaptive strategy to improve water quality and limit flooding by mitigating stormwater runoff.

Administrative and Technical Capability

The ability of a local government to develop and implement mitigation projects, policies, and programs is directly tied to its ability to direct staff time and resources for that purpose. Administrative capability can be evaluated by determining how mitigation-

DRAFT

related activities are assigned to local departments and if there are adequate personnel resources to complete these activities. The degree of intergovernmental coordination among departments will also affect administrative capability for the implementation and success of proposed mitigation activities.

Technical capability can be evaluated by assessing the level of knowledge and technical expertise of local government employees, such as personnel skilled in using Geographic Information Systems (GIS) to analyze and assess community hazard vulnerability. The Capability Assessment Review Form was used to capture information on administrative and technical capability through the identification of available staff and personnel resources. Table 5-4 provides a summary of the Capability Assessment Review Form results for Ann Arbor with regard to relevant staff and personnel resources.

Table 5-4: Relevant Staff / Personnel Resources

Staff / Personnel Resources	Ann Arbor
Planners with knowledge of land development / land management practices	✔
Engineers or professionals trained in construction practices related to buildings and/or infrastructure	✔
Planners or engineers with an understanding of natural and/or human-caused hazards	✔
Planners or engineers with an understanding of climate change impacts	✔
Emergency Manager	✔
Floodplain Manager	✔
Sustainability or Climate Change Coordinator	✔
Locally Specific Climate Data	✔
Land Surveyors	✔
Scientists familiar with the hazards of the community	✔
Scientists familiar with the community’s climate change impacts	✔
Staff with education or expertise to assess the community’s vulnerability to hazards	✔
Personnel skilled in GIS and/or HAZUS	✔
Resource development staff or grant writers	✔

Ann Arbor’s staff capabilities for implementing the hazard mitigation plan are exceptional. With the presence of the University of Michigan, the staff has access to scientists and research that can enhance those capabilities. Several City departments key to implementing the mitigation strategy indicate that they do not have sufficient personnel to accomplish all of what they are asked to do. Additional personnel would be particularly helpful in the Water Treatment Department and Systems Planning.

DRAFT

Financial Capability

The ability of a local government to take action is closely associated with the amount of money available to implement policies and projects. This may take the form of outside grant funding awards or locally based revenue and financing. The cost of mitigation policy and project implementation vary widely. In some cases, policies are tied primarily to staff time or administrative costs associated with creation and monitoring of a given program. In other cases, direct expenses are linked to an actual project, such as acquisition of flood-prone homes, which can require a substantial commitment from local, state, and federal funding sources.

The Capability Assessment Review Form was used to capture information Ann Arbor's fiscal capability through the identification of locally available financial resources. Table 5-5 provides a summary of the results for Ann Arbor with regard to relevant fiscal resources.

Table 5-5: Relevant Fiscal Resources

Fiscal Tool / Resources	Ann Arbor
Capital Improvement Programming	✔
Community Development Block Grants (CDBG)	✔
Special Purpose Taxes (or taxing districts)	✔
Gas / Electric Utility Fees	
Water / Sewer Fees	✔
Stormwater Utility Fees	✔
Development Impact Fees	
Tree Removal Fees	✔
General Obligation, Revenue, and/or Special Tax Bonds	
Partnering Arrangements or Intergovernmental Agreements	✔

Education and Outreach Capability

The ability of a local government to effectively communicate with residents and offer educational opportunities is key to building a more resilient community. Education and outreach capabilities include programs and methods already in place that could be used to support implementation of mitigation actions and communicate hazard-related information, including activities related to social cohesion.

DRAFT

The Capability Assessment Review Form was used to capture information Ann Arbor's education and outreach capability through the identification of current programs and tools. Table 5-6 provides a summary of the results for Ann Arbor with regard to education and outreach capabilities.

Table 5-6: Education and Outreach Capabilities

Education/Outreach Program	Ann Arbor
StormReady	✔
Emergency Notification System	✔
Emergency Outdoor Siren System	✔
Seasonal Emergency Management Outreach	✔
Equitable Engagement Initiative	✔

StormReady

Washtenaw County is a StormReady community. The StormReady program encourages communities to take a proactive approach to improving local hazardous weather operations by providing emergency managers with clear-cut guidelines on how to improve their hazardous weather operations. To be officially StormReady, a community must:

- Establish a 24-hour warning point and emergency operations center.
- Have more than one way to receive severe weather warnings and forecasts and to alert the public.
- Create a system that monitors weather conditions locally.
- Promote the importance of public readiness through community seminars.
- Develop a formal hazardous weather plan, which includes training severe weather spotters and holding emergency exercises.

Emergency Notifications

The City of Ann Arbor uses Washtenaw County's emergency notification system powered by Everbridge to send emergency notification to residents. This system allows the City of Ann Arbor and Washtenaw County to contact thousands of residents and businesses quickly via phone, email, or text. The City of Ann Arbor and Washtenaw County deliver these important notifications by email, text message, or by telephone. This service is free to all residents and businesses located within Washtenaw County. Alerts are broadcast via the following delivery methods:

DRAFT

- Email
- SMS Text
- Cell Phone
- Home Phone
- Twitter
- Facebook

Emergency Outdoor Weather Sirens

The City of Ann Arbor maintains 22 sirens throughout city limits. The sirens are tested every second Tuesday of the month at 1 p.m., with a one-minute wail. Testing of sirens is performed from March through October. Ann Arbor Emergency Management is responsible for activating this system in the event of a Tornado Warning or a Severe Thunderstorm Warning with winds 75 mph or greater. The sirens are used to notify residents to seek shelter indoors.

WaterMatters Newsletter

WaterMatters is a semi-annual newsletter produced by the Water Resources division of the Systems Planning department to share information about all things water.

A² City News

A² City News is an e-newsletter emailed to subscribers by the City of Ann Arbor.

Office of Sustainability and Innovations (OSI) Newsletter

OSI produces a bi-monthly newsletter to give Ann Arbor residents a glimpse into the City's work towards an equitable, healthy, safe, and carbon neutral community. In addition, the OSI provides an annual report highlighting major accomplishments, lessons learned, and priorities for the coming year. Email Notifications

Residents can subscribe to the email service, additionally, they can subscribe to specific topics. In emergency situations, when an emergency alert is activated, the city will send urgent/public safety notifications to all subscribers, bypassing "digest" preferences and regardless of the topic for which you originally subscribed.

Open Town Hall

A2 Open City Hall is an online forum for civic engagement. Residents can read what others are saying about important Ann Arbor topics and post their own statement. City officials read the statements and incorporate them into their decision process.

DRAFT

Community Television Network (CTN)

CTN provides multimedia resources and programming to serve public interests and strengthen the fabric of the Ann Arbor community. CTN can share content via cable, streaming (Roku, Apple, Amazon Fire), smartphone app; CTN local series, promos, PSA's, community messages, and meeting coverage.

Social Media

Ann Arbor shares information with residents through City Facebook, NextDoor, YouTube. and Twitter accounts.

Floodplain Workshops

Ann Arbor's floodplain manager held virtual workshops to provide an overview of proposed regulation changes establishing higher building standards within the floodplain with the intent of minimizing public and private losses due to flooding. Recordings of the workshops are available on the city's YouTube channel.

Sustainability Workshops

OSI offers virtual educational sessions with the opportunity for participants to ask questions. Topics include Sustainable Energy Utility, Intergovernmental Panel on Climate Change (IPCC) report, and the A2ZERO Sustainability Series.

General Public Engagement

OSI conducts nearly a hundred public engagement events every year – working with a wide variety of community stakeholders to engage traditional and non-traditional stakeholders in climate action. These events include large, community-wide forums, organization specific-events, neighborhood events, and customized engagement based on the needs of local stakeholders.

A^{2}ZERO Collaborators Network

Over 100 organizations have joined OSI as A2ZERO Collaborators, committing to supporting at least one action outlined in the A^{2}ZERO plan and working with the City to achieve the goal of a just transition to community-wide carbon neutrality. A list of collaborators can be found here.

Political Capability

One of the most difficult capabilities to evaluate involves the political will of a jurisdiction to enact meaningful policies and projects designed to reduce the impact of future hazard events. Hazard mitigation may not be a local priority or may conflict with the community's growth and economic development goals. Therefore, the local political climate must be considered in designing mitigation strategies as it could be the most difficult hurdle to overcome in accomplishing their adoption and implementation.

The Capability Assessment Review Form was used to capture information on political capability of Ann Arbor. Previous planning efforts were reviewed for general examples of local political capability, such as guiding development away from identified hazard areas, restricting public investments or capital improvements within hazard areas, or enforcing local development standards that go beyond minimum state or federal requirements (i.e., building codes, floodplain management, etc.).

Ann Arbor's commitment to addressing hazards and climate change and political capability is demonstrated by the 2017 Hazard Mitigation Plan, the 2020 A^{2}Zero Carbon Neutrality Plan, and other plans, studies, and ordinance reviewed in this section. Perhaps more important is the inclusion of projects addressing impacts of hazards and climate change, as well as greenhouse gas reduction actions in the city's Capital Improvement Plan. The city successfully funded several flood mitigation projects through grant awards and is transitioning the city's vehicles to electric power.

Conclusion on Local Capability

A Capability Assessment examines local capabilities to detect any existing gaps or weaknesses within ongoing government activities that could hinder proposed mitigation activities and possibly exacerbate community hazard vulnerability. The results of the Capability Assessment form part of the basis for the Mitigation Actions that are identified in Section 6, helping Ann Arbor to improve its ability to mitigate and adapt to the impacts of hazards and climate change.

The conclusions of the Risk Assessment and Capability Assessment serve as the foundation for the development of a meaningful hazard mitigation strategy. During the process of identifying specific mitigation actions to pursue, the city considered not only level of hazard risk, but also the existing capability to minimize or eliminate that risk. The list below outlines key capabilities Ann Arbor can address in the Mitigation Strategy.

Planning and Regulatory Capability

- Comprehensive Plan – The Hazard Mitigation Plan is not one of the eight elements of the Comprehensive Plan, nor is it referenced as a resource document. Ann Arbor is initiating the process to update the Comprehensive Plan and the update will be a great opportunity to incorporate community resilience considerations, including hazard mitigation and climate adaptation, into the City's plans for growth.

Emergency Management

- Emergency Operations Plan - Comprehensive update to the Emergency Operations Plan to include:
  - Dam Failure Inundation Map and Evacuation Plan
  - Continuity of Operations Plan (COOP) – Updating and integrating the city's COOP plans will enhance the city's ability to function during an event and continue to provide services to residents. Similarly, businesses with COOPs return preserve jobs and offer needed goods and services following a hazard event.
  - Cybersecurity Plan
- Disaster Recovery Plan - With the results of this plan's risk assessment, Ann Arbor will know where disasters are likely to occur and what is at risk. Preparing a plan pre-disaster for how to recover and rebuild in those areas that complements the economic development strategy is a small investment with potentially large rewards. Recovery will be smarter and faster with a recovery plan in place and can further the city's economic development goals. This plan should also address post-disaster redevelopment and mitigation policies and procedures. These policies and procedures should account for the expected damage from a base flood or other disaster.
- Community Resilience Program - Resilience hubs and backup power for city-owned housing communities.

Administrative and Technical Capability

- Grant Writer – Ann Arbor has a long list of unfunded projects in the Capital Improvement Plan, and more are identified in this plan's mitigation strategy. Ann Arbor can increase its potential to fund those projects by adding additional grant writing staff to pursue grants from FEMA and other funding agencies.

Floodplain Management

- Develop a comprehensive stormwater master plan to address hotspots, mapping, policy, and funding. The planning process should evaluate public and private detention basins and update the design storm. The plan should consider expanding the regulatory floodplain where appropriate.

DRAFT

Notes

i While the Final Rule for implementing the Disaster Mitigation Act of 2000 does not require a local capability assessment to be completed for local hazard mitigation plans, it is a critical step in developing a mitigation strategy that meets the needs of the region while taking into account their own unique abilities. The Rule does state that a community's mitigation strategy should be "based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools" (44 CFR, Part 201.6(c)(3)).

ii A copy of the Capability Assessment Review Form can be found in Appendix B.

iii Participation in BCEGS is voluntary and may be declined by local governments if they do not wish to have their local building codes evaluated.

iv https://www.a2gov.org/departments/engineering/Pages/Allen-Creek-Railroad-Berm-Project.aspx

DRAFT

Section 6 – Mitigation Strategy

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Introduction

The purpose of the Mitigation Strategy is to provide the City of Ann Arbor with the goals that will serve as guiding principles for future mitigation policy along with an analysis of mitigation actions deemed obtainable to meet those goals and reduce the impact of identified hazards. It is designed to be comprehensive, strategic, and functional in nature:

- In being *comprehensive*, the development of the Mitigation Strategy includes a thorough review of all hazards and identifies extensive mitigation measures intended to not only reduce the future impacts of hazards, but also to help the city achieve compatible economic, environmental, social, and equity goals.
- In being *strategic*, the development of the Mitigation Strategy ensures that the policies and projects proposed for implementation are consistent with pre-identified, long-term planning goals.
- In being *functional,* each proposed mitigation action is linked to established priorities and assigned to specific departments or individuals responsible for their implementation with target completion deadlines. When available, funding sources are identified that can be used to assist in project implementation.

The first step in designing the Mitigation Strategy includes the identification of mitigation goals. Mitigation goals represent broad statements that are consistent with the hazards identified within the plan. These goals set the blueprint for the Mitigation Strategy and encouraged the stakeholders to vision what they wanted to achieve over the next five-year period.

The second step involves the identification, consideration, and analysis of available mitigation measures (i.e., activities, policies, etc.) that lead to identifying mitigation actions that will help achieve the identified mitigation goals. These actions include both hazard mitigation policies (such as the regulation of land in known hazard areas through a local ordinance) and hazard mitigation projects that seek to address specifically targeted hazard risks (such as the acquisition and relocation of repetitive loss structures). Alternative mitigation measures will continue to be considered as future mitigation opportunities are identified, as data and technology improve, as mitigation funding becomes available, and as this Plan is maintained over time.

The third and last step in designing the Mitigation Strategy section is the development of the Mitigation Action Plan. The Mitigation Action Plan represents an explicit and functional plan for each action and is the essential outcome of the mitigation planning process. The Mitigation Action Plan includes a prioritized listing of proposed hazard mitigation actions (policies and projects) for the City of Ann Arbor to complete. Each action has accompanying information, such as those departments or individuals assigned responsibility for implementation, potential funding sources, an estimated implementation schedule for completion and a prioritization status (the process of which was revised during the 2022 plan update). The Mitigation Action Plan provides those departments or individuals responsible for implementing mitigation actions with a clear roadmap that also serves as an important tool for monitoring success or progress over time. The cohesive collection of actions listed in the Mitigation Action Plan can also serve as an easily understood menu of mitigation policies and projects for those local decision makers who want to quickly review the recommendations and proposed actions of the Plan and potentially integrate with other planning documents.

DRAFT

In preparing the 2022 Mitigation Action Plan, members of the City of Ann Arbor Steering Committee considered the overall hazard risk and capability to mitigate the effects of hazards as recorded through the risk and capability assessment process. The mitigation goals were also considered when developing each action. The Steering Committee and TAC refined the action prioritization process which now includes the following categories: feasibility/urgency, equity, climate adaptation, public survey data (project type and hazard of greatest concern), risk reduction/benefits, and costs. Lastly, a thorough review of the Mitigation Strategy from the 2017 City of Ann Arbor Hazard Mitigation Plan was completed to identify progress and align it to the 2022 Mitigation Strategy.

Updating the 2017 Mitigation Strategy

The objective for the 2022 Mitigation Strategy is to have a concise, prioritized, actionable mitigation strategy that will promote successful implementation of hazard mitigation actions over the next 5 years and beyond. While the overall structure from the prior Mitigation Strategy remains intact, the 2022 Mitigation Strategy revamped the 2017 mitigation goals and action plan.

The City of Ann Arbor reviewed, amended, enhanced, and defined five goal statements for the 2022 plan update to align the goals to the current hazard mitigation planning needs of the city and to be reflective of current priorities within the city (including the incorporation of climate resilience and equity considerations). The consultant team used information gathered from the previous plan and discussions with the Steering Committee to recommend a set of goals to the Steering Committee and the TAC, which were reviewed and revised before finalization.

In order for the Steering Committee, TAC, and consultant team to capture the mitigation activities that had taken place over the last five years it was crucial to receive feedback from the Steering Committee and TAC members. The Steering Committee, TAC, and consultant team reviewed the 2017 Mitigation Action Plan. The Steering Committee identified the actions that were completed, implemented, required editing to be more actionable, and actions that should remain in the plan. the status of each of the 2017 actions can be found in Appendix C. New actions were identified during the planning process and incorporated onto the Mitigation Action plan. Meanwhile, the revised prioritization process was developed, refined, and approved by the Steering Committee and TAC.

Updating the 2022 Mitigation Goals

44 CFR Requirement
44 CFR Part 201.6(c)(3)(i): The mitigation strategy shall include a description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.

The primary goal of all local governments is to promote the health, safety, and welfare of its citizens. In keeping with this standard and promoting a proactive and equitable approach to disaster management and risk reduction, the City of Ann Arbor reviewed, revised and ultimately defined five goal statements for the 2022 plan update. The current goals were developed to be reflective of

DRAFT

current priorities within the city (including the incorporation of climate resilience and equity considerations). The goals were initially introduced and reviewed at the Steering Committee Meeting (April 29, 2022). The revised goals were reviewed at the TAC meeting (June 9, 2022). (Of note, specific changes to the goals can be found in the meeting notes found in Appendix C.). The revised goals for the 2022 plan update are presented in Table 6-1.

Table 6-1: 2022 Ann Arbor Hazard Mitigation Plan Goals

	Goals
1	Utilize personal experiences and sciences to inform strategies and decision-making to increase resilience.
2	Develop tailored solutions that result in community members being equitably represented and protected from hazards, focusing on those that are most vulnerable to hazards and climate change.
3	Integrate hazard risk reduction activities into city practices including policy development, procedural implementation, operations, and funding mechanisms.
4	Expand and enhance partnerships between government, businesses, the public, and education to foster more effective mitigation action and build community resilience.
5	Promote public awareness of hazard risk and mitigation actions and sustain public engagement through community champions.

Updating the 2022 Mitigation Actions

In keeping with FEMA requirements for hazard mitigation plan updates, the mitigation actions identified in the previous City of Ann Arbor Hazard Mitigation Plan were evaluated. The initial review of the 2017 Mitigation Strategy was completed by the Steering Committee. In order for the Steering Committee, TAC, and consultant team to capture the mitigation activities that had taken place over the last five years, it was crucial to receive feedback from the Steering Committee and TAC members. There were 57 mitigation actions in the 2017 Mitigation Strategy. Of the 57 total action items in the 2017 Mitigation Strategy, the Steering Committee removed 38 action items because they were completed or are being implemented on an ongoing basis. For the remaining 20 mitigation actions, some actions remained the same, while others were revised to be more inclusive and/or actionable or were combined with new actions. Appendix C includes a table to document the status for each 2017 action and the justification for the changes.

The new mitigation actions were developed with information collected from several sources, including the risk assessment, the capability assessment, existing planning documents, public survey data, and Social Pinpoint (the project's website and a mechanism for public input). As described in *Section 5: Capability Assessment*, the stakeholder interviews were conducted to understand the current capabilities and needs of local departments and agencies. Actions identified during the interviews were included in a draft Mitigation Action Plan.

The following information was collected or assessment for each action:

- Action Number
- Action Name
- Action Description
- Responsible Office
- Hazards Addressed
- Feasibility
- Equity
- Climate Adaptation
- Public Input (Project Type)
- Public Input (Hazard of Greatest Concern)
- Risk Reduction/Benefits
- Costs
- Total Prioritization Score
- Potential Funding Source
- Project Type
- Other Partners Involved

The majority of these categorizations are standard in hazard mitigation plans and were included in the previous mitigation action plan. However, for the 2022 update, the city incorporated a prioritization process that included elements important to the citizenry of Ann Arbor and reflect Ann Arbor's mitigation needs. The prioritization builds upon the FEMA requirements by including considerations for project feasibility, equity, climate resilience, and public input including project type and hazard of greatest concern within this plan. These concepts were discussed at the Steering Committee meetings, TAC meetings, and public meetings and are described in more detail in the section below titled Mitigation Action Prioritization.

The last step in revising the Mitigation Strategy was accomplished through submitting the draft mitigation action plan to the TAC for their review. During the review period, the TAC provided missing required information, additional information regarding the mitigation actions and feedback to eliminate conflicts between different city service areas. Through this process, the final Mitigation Action Plan was developed as presented at the end of this section.

Mitigation Action Implementation Success

It is important to document the mitigation successes that have occurred over the last five years. The Steering Committee captured completed mitigation actions that were identified in the 2017 plan as found in Appendix C. Some highlights include the following:

- Allen Creek Railroad Berm Project: The Allen Creek Railroad Berm economic development/flood mitigation project was successfully completed. The project was funded in part through HMGP funding. Project benefits include reduced the floodplain by seven feet, reduced flood insurance premiums, and is a means for the city to promote non-motorized transportation.

- The city continued participation in the Washtenaw County Hazardous Materials Response Authority, including the Pollution Prevention Program, Emergency Preparedness Plan and Local Emergency Planning Committee (LEPC).
- The city considers up-to-date technology when equipment is purchased, to provide better on-scene performance.
- The city continued assessment and maintenance of the city's siren coverage and warning systems.
- Roads are plowed promptly during snowstorms and plow routes are continually evaluated for effectiveness.
- The city refined evacuation planning with a focus on downtown, special events, and University of Michigan football.
- Backup power sources for streetlights and signals were evaluated and integrated along evacuation routes and high-traffic areas.
- The Technical Advisory Committee was formally adopted by resolution to help manage hazard mitigation activities.
- The city continues to explore opportunities of linking and advancing green Infrastructure projects through the city's Greenway Plan.
- Watershed Management Planning studies are ongoing for the key watersheds located within the region.
- The city hired additional building inspection staff to review new building permits for the use of up-to-date fire-resistant technologies and explored incentive-based programs to encourage residents and business owners to install fire-resistant technologies when building or remodeling a structure.
- Code enforcement programs continue to be implemented to maintain and install heating and cooling equipment.
- As part of inspection programs, the city continued to distribute materials to residents that include fire safety practices through the safety program.
- The citywide notification system is used during citywide disaster events.
- The Urban and Community Forest Management Plan recommendations are being implemented including a pruning cycle to increase the health of trees to reduce their susceptibility to infestation and negative effects on the power grid and increasing the tree canopy to help with the heat island effect.
- An interdepartmental committee/taskforce was implemented and charged with the review of planning documents with respect to hazard mitigation.
- The Floodplain Management Overlay Ordinance was approved to provide residents, property owners and decision makers with the opportunity to consider floodplain and floodway land use independently of other zoning decisions.
- Source and finished water are monitored for indicators of disease-causing organisms and contaminants of emerging concern.
- The city is implementing actions identified in the City of Ann Arbor Stormwater Model Calibration and Analysis Project.
- Implementation of building code requirements to install proper anchors for manufactured home units.
- Public education is available to inform the public regarding the remediation of household hazardous waste that could cause secondary hazard effects in identified vulnerable areas (e.g., floodplains).

DRAFT

- The city is providing floodplain 101 training to city staff and elected officials to foster a greater understanding of flood issues.

Identification and Analysis of Mitigation Techniques

44 CFR Requirement
44 CFR Part 201.6(c)(3)(ii): The mitigation strategy shall include a section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effect of each hazard, with particular emphasis on new and existing buildings and infrastructure.

In formulating the Mitigation Strategy for the City of Ann Arbor Hazard Mitigation Plan, a wide range of activities were considered to help advance the established five mitigation goals, in addition to addressing any specific hazard concerns. In order to help the community and the TAC understand what mitigation activities to consider, the consultant team presented the following six broad categories of mitigation techniques: Prevention, Property Protection, Natural Resource Protection, Structural Projects, Emergency Services, Public Awareness and Education, and Social Cohesion. Presenting mitigation activities examples under these category types helped the decision makers understand the kinds of activities addressed under a Hazard Mitigation Plan. The following provides example activities presented under each category:

Prevention

Preventative activities are intended to keep hazard problems from getting worse and are typically administered through government programs or regulatory actions that influence the way land is developed and buildings are built. They are particularly effective in reducing a community's future vulnerability, especially in areas where development has not occurred, or capital improvements have not been substantial. Examples of preventative activities include:

- Planning and zoning
- Building codes
- Open space preservation
- Floodplain regulations
- Stormwater management regulations
- Drainage system maintenance
- Capital improvements programming
- Riverine / fault zone setbacks

DRAFT

Property Protection

Property protection activities involve the modification of existing buildings and structures to help them better withstand the forces of a hazard, or removal of the structures from hazardous locations. Examples include:

- Acquisition
- Relocation
- Building elevation
- Critical facilities protection
- Retrofitting (e.g., windproofing, floodproofing, seismic design techniques, etc.)
- Safe rooms, shutters, shatter-resistant glass
- Insurance

Natural Resource Protection

Natural resource protection activities reduce the impact of natural hazards by preserving or restoring natural areas and their protective functions. Such areas include floodplains, wetlands, and steep slopes. Parks, recreation, or conservation agencies and organizations often implement these protective measures. Examples include:

- Floodplain protection
- Watershed management
- Riparian buffers
- Erosion and sediment control
- Wetland preservation and restoration
- Habitat preservation
- Slope stabilization
- Forest and vegetation management (e.g., fire resistant landscaping, fuel breaks, etc.)

Structural Projects

Structural mitigation activities are intended to lessen the impact of a hazard by modifying the environmental natural progression of the hazard event through construction. They are usually designed by engineers and managed or maintained by public works staff. Examples include:

- Reservoirs
- Dams / levees / dikes / floodwalls
- Diversions / detention / retention
- Channel modification

DRAFT

- Storm sewers

Emergency Services

Although not typically considered a "mitigation" technique, emergency service activities do minimize the impact of a hazard event on people and property. These commonly are actions taken immediately prior to, during, or in response to a hazard event. Examples include:

- Warning systems
- Evacuation planning and management
- Emergency response training and exercises
- Sandbagging for flood protection
- Installing temporary shutters for wind protection

Public Education and Awareness

Public education and awareness activities are used to advise residents, elected officials, business owners, potential property buyers, and visitors about hazards, hazardous areas, and mitigation techniques they can use to protect themselves and their property. Examples of measures to educate and inform the public include:

- Outreach projects
- Speaker series / demonstration events
- Hazard map information
- Real estate disclosure
- Library materials
- Educational programs for school children
- Hazard expositions
- Social Media

Social Cohesion

Social cohesion refers to the "strength of relationships and the sense of solidarity among members of a community."[iii] Actions that help residents build and maintain relationships with each other (especially neighbors), create shared plans, and develop shared resources to jointly prepare for, withstand, and recover from hazards are social cohesion projects.

Examples of social cohesion projects include:

- Resilience hubs

DRAFT

- Block party / parade
- Storm drain clean up
- Free little libraries/pantries

Mitigation Action Prioritization

During the 2022 planning process the TAC refined the mitigation action prioritization process. Mitigation action prioritization emphasizes the extent to which benefits are maximized, according to a review of the proposed projects and their prioritization categories. Through the scoring, the higher the number of points the higher priority the mitigation action was determined to be for the city. The prioritization process included prioritization metrics, weighting factor, and scoring criteria. Seven prioritization categories were selected: feasibility, equity, climate resilience, public input including project type and hazard of greatest concern, risk reduction/benefits, and costs. The weighting factor contributed to the final score and ranged between 10-20% depending on the prioritization metric. The scoring ranged from 0-5 for each prioritization metric as shown in Table 6-2 below.

The scoring criteria for the prioritization metrics are as follows:

- Feasibility: Considered whether funding was identified and the degree of ease or complexity of the proposed project implementation.
- Equity: Equity is the consistent and systematic fair, just, and impartial treatment of all individuals. The city considered a couple of approaches for the scoring criteria for equity and selected the Opportunity Index for Washtenaw County. More information regarding the Opportunity Index for Washtenaw County can be found at User Guide (opportunitywashtenaw.org). The current categories in the index include the following:
    - Very low access to opportunity
    - Low access to opportunity
    - High access to opportunity
    - Very high access to opportunity

From an equity perspective, the scoring was based on whether the action will benefit citizens who have low access to opportunities. If the action benefits citizens with lower access to opportunity a higher score was applied. For future scoring, as structural projects are identified and can be geospatially located, they can be further categorized based on their locations consistent with Opportunity Index.

- Climate Resilience: Resilience is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions.[iii] The city views resilience as the ability to bounce forwards, not backwards. This definition acknowledges that the climate is changing and there is a need to build the ability of residents, neighborhoods, ecosystems, and processes to bounce forward and remain flexible.

- Public Input: Public input was solicited through a survey and data collected through Social Pinpoint on the city's website. More information regarding the survey and Social Pinpoint are located in Section 2. Planning Process. For purposes of prioritizing actions in the mitigation strategy two of the survey questions were incorporated into the prioritization.
    - Project type: The public was asked to identify and rank the projects that were important to them. The following project types were included: prevention, emergency services, natural resources protection, public education and awareness, structural projects, property protection, and social cohesion projects.
    - Hazard of greatest concern: The public was asked to identify the hazards of greatest concern. The hazards included in the prioritization: More extreme rain/flood, heat, thunderstorm, tornado, winter weather, loss and change of vegetation, reduced air quality, habitat disruption, and in migration of people to the area from areas severely impacted by climate change.
- Risk Reduction/Benefits: Risk reduction includes the proactive measures a community takes to reduce the impacts of risks, including hazards on the economic, social, and environmental losses avoided or benefits gained by the action.
- Costs: Project costs for purposes of the scoring criteria ranged from predominantly staff time to more than $500,000.

Table 6-2: Mitigation Action Prioritization

Prioritization Metric		Weighting Factor	Scoring Criteria
1	Feasibility	20%	5 – Funding identified, easily implemented within five years 3 – Funding identified, implemented with only moderate complexity or delays 1 – Funding identified, implementation is complex and faces certain delays for implementation 0 – Not feasible, no funding identified and/or not able to be implemented
2	Equity (as tied to Opportunity Index)	20%	5 – Very low access to opportunity 3 – Low access to opportunity 1 – High access to opportunity 0 – Very high access to opportunity
3	Climate Resilience	20%	5 – Very High (Action provides multiple benefits for climate resilience, including greenhouse gas or adaptive measures) 3 – High (Action provides at least one benefit for climate resilience) 1 – Moderate (Action provides limited benefits for climate

Prioritization Metric		Weighting Factor	Scoring Criteria
			resilience) 0 – Low (Action does not provide benefits for climate resilience)
4	Public (Project Type)	10%	5 – Prevention 5 – Emergency Services 3 – Natural Resources Protection 3 – Public Education and Awareness 3 – Structural Projects 1 – Property Protection 1 – Social Cohesion Projects
5	Public (Hazard of greatest concern)	10%	5 – Action addresses one or more hazards identified for the public as of greatest concern (More extreme rain/flood, heat, thunderstorm, tornado, winter weather) 3 – Action addresses one or more hazards identified for the public as of lesser concern (Loss and change of vegetation (including trees), Reduced air quality, habitat disruption) 1 – Action addresses one or more hazards identified for the public as of least concern (In-migration of people to the area from areas more severely impacted by climate change)
6	Risk Reduction/Benefits	10%	5 – Very High (Significant losses avoided and/or significant benefits with consideration to economic, social, and environmental factors) 3 – High (Numerous losses avoided and/or numerous benefits with consideration to economic, social, and environmental factors) 1 – Moderate (Some losses avoided, some benefits with consideration to economic, social, and environmental factors) 0 – Low (No losses avoided, no public benefits with consideration to economic, social, and environmental factors)
7	Costs	10%	5 – Project Costs are predominantly staff time 3 – Project Costs are estimated between $0-$100,000

DRAFT

Prioritization Metric		Weighting Factor	Scoring Criteria
			1 – Project Costs are estimated between $100,001-$500,000 0 – Project Costs are estimated above $500,000
Total		100%	Sum of parameter scores (max = 500)

Once the actions were prioritized, the action priority was classified based on scoring as shown in the Prioritization Table below (Table 6-3). It should be noted that the prioritization methodology provides a mechanism for benefit-cost review, though a more detailed benefit-cost analysis is likely required for future grant applications.

Table 6-3: Prioritization Matrix

Prioritization Matrix	
Prioritization	Points
Very High	500 – 375
High	374 – 250
Medium	249 – 125
Low	124 – 0

As actions are completed and new actions are identified the prioritization may include actions that fall in the lower prioritizations.

2022 Mitigation Action Plan

As noted throughout this section, the 2022 Mitigation Strategy section incorporated significant changes to accommodate city needs, priorities and a more actionable plan.

The mitigation actions were organized by Mitigation Technique Categories (Prevention; Property Protection; Natural Resource Protection; Structural Projects; Emergency Services; Public Education and Awareness). By organizing the mitigation actions by mitigation technique categories one can see that there was a broad range of mitigation action types captured within this plan. Table 6-4 provides a breakdown of how many mitigation actions there are per mitigation technique category, while Table 6-5 presents the entire Action Plan.

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Table 6-4: Number of Mitigation Action by Technique Category

Mitigation Category	Number of Actions
Emergency Services	16
Natural Resource Protection	5
Prevention	15
Property Protection	9
Public Education/Awareness	11
Structural Projects	1
Social Cohesion Projects	
Total	57

As described earlier in this section, the following key elements are captured within the Mitigation Action Plan to help the city track each action over the next five years.

- Action Number
- Action Name
- Description
- Responsible Entity
- Hazard(s) Addressed
- Feasibility
- Equity
- Climate Resilience
- Public (Project Type)
- Public (Hazard of Greatest Concern)
- Risk Reduction/Benefits
- Estimated Costs
- Priority
- Potential Funding Source
- Project Type
- Lead Implementer/Other Partners
- Implementation Schedule
- Comments and Status

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Table 6-5: 2022 Mitigation Action Plan

Action # (does not indicate priority)	Action Name	Description	Responsible Entity	Hazard	Feasibility	Equity (as tied to Opportunity Index)	Climate Resilience	Public (Project Type)	Public (Hazard of greatest concern)	Risk Reduction /Benefits	Estimated Costs	Total Prioritization Score	Potential Funding Source	Project Type	Other Partners	Implementation Schedule
1	Stormwater Master Plan	Develop a stormwater master plan to address localized flooding with structural and non-structural recommendations/projects to mitigate flooding. The stormwater masterplan will include a public engagement framework and will incorporate relevant studies, new data (contours, NOAA rainfall data etc.), the design storm for sizing infrastructure (sanitary and stormwater), climate change impacts, impacts of climate migration, funding options, and an assessment of policy/ordinance modifications for stormwater detention and construction in the floodplain.	Systems Planning, Engineering, Planning, Office of Emergency Management	Flood and Extreme Precipitation	100	60	60	50	50	30	10	360	Operating Budget	Prevention	OECD	2026
2	Flood Information Campaign	Working in collaboration with CRS requirements continue to develop and update, as needed, the robust flood public information campaign using the following elements: brochures, mailings, displays, articles, videos, signs, presentations, and emergency action plans. Consider incorporating products in the stormwater master plan public framework.	Systems Planning, Red Cross, HRWC, CTN - Rain Ready Program	Flood and Extreme Precipitation	100	60	60	50	50	30	30	380	Operating Budget	Prevention	0	2023
3	Swift Run Marsh Weir	Swift Run Marsh Weir has been studied and determined that dredging and weir modifications are necessary to reduce downstream flooding. The next step is project design.	Engineering, Systems Planning, Office of Emergency Management	Flood and Extreme Precipitation	60	20	60	30	50	30	30	280	Operating Budget	Prevention	0	2027
4	Next Steps to Advance the Floodplain Management Overlay Zoning District	Research and conduct public outreach to determine feasible options to reduce risk through modifications to the Floodplain Management Overlay Zoning District considering floodway restrictions in the floodplain and flood fringe and development of local floodplain district for areas beyond the SFHA. These are potential options that have been identified to date: •Apply floodway restrictions to the flood fringe (no new buildings, no residential in redevelopment)	Engineering, Planning, Systems Planning	Flood and Extreme Precipitation	60	60	60	50	50	30	30	340	Operating Budget	Prevention	0	2025

		•Apply flood fringe restrictions to the 0.2% flood area (expand district) •Create “Local” floodplain district for areas beyond FEMA floodplain like shown in our Stormwater model														
5	Repetitive Loss Area Analysis	Develop a repetitive loss area analysis (RLAA) plan meeting CRS requirements for areas that have or are expected to experience repeated losses from flooding to understand the causes of repetitive flood damage at those locations.	Systems Planning, Office of Emergency Management, Engineering	Flood and Extreme Precipitation	60	60	60	50	50	30	30	340	Operating Budget	Prevention	0	2027
6	Flood Disclosure for Rentals	Assess and document the feasibility of flood disclosure (e.g., form), and educational information as part of lease agreements for residential properties.	Office of Emergency Management, Systems Planning	Flood and Extreme Precipitation	100	60	60	30	50	10	50	360	Operating Budget	Prevention	0	2024
7	Substantial Damage Management Plan	Develop a substantial damage management plan per National Flood Insurance Program (NFIP) and Community Rating System (CRS) requirements. The plan will serve as a tool to meet the following needs: educate the public and community leaders, detail mitigation strategies, describe procedures for conducting post-flood substantial damage determinations, including steps the community will take to address substantially damaged buildings.	Office of Emergency Management, Systems Planning, Planning, Engineering	Flood and Extreme Precipitation	60	60	60	50	50	30	30	340	Operating Budget	Prevention	0	2025
8	Flood Education and Outreach	Develop content for flooding outreach and education to educate the public and elected officials regarding the various types of flooding impacting Ann Arbor including riverine and localized flooding from undersized or lack of stormwater infrastructure.	Systems Planning, Planning, Engineering, Office of Emergency Management	Flood and Extreme Precipitation	100	60	60	30	50	10	30	340	Operating Budget	Public Education and Awareness	0	2025
9	EOP and COOP Update	Develop/update a state-approved, NIMS-compliant Emergency Operations Plan (EOP) and Continuity of Operations Plan (COOP) inclusive of lessons learned during the COVID-19 pandemic.	Office of Emergency Management	All Hazards	100	60	100	50	50	30	30	420	Operating Budget	Emergency Services	Washtenaw County, University of Michigan, and Ann Arbor Public Schools.	2026

10	Create Community Resilience Networks	Create community resilience networks with key community partners (i.e., schools, child care facilities, long-term care facilities, etc.	Office of Emergency Management	All Hazards	100	60	100	50	50	30	30	420	Operating Budget	Emergency Services	Washtenaw County, University of Michigan, and Ann Arbor Public Schools.	2026
11	Cybersecurity Plan	Develop Cybersecurity Plan, including Continuity of Operations Plan as part of the EOP updates. Include cybersecurity in future emergency planning exercises.	IT, Office of Emergency Management	Cyber-Attacks	100	60	20	50	10	10	30	280	Operating Budget	Prevention	0	2025
12	Dam Safety Program EAP Exercises	Enhance EAP exercises and communicate findings and necessary improvements after Emergency Action Plan exercises at dams (including HHPD) to key stakeholders in the planning process and emergency exercises.	Water Treatment Plant Services Unit, Office of Emergency Management	Dam Failure	100	20	60	50	50	30	30	340	Operating Budget	Emergency Services	0	Based on EAP requirements
13	Update Dam Inundation Maps	Update dam (including HHPD) inundation maps and depict dam failure inundations areas on Ann Arbor Geographic Information System (A2Spatial).	Water Treatment Plant Services Unit	Dam Failure	100	20	60	50	50	30	30	340	Operating Budget	Emergency Services	0	Based on EAP requirements
14	Dam Evacuation Maps, Shelter Plan, and Strategic Exercise Plan	Develop dam (HHPD) evacuation maps and a shelter plan, and develop a FERC and HSEEP compliant strategic exercise plan that includes a framework for after-action plan implementation.	Office of Emergency Services, Water Treatment Plant Services Unit	Dam Failure	100	20	60	50	50	30	30	340	Operating Budget	Emergency Services	0	Based on EAP requirements
15	Hazard Response Training Events	Develop a training and exercise program designed to educate key emergency response stakeholders, City leadership, community partners etc. and test the validity of the City's EOP and COOP plans.	Office of Emergency Management	All Hazards	100	60	60	50	50	30	30	380	Operating Budget	Emergency Services	Multiple City Departments	2024
16	Post-disaster Planning	Develop Disaster Recovery Plan that addresses post-disaster redevelopment and mitigation policies and procedures. These policies and procedures should account for the expected damages from a base flood or other disaster.	Office of Emergency Management, Planning, Engineering, Systems Planning	All Hazards	100	60	100	50	50	10	30	400	Operating Budget, Grant	Emergency Services	0	2026
17	Expand Green Space and Green Infrastructure	Capitalize on opportunities to install green infrastructure projects on existing city-owned/managed property such as through street resurfacing projects, park re-designs, and right-of-way enhancements.	Systems Planning Unit, City Attorney, Planning	Flood and Extreme Precipitatio n	100	20	20	30	50	10	30	260	Operating Budget	Natural Resources Protection	Operations	2023

DRAFT

18	Vulnerable Populations	Implement the following policies to support vulnerable populations in the city: Publicize information about the special needs registry and how residents with special needs can register themselves. Develop a community resilience public engagement strategy that focuses on building partnerships and creating space for vulnerable populations to share their lived experiences and use this information to help shape the City's approach to emergency planning and mitigation. Include Housing Commission and other low-income and senior housing entities in EOP update. Complete the content for citizen engagement and implement the equitable engagement steering committee.	Office of Emergency Management, Housing Commission, Office of Sustainability and Innovation	All Hazards	100	60	100	50	50	30	50	440	Operating Budget	Social Cohesion Projects	Libraries, Community and Economic Development, Avalon	2023
19	Vulnerability Assessments	Incorporate climate forecasts and utilize worst-case scenarios in vulnerability assessments.	Office of Emergency Management, HRWC	All Hazards	60	60	100	50	50	50	30	400	Grant, Operating Budget	Prevention	0	2026
20	Comprehensive Plan	Incorporate hazard mitigation and climate adaptation in the Comprehensive Plan Update, including adopting the Hazard Mitigation Plan as an annex.	Planning, Planning Systems	All Hazards	60	60	100	50	50	30	50	400	Operating Budget	Prevention	0	0
21	Air Quality Monitoring	Assess the need, location, and parameters for air quality monitoring in areas of the City that have not historically been monitored for prioritization and potential funding.	Engineering	HAZMAT – fixed and transportation	60	60	60	30	30	10	30	280	Operating Budget, Grant	Natural Resources Protection	0	2027
22	Potable Water Recovery Plan	Develop a potable water recovery plan for disasters and system impacts including the identification of resources for more frequent preventative maintenance for the system.	Water Treatment	HAZMAT – fixed and transportation	60	60	100	50	50	30	10	360	Operating Budget	Prevention	0	2026
23	Action Plan for Public Housing	Develop and implement an action plan to increase resiliency by assisting residents in existing and future public facilities owned by the Housing Commission during disasters including resilience hubs and measures to mitigate impacts to communication systems and the loss of basic necessities (including food, medicines, and power), identify and prioritize locations requiring emergency generators and/or redundant power, and identify funding sources and resources for assistance.	Office of Emergency Management, Housing Commission	All Hazards	60	60	100	50	50	30	30	380	Operating Budget	Emergency Services	Operations	2026

DRAFT

24	Covid Response Debrief	Hold debrief with agencies regarding Covid response and lessons learned for application to future disasters.	Office of Emergency Management, City Departments and Stakeholders	Public Health Emergencies	100	60	100	50	50	30	50	440	Operating Budget	Prevention	Operations	2023
25	Funding for IT	Identify additional funding sources and resources needed to maintain IT needs, including security and infrastructure.	IT	Cyber-Attacks	100	20	60	50	50	10	30	320	Operating Budget	Prevention	0	2024
26	Fire Station No. 4	Complete design and construction for Fire Station No. 4 which is planned to be a net zero energy facility.	Ann Arbor Fire Department, Office of Emergency Management	All Hazards	100	20	20	50	50	10	0	250	Operating Budget	Structural Projects	0	0
27	Grant Strategy	Develop an explicit strategy for applying for grants (e.g. BRIC), including the purchase and removal of structures in the floodplain	Systems Planning Unit	All Hazards	60	60	100	50	50	30	10	360	Operating Budget, HMGP, BRIC, FMA	Prevention	0	2026
28	Energy Assurance Strategy	Develop an energy assurance strategy for critical facilities.	Office of Emergency Management, Office of Sustainability and Innovation	All Hazards	60	60	100	50	50	30	30	380	Operating Budget	Emergency Services	0	2027
29	Flood Hazard Vulnerable Property Identification	Use the Hazard Mitigation Plan flood risk assessment (Section 4) and other relevant flood modeling information to identify vulnerable properties (such as affordable housing) and review potential mitigation improvements and develop emergency action plans to prepare for flood events.	Office of Emergency Management, Planning Systems, Housing Commission	Flood and Extreme Precipitation	60	60	60	50	50	30	30	340	Operating Budget	Prevention	0	2027
30	Floodplain Studies	The SWMM model shows three areas that indicate flooding beyond FEMA's model. As a result, the City is currently working with FEMA to do a LOMR for the Allen Creek area. The two other areas are on Malletts Creek. Alternatives will be explored for future modeling of the Malletts Creek areas such as the approach being taken for the Allen Creek area.	Planning Systems, Office of Emergency Management	Flood and Extreme Precipitation	60	60	100	50	50	30	10	360	Operating Budget	Prevention	0	2027
31	Hardening Measures for City-Owned Buildings	The city is planning and implementing hardening measures to strengthen security at city-owned buildings.	Office of Emergency Management	All Hazards	60	60	60	30	50	10	10	280	Operating Budget	Emergency Services	0	2027
32	Structural Integrity of City Managed Infrastructure	Coordinate with appropriate departments/agencies regarding the structural integrity of traffic signals, aerial fiber, power lines, signs, communication, and other city managed infrastructure that may be impacted by severe weather. A list of infrastructure will be developed along with the responsible department and whether structural components	Office of Emergency Management, Planning Systems, Public Works	All Hazards	60	60	100	50	50	10	10	340	Operating Budget	Prevention	0	2027

DRAFT

		are evaluated and if so, the results.														
33	Power and communications mitigation	When updating asset management plans incorporate climate change impacts into the analysis to reflect changes in maintenance, monitoring, and infrastructure refurbishment cycles.	Systems Planning	All Hazards	60	20	100	50	50	30	30	340	Operating Budget	Prevention	0	2027
34	Acquire at risk properties	Voluntarily acquire properties at risk of flooding as opportunities arise with a priority on properties that are in the floodway, advance the treeline, or connected to an existing park.	Office of Emergency Management, Systems Planning	All Hazards	60	20	60	50	50	10	10	260	Operating Budget	Prevention	0	2027
35	Grant application for next hazard mitigation plan update	Apply for a grant to update the next iteration of the city's hazard mitigation plan well in advance of next cycle (2024 FEMA non-disaster grant cycle)	Office of Emergency Management	All Hazards	100	20	100	50	50	30	50	400	Operating Budget	Prevention	0	2024

DRAFT

Notes

[i] Kawachi, I. and Berkman, L.F. (2000) Social cohesion, social capital and health. In: Berkman, L.F. and Kawachi, I., Eds., Social Epidemiology, Oxford University Press, New York, 147-190.[ii]

[ii]Federal Emergency Management Agency (2021). FEMA Resources for Climate Resilience. Retrieved June 24, 2022 from https://www.fema.gov/sites/default/files/documents/fema_resources-climate-resilience.pdf

Section 7 – Plan Maintenance

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Implementation and Integration

44 CFR Requirement
44 CFR Part201.6(c)(4)(i): The plan shall include a plan maintenance process that includes a section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle. *44 CFR Part 201.6(c)(4)(ii): The plan maintenance process shall include a process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.*

Implementation

Each agency, department, or other partner participating under the City of Ann Arbor Hazard Mitigation Plan is responsible for implementing specific mitigation actions as prescribed in the Mitigation Action Plan. Every proposed action listed in the Mitigation Action Plan is assigned to a specific "lead" agency or department in order to assign responsibility and accountability and increase the likelihood of subsequent implementation.

In addition to the assignment of a local lead department or agency, an implementation time period or a specific implementation date has been assigned in order to assess whether actions are being implemented in a timely fashion. The city will seek outside funding sources to implement mitigation projects in both the pre-disaster and post-disaster environments. When applicable, specific potential funding sources have been identified for proposed actions listed in the Mitigation Action Plan.

To further promote implementation, the Steering Committee intends to meet bi-annually (twice a year). A key agenda item will be to review which actions are being implemented and to update the action plan accordingly. The action plan will be posted to the city's website for public transparency and to meet Community Rating System (CRS) requirements. To further facilitate implementation, the Steering Committee, led by the city's Emergency Management Coordinator, will create working groups for each of the actions that are deemed to be high priority for completion in the next five years. It is likely that members of the Technical Advisory Group (TAC) will be assigned to the working groups, and they will also be engaged through updates on the action status (twice a year via email) and through educational opportunities as they arise.

Integration

The city will integrate this Hazard Mitigation Plan into relevant city government decision-making processes, plans, and mechanisms where feasible. This includes integrating the Hazard Mitigation Plan into other local planning documents, processes, or mechanisms, such as comprehensive or capital improvement plans, when appropriate.

DRAFT

The members of the Steering Committee and the TAC are charged with ensuring that the plans for their respective agency or city service area incorporates or aligns with the goals and actions of the Hazard Mitigation Plan. The committee members are actively committed to advancing resilience within their organizations and reducing hazard vulnerability across the city.

Since the previous plan was adopted, the city has worked to integrate the Hazard Mitigation Plan into other planning mechanisms where applicable/feasible. Examples of this integration is documented in Section 5: Capability Assessment. Specific examples include:

- Integrating the mitigation plan into creation of new Floodplain Management Overlay Zoning District;
- Integrating the mitigation plan into reviews and updates for the Community Rating System.

Opportunities to further integrate the requirements of this Plan into other local planning mechanisms shall continue to be identified through future planning efforts. The city Planning Manager outlined the mechanisms underway and under consideration:

- Integration of the city's Mitigation Plan is considered on a case-by-case basis and identified at the onset of plan development;
- Capital improvement projects are scored on a variety of factors including: 1) Safety/Compliance/Emergency Preparedness; 2) Funding 3) Coordination with Other Projects; 4) Innovation; and 5) Partnerships. This scoring matrix can be found in Appendix C;
- Per State of Michigan enabling legislation (e.g., Municipal Planning Act and the Township Planning Act), when the city undertakes a master planning process, the city communicates their intent to outside agencies, adjacent jurisdictions, utilities, and other entities at the start of a planning process. The draft document is also distributed to these stakeholders for comment. The city will evaluate expanding this distribution process, beyond the minimum prescribed by law, to include the TAC, or other stakeholders to best capture the data, information, and concern pertaining to hazard mitigation.

Monitoring, Evaluation and Enhancement

Periodic revisions and updates of the Hazard Mitigation Plan are required to ensure that the goals of the Plan are kept current, taking into account potential changes in hazard vulnerability and mitigation priorities. In addition, revisions may be necessary to ensure that the Plan is in full compliance with applicable federal and state regulations. Periodic monitoring and evaluation of the Plan will also ensure that specific mitigation actions are being reviewed and carried out according to the Mitigation Action Plan.

The Steering Committee shall meet bi-annually (twice a year) to monitor and evaluate the progress attained and to revise, where needed, the activities set forth in the Plan. In addition, distinct working groups will be created to monitor the progress of specific actions. The working groups will be encouraged to meet monthly and will provide bi-annual updates on progress. These meetings

DRAFT

will also assist in fulfilling elements of the 510 Community Rating System requirements. The bi-annual meetings provide the Steering Committee with an opportunity to:

- Evaluate actions that have been successfully implemented;
- Determine if additional support is needed to advance near-term actions;
- Update the TAC and the public on action status;
- Document hazard occurrences and impacts;
- Explore the possibility of documenting potential losses avoided due to the implementation of specific mitigation measures; and
- Identify any new or additional vulnerabilities that may be faced by the city and may need to be addressed in a future update of this Plan.

The findings and recommendations of the Steering Committee shall be documented in the form of a report that can be shared with interested stakeholders, including City Council members and the public at least once annually. This report, which includes, at minimum, the Mitigation Action Plan, will be posted to the city's hazard mitigation planning website. The Steering Committee will also meet following any disaster events warranting a reexamination of the mitigation actions being implemented or proposed for future implementation. This will ensure that the Plan is continuously updated to reflect changing conditions and needs within the city. The city's Emergency Management Coordinator will be responsible for reconvening the Steering Committee for these reviews.

Five Year Plan Review and Update

The Plan will be thoroughly reviewed by the Steering Committee and the TAC every five years in alignment with federal regulations. This update is also used to determine whether there have been any significant changes in the city that may, in turn, necessitate changes in the types of mitigation actions proposed, goals, or priorities. New development in identified hazard areas, an increased exposure to hazards, an increase or decrease in capability to address hazards, and changes to federal or state legislation are examples of factors that may affect the necessary content of the Plan. The Ann Arbor Emergency Management Coordinator will be responsible for reconvening the TAC and conducting the five-year review.

Upon completion of the review and update/amendment process, the City of Ann Arbor Hazard Mitigation Plan will be submitted to the State Hazard Mitigation Officer at the Michigan State Police, Division of Emergency Management and Homeland Security for a compliance review. Upon passing the state review, the Plan is escalated to the Federal Emergency Management Agency for a final compliance review. Once all requirements have been deemed met by FEMA, the agency will grant an "approved pending adoption" status to the city. City Council will then review, approve, and adopt the Plan. The city review consists of review by the Environmental Planning Commission, Planning Commission with final approval by City Council.

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Disaster Declaration

Following a disaster declaration, the City of Ann Arbor Hazard Mitigation Plan may be revised as necessary to reflect lessons learned, or to address specific issues and circumstances arising from the event. It will be the responsibility of the City of Ann Arbor Emergency Management Director to reconvene the TAC and ensure the appropriate stakeholders are invited to participate in the Plan revision and update process following declared disaster events.

Plan Amendment Process

Unique circumstances, such as availability of critical data or an omission, may necessitate a plan amendment. Upon the initiation of the amendment process by Steering Committee as led by the Emergency Management Coordinator, the city will forward information on the proposed change(s) to all interested parties including, but not limited to, all directly affected city service areas, community partners, residents, and businesses. Information will also be forwarded to Michigan State Police, Division of Emergency Management and Homeland Security, and FEMA. This information will be disseminated in order to seek input on the proposed amendment(s) for no less than a 45-day review and comment period (unless circumstances necessitate a shorter review).

At the end of the 45-day review and comment period, the proposed amendment(s) and all comments will be forwarded to the TAC for final consideration. The TAC will review the proposed amendment along with the comments received from other parties, and if acceptable, the TAC will submit a recommendation for the approval and adoption of changes to the Plan.

In determining whether to recommend approval or denial of a plan amendment request, the following factors will be considered by the TAC:

- There are errors, inaccuracies, or omissions made in the identification of issues or needs in the Plan;
- New issues or needs have been identified that are not adequately addressed in the Plan;
- There has been a change in information, data, or assumptions from those on which the Plan is based.

If the TAC opts to move forward with the amendment, the revised Plan must be reviewed and approved by the state and FEMA. City Council will also need to approve and adopt the revised Plan. Prior to adoption, City Council shall hold a public meeting. The City Council will review the recommendation from the TAC (including the factors listed above) and any oral or written comments received at the public hearing. Following that review, the governing bodies will take one of the following actions:

- Adopt the proposed amendments as presented;
- Adopt the proposed amendments with modifications;
- Refer the amendments request back to the TAC for further revision; or
- Defer the amendment request back to the TAC for further consideration and/or additional hearings.

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Continued Public Involvement

44 CFR Requirement
44 CFR Part 201.6(c)(4)(iii): The plan maintenance process shall include a discussion on how the community will continue public participation in the plan maintenance process.

Public participation is an integral component to the mitigation planning process and will continue to be essential as this Plan evolves over time. Public involvement procedures were reviewed as part of the 2022 plan update. As described above, significant changes or amendments to the Plan shall require a public hearing prior to any adoption procedures. Outcomes of the bi-annual Steering Committee are posted to the city's website, which is accessible to the public. In addition, Ann Arbor regularly posts information about hazard and risk assessment on city communication channels (e.g., social media and e-newsletters). This is led by the Public Information Officer. Any updates and the most current version of the Plan are posted the city's hazard mitigation planning website at the following link: Hazard Mitigation Plan (a2gov.org).

By keeping the Plan available on the city's website with an open invitation and instructions to provide feedback, public awareness and comment opportunities will be maintained on a round-the-clock basis, 365 days per year.

Other efforts to involve the public in the maintenance, monitoring, evaluation, and revision process will be made as necessary. These efforts may include:

- Designating willing and voluntary citizens and private sector representatives as official members of the TAC or action working groups;
- Utilizing available city channels and local media to update the public on any maintenance and/or periodic review activities taking place;
- Keeping a current version of the Hazard Mitigation Plan posted on the city's website and available by request.

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