CITY OF TULSA

2024 MULTI-HAZARD MITIGATION PLAN

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TABLE OF CONTENTS

Chapter 1: Introduction....7
1.1. Introduction....7
1.2. Community....7
1.3. Resilient Tulsa....9
1.4. Community Assets....12

Chapter 2: Planning Process....19
2.1. Hazard Mitigation Planning and the Community Rating System....19

Chapter 3: Capability....25
3.1. Types of Capabilities....25
3.2. National Flood Insurance Program (NFIP)....26
3.3. Flood and Stormwater Management....27
3.4. Planning and Regulatory Capabilities....32
3.5. Administrative and Technical Capabilities....36
3.6. Financial Capabilities....40
3.7. Education and Outreach Capabilities....41

Chapter 4: Risk Assessment....43
4.1. Flood....45
4.2. Severe Winter Storms....61
4.3. High Wind and Tornado....67
4.4. Dam/Levee Incidents....77
4.5. Extreme Heat....96
4.6. Fire....99
4.7. Hailstorm....105
4.8. Drought....109
4.9. Expansive Soils, Subsidence and Erosion....112
4.10. Lightning....116
4.11. Earthquake....120
4.12. Ransomware....123

Chapter 5: Mitigation Strategy....126
5.1. Mitigation Goals....126
5.2. Goals for All Hazards....127
5.3. Recommended Mitigation Actions....128
5.4. Financial Assistance for Hazard Mitigation Actions....146

Chapter 6: Plan Adoption and Maintenance....148
6.1. Introduction....148

Appendix A: Planning Team....151

Appendix B: Critical Facilities....153

Appendix C: Strategies....167
C.1. FEMA Hazard Mitigation Strategies....167
C.2. Public Information and Education....170
C.3. Preventive Measures....175
C.4. Structural Projects....185
C.5. Property Protection....188
C.6. Emergency Services....194
C.7. Natural Resource Protection....201

Appendix D: Public Engagement....205

Appendix E: Major Employers....218

Appendix F: High Hazard Potential Dam (HHPD) Amendment....220
F.1. Introduction....220
F.2. Hazard Profile: High Hazard Potential Dam....220
F.3. Location and Extent....222
F.4. Probability of Future Occurances....227
F.5. Vulnerability & Risk Assessment....227
F.6. Mitigation Strategy....239
F.7. Recommended Mitigation Actions....239

CHAPTER 1
INTRODUCTION

1.1 Introduction

This document is the Multi-Hazard Mitigation Plan 2024 Update for the City of Tulsa, Oklahoma. This plan update is developed according to and fulfills the requirements for the Community Rating System Plan (CRS) from FEMA. The plan addresses natural and manmade hazards affecting people and property in the City of Tulsa.

1.1.1 Purpose and Scope

Mitigation is most effective when it is based on a comprehensive, long-term plan developed before a disaster occurs. Mitigation planning aims to identify local policies and actions that can be implemented over the short- and long-term to reduce risk and future losses from hazards. The objective of this plan is to guide mitigation activities for the next five years. It will ensure that the City of Tulsa implements hazard mitigation activities that are most effective and appropriate for the hazards that threaten the community. The scope of the City of Tulsa Multi-Hazard Mitigation Plan Update is citywide. The plan addresses short-term and long-term hazard mitigation opportunities beyond existing federal, state, and local funding programs.

1.1.2 Goal

The overall goal of the City of Tulsa Multi-Hazard Mitigation Plan is to create a disaster-resistant community and improve the safety and well-being of Tulsans by reducing deaths, injuries, property damage, environmental, and other losses from natural, human-caused, and technological hazards in a manner that advances community goals and quality of life and results in a more livable, viable, and sustainable community. Specific goals and the process by which they were developed are included in Chapter 5.

1.1.3 The Planning Process

Planning for the 2024 Plan Update followed a ten-step process, based on guidance and requirements of FEMA and the Community Rating System (CRS):

1. Organize to prepare the plan
2. Involve the public
3. Coordinate with other agencies and organizations
4. Assess the hazard
5. Assess the problem
6. Set goals
7. Review possible activities
8. Draft the action plan
9. Adopt the plan
10. Implement, evaluate, and revise

1.1.4 Plan Organization

The Plan is organized into chapters based on the specific tasks identified in the FEMA Local Mitigation Planning Handbook and the FEMA 10-step Planning Process.

1.2 Community

The City of Tulsa is primarily located in Tulsa County, in northeast Oklahoma, 99 miles northeast of Oklahoma City, at the intersection of Interstate 44 and the Arkansas River.

Some of the tasks and steps are combined into one chapter.

The American Community Survey estimated the total 2022 population at 413,142. At a 2.6% growth rate, the projected 2028 population of the City of Tulsa will be around 423,884.

1.2.1 Governance

All legislative powers of the City of Tulsa, except for the rights of initiative and referendum reserved to the people of the City of Tulsa by the Constitution of Oklahoma, are exercised by a Council composed of nine Councilors elected by district. The executive and administrative powers of the City of Tulsa and any executive and administrative powers conferred on the city by the Constitution or the laws of the state of Oklahoma are exercised by the Mayor.

1.2.2 Geography

Tulsa is situated between the edge of the Great Plains and the foot of the Ozark Mountains in a generally forested region of rolling hills. The city touches the eastern extent of the Cross Timbers, an ecoregion of forest and prairie transitioning from the drier plains of the west to the wetter forests of the east. With a wetter climate than points westward, Tulsa serves as a gateway to "Green Country," a designation for northeast Oklahoma that stems from the region's green vegetation and relatively high number of hills and lakes compared to central and western areas of Oklahoma, which lie largely in the drier Great Plains region of the Central United States. Holmes Peak in the northwest corner of the city is the tallest point in five counties at 1,030 feet.

1.2.3 Climate

Tulsa has a temperate climate with a yearly average temperature of 61°F with an average high temperature of 72°F and an average rainfall of 41 inches. Weather patterns vary by season with occasional extremes in temperature and rainfall. Temperatures of 100°F or higher are often observed from July to early September, usually accompanied by high humidity brought in by southerly winds. The autumn season is usually short, consisting of pleasant, sunny days followed by cool nights. Winter temperatures, while generally mild, occasionally experience extremes below 0°F while annual snowfall averages about 10 inches.[1]

1.2.4 History

Tulsa's beginnings can be traced back to the Lockapoka Creek Indians, who, fleeing from their native Alabama due to the enforced exodus of Indians from the Southeastern states, settled between 1828 and 1836 near present-day Cheyenne Avenue and South 18th Street. The discovery of oil at Glenpool in 1905, a mere 15 miles south, positioned Oklahoma and Indian Territory as focal points for oil speculation and exploration, fueling Tulsa's early growth. By 1907, when Oklahoma

1 weather.gov/tsa/climo_tulsacli

attained statehood, Tulsa had a burgeoning population of 7,298.

As Tulsa expanded south and east during the 1950s and 60s, encroaching into the Mingo and Joe Creek watersheds, the growing city grappled with the increasing issue of flooding from both inland creeks and the Arkansas River. By 1980, with its population peaking at 360,919, Tulsa stood as the thirty-eighth largest city in the United States, its cityscape a tapestry woven with the rich threads of its Native American roots and its legacy as an oil boomtown.

Tulsa bears another historical significance as the host of the Greenwood District, known post-World War I as a symbol of African American prosperity, earning the nickname "Black Wall Street" for its flourishing businesses and community. However, the Tulsa Race Massacre of June 1921 saw this vibrant district almost entirely decimated, a somber event that has etched itself into the city's complex racial history. Despite this, Tulsa has emerged as a pivotal landmark for Black history and culture, its resilience and growth reflective of a city that has been shaped by both its triumphs and its tribulations.

1.3 Resilient Tulsa

The 2024 Tulsa Multi-Hazard Mitigation Plan Update acknowledges the city's dedication to equity. The plan recognizes Tulsa's historical context, notably as the site of the largest race-based massacre in American history, and its ongoing challenges that various populations—including immigrants and individuals interacting with the criminal justice system—continue to face. This section bridges the diligent endeavors of the Mayor's Office of Resilience and Equity with the fifth iteration of Tulsa's Multi-Hazard Mitigation Plan. With Tulsa's reputation as a leader in floodplain and stormwater management, this plan aims to be a unifying force, underscoring the essential contributions of every department and initiative within the City of Tulsa toward ensuring a safe and resilient city for all residents.

1.3.1 Integrating Tulsa's Equality Indicators

The 2022 Tulsa Equality Indicators report plays a significant role in guiding the city's efforts to reduce disparities and enhance resilience. The fifth in a series, this report draws on a collaboration between the City of Tulsa Mayor's Office of Resilience and Equity and the Community Service Council. It utilizes a unique methodology developed by the City University of New York to provide insights into inequality across economic, educational, housing, justice, public health, and service sectors in Tulsa.

The 2022 findings give Tulsa an overall equality score of 42.63 out of 100, indicating a gradual improvement in equality across various indicators. While Education (48.44) and Public Health (47.67) show the highest scores, Economic Opportunity (37.78) and Justice (33.78) lag behind. Notably, except for Justice, all themes have seen score improvements over four years, signaling progressive strides towards equity.

Highlighted successes include perfect scores for three indicators and significant score increases in seven indicators since 2018. Conversely, the report also identifies areas needing urgent attention, such as financial services accessibility, with "payday loans and banks by geography," a component of Economic Opportunity scoring as low as 1. Other indicators with pressing concerns include "teacher certification," "housing affordability," "homelessness," and "child welfare."

Tulsa's hazard mitigation strategy integrates the city's equality indicators as it underscores the critical intersections between social equity and community resilience. It serves as a data-driven compass to steer the city's actions towards mitigating hazards while ensuring equitable opportunities and outcomes for all citizens.

1.3.2 Understanding Equity and Social Vulnerability

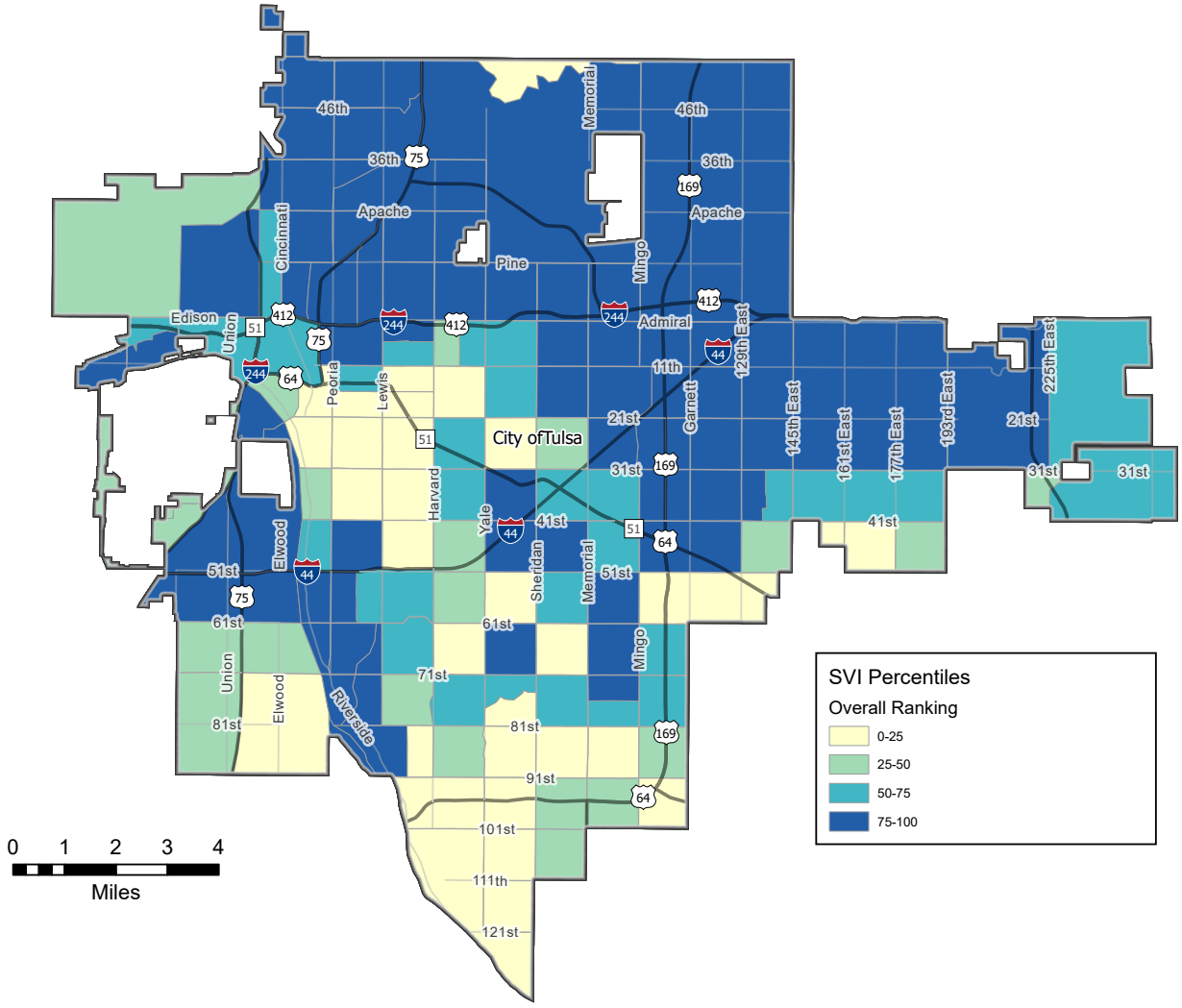
Social vulnerability encompasses a combination of social, cultural, economic, political, and institutional factors that influence the capacity of individuals, organizations, and communities to withstand and bounce back from stressors and shocks. Equity is viewed as a comparative framework, grounded in perceptions of fairness among diverse groups. It allows for an unequal allocation of benefits and burdens, provided there's an overall social benefit. The ultimate objective of equity is to ensure fair access to livelihood, education, and other essential resources, with the aim that sociodemographic attributes like race, gender, and age don't dictate the adverse effects of disasters or the distribution of disaster assistance. The map provided in Figure 1-1 displays the Social Vulnerability Index (SVI) percentiles within Tulsa.

Every person in the City of Tulsa is exposed to at least one of the hazards identified in this plan. While disasters affect all residents, the impacts are not felt equally among all communities. A direct connection between hazard mitigation and equity exists. True resiliency is only achieved with equitable prioritization and action to reduce vulnerabilities for all residents. Following in the footsteps of Resilient Tulsa, the 2024 Multi-Hazard Mitigation Plan recognizes the importance of equitable access to mitigation resources and efforts. This commitment reinforces our aim to build a city that is not only physically resilient but also socially equitable, where every resident, regardless of their starting point, can enjoy a safe and secure environment.

In January 2021, following President Biden's Executive Order 14008, the Council on Environmental Quality (CEQ) unveiled the Climate and Economic Justice Screening Tool (CEJST). Featured within this tool is an interactive map that employs datasets spanning eight domains: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. Presented below is a map delineating the regions within Tulsa reflecting the CJEST-J40 Disadvantaged Threshold Criteria.

FIGURE 1.1

City of Tulsa Social Vulnerability Index



From a visual assessment, large portions of Tulsa and its eastern neighboring areas are in the highest vulnerability bracket (dark blue). The southwestern regions surrounding Tulsa exhibit the lowest vulnerability (light green). The map highlights the diverse levels of social vulnerability in the broader Tulsa area, emphasizing areas that might require more focused attention and resources.

1.4 Community Assets

Community Assets are defined broadly to include anything that is important to the character and function of a community and can be described very generally in the following four categories: People, Economy, Built Environment, and Natural Environment. Although all assets may be affected by hazards, some assets are more vulnerable because of their physical characteristics or socioeconomic uses. This section describes community assets in the City of Tulsa.

1.4.1 People

Every person in the City of Tulsa is exposed to at least one of the hazards identified in this plan. Following in the footsteps of resilience Tulsa, it was important for this plan update to focus on areas within Tulsa that may not be as quick to recover. Understanding who is being affected by disaster is important when preparing for future events. Social and economic characteristics may limit an individual's ability to understand their risk, respond to and recover from disasters.

These groups of people will be referenced throughout the vulnerability sections in Chapter 4, their locations are displayed on the following maps.

1.4.2 Economy

After a disaster, economic resiliency drives recovery. Tulsa has specific economic drivers that are important to understand when planning to reduce the impacts of hazards and disasters to the local economy. Tulsa's major industries are aerospace, including aerospace manufacturing and aviation; health care; energy; machinery; and transportation, distribution, and logistics. In the five-year period ending 2017, all sectors in the Tulsa economy except mining, information, and air transportation showed positive average annual growth.

Partner Tulsa

The Tulsa Authority for Economic Development, known as Partner Tulsa, is an organization formed to spearhead the City's economic development projects and programs. The organization launched in 2021 with the consolidaton of several economic deveclopment authorities, boards, and commissions.

The Partner Tulsa team aims to position all areas of the city for appropriate development, redevelopment, and community revitalization opportunities. Current efforts include projects to implement the Kirkpatrick Heights - Greenwood Master Plan, which outlines desirable uses for city-owned property that is currently used for regional flood control.

Stormwater system challenges in downtown Tulsa limit growth potential and infill opportunities. The Pearl District, a near-downtown mixed-use neighborhood, is positioned for revitalization, but cannot fully achieve planned improvements because the area can only withstand a 2- to 5-year storm at this time.

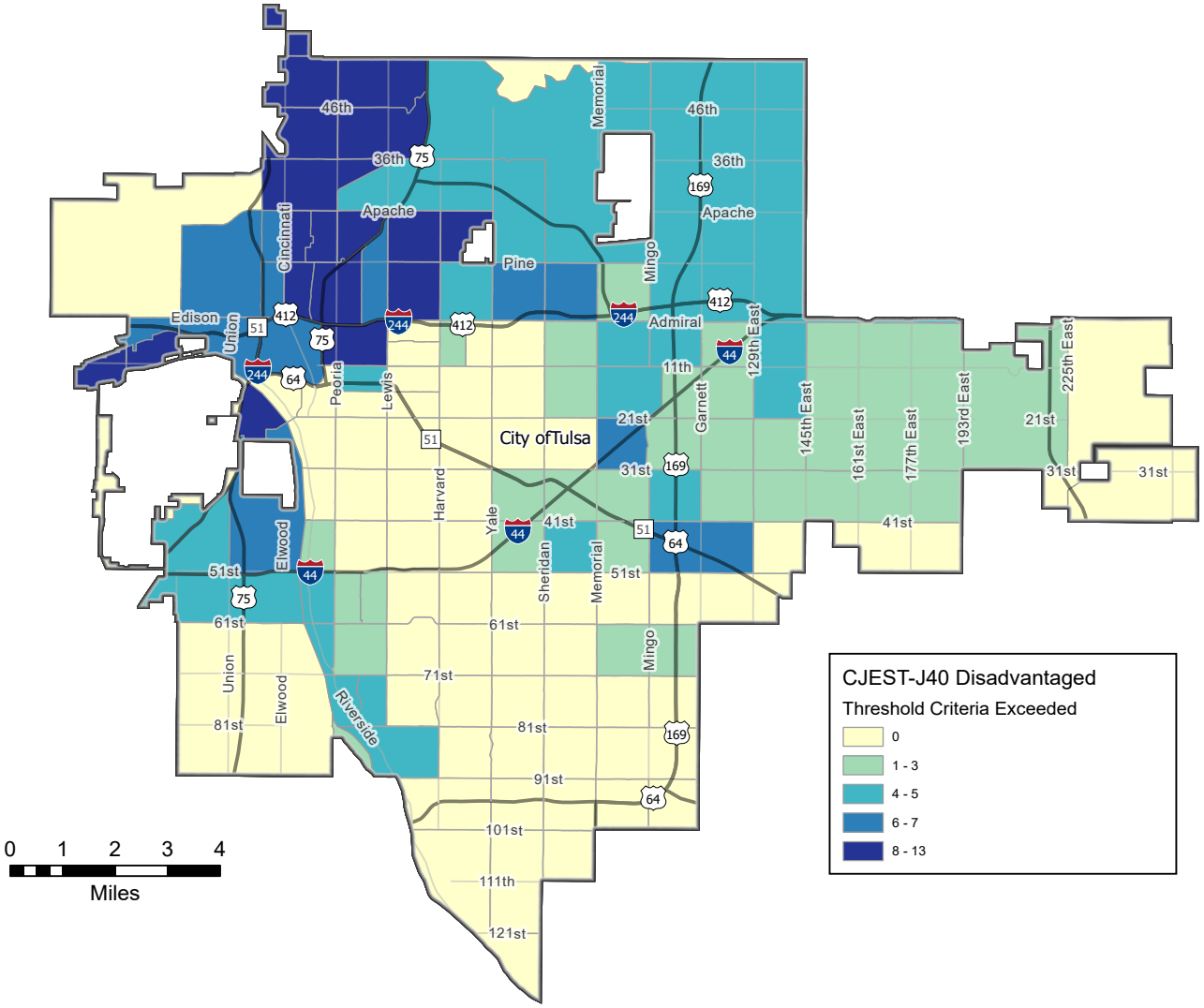
A 2017 tornado in mid-town Tulsa demonstrated the need for more proactive work to prepare businesses for possible disruptions due to hazards. Partner Tulsa can support the development of continuity plans for storms, pandemics, and other business disruptions to improve both awareness and outcomes for the local economy.

Each of these efforts will advance the seven core objectives of the Partner Tulsa Strategic Plan:

1. Craft transformative economic strategies.
2. Build capacity and empower communities.
3. Leverage public-private partnerships.
4. Create pathways to quality employment.
5. Support small businesses and entrepreneurs.
6. Invest in neighborhood infrastructure.
7. Build and sustain robust operations.

FIGURE 1.2

Climate & Environmental Justice Screening Tool



The map uses a color code to show the extent to which different regions within the city exceed these criteria, which likely relate to factors such as income, education, employment, and housing quality. The central part of Tulsa shows a moderate level of disadvantage (1-5 criteria exceeded). The northern and some eastern sections of Tulsa exhibit the highest levels of disadvantage (6-13 criteria exceeded). Certain streets and districts are highlighted, suggesting that these are significant in the context of the disadvantaged areas.

FIGURE 1.3

Percent of Population, Non-High School Graduates

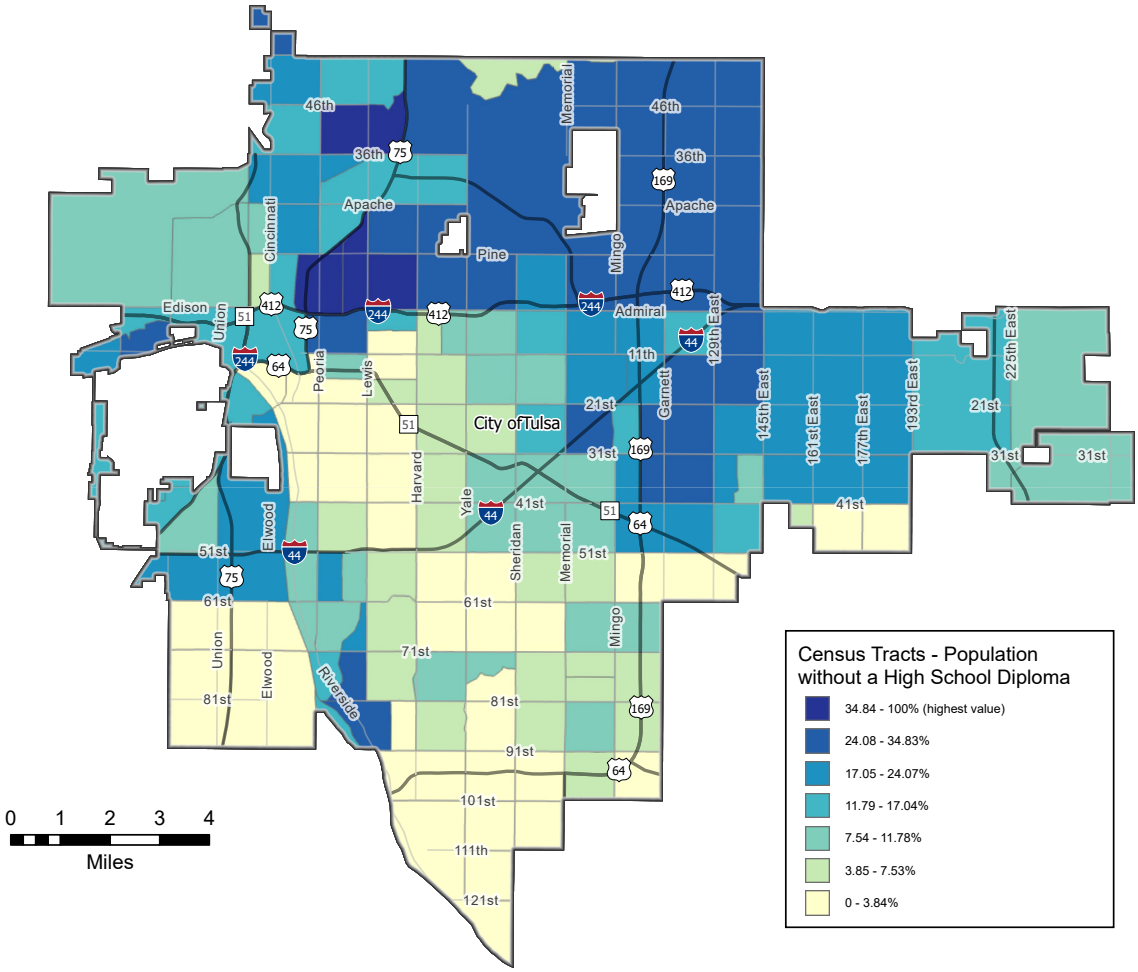


FIGURE 1.4

Percent of Population over age 65

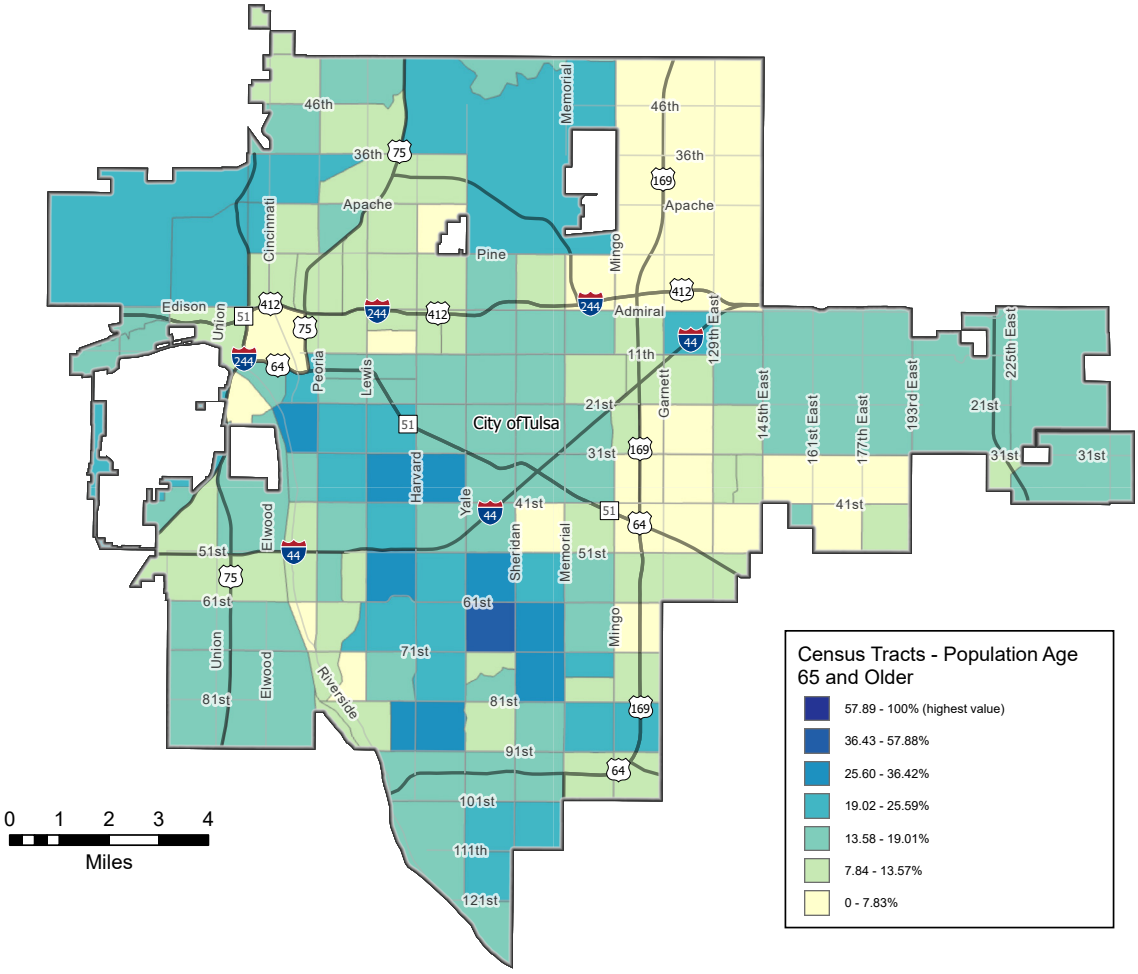


Table 1-2: City of Tulsa At Risk Populations by Council District

DISTRICT	% 65+	$<18	%HH NON ENG	% POP IN POVERTY	% NON HS GRADS
1	37.28%	50.47%	13.94%	30.79%	18.94%
2	30.72%	41.73%	15.37%	20.39%	11.53%
3	33.47%	58.56%	27.32%	25.66%	23.95%
4	32.77%	25.63%	9.48%	15.21%	7.37%
5	34.62%	40.56%	19.55%	18.31%	14.01%
6	28.80%	72.41%	29.84%	16.38%	17.84%
7	35.00%	38.57%	20.24%	12.00%	7.45%
8	47.16%	42.11%	11.95%	7.05%	3.41%
9	43.10%	27.42%	7.68%	14.62%	5.84%
TOTAL	**14.72%**	**17.44%**	**16.71%**	**17.60%**	**11.87%**

Source: US Census Bureau, American Community Survey (ACS) 2016-2021

Aligning the City's economic strategies with this Multi-Hazard Mitigation Plan offers the ability to leverage projects and programs to accomplish multiple goals. Where resources are allocated for projects that generate economic development, mitigation strategies can also be achieved. Coordination of these planning efforts and the inclusion of economic development projects and programs in the mitigation strategies matrix will support the efficient use of City's resources.

1.4.3 Built Environment

The built environment includes existing structures, infrastructure systems, critical facilities, and cultural resources.

Existing Structures

All structures are exposed to risk, but certain buildings or concentrations of buildings may be more vulnerable because of their location, age, construction type, condition, or use. The total number of structures by type and estimated market value are included in Table 1-1.

Infrastructure

Infrastructure systems are critical for life safety and economic viability and include transportation, power, communication, and water and wastewater systems. Many critical facilities depend on infrastructure to function. For example, hospitals need electricity, water, and sewer to continue helping patients. As with critical facilities, the continued operations of infrastructure systems during and following a disaster are key factors in the severity of impacts and the speed of recovery. Oklahoma Natural Gas and Public Service Company of Oklahoma (PSO) provide gas and electric service to Tulsans. Water, sanitary sewer, storm-water, trash, and EMSA are services provided by the city, and paid for by citizens. Hospitals and medical facilities are critical facilities.

Critical Facilities

Critical facilities are structures and institutions necessary for a community's response to and recovery from emergencies. Critical facilities must continue to operate during and following a disaster to reduce the severity of impacts and accelerate recovery. When identifying vulnerabilities, consider both the structural integrity and content value of critical facilities and the effects of interrupting their services to the community. A complete list of public and private critical facilities from the 2019 All Hazard Mitigation Plan is included in Appendix A. One of the Mitigation Actions identified in Sec. 5.3 Recommended Mitigation Actions in this plan is to perform an update of this list of critical facilities to serve the Tulsa community moving forward.

Table 1-1: City of Tulsa Built Environment

STRUCTURE TYPE	NUMBER	EST. MARKET VALUE
Residential Single Family	111,183	$16,558,279,241
Residential Multi-Family	9,851	$2,791,272,842
Commercial	7,454	$8,470,055,457
Other	4,450	$221,426,472
Total	132,938	$28,041,034,012

Cultural Resources[1]

Tulsa is home to many cultural and historic assets that are unique or irreplaceable. Any asset that is important to the community can be considered a cultural resource. Tulsa has an amazing variety of arts and culture. Tulsa boasts the nationally recognized Tulsa Ballet, Tulsa Opera, and two orchestras, as well as numerous theatrical groups. Concert venues range from nightspots with live music to outdoor public spaces, and historic theaters to the 19,199-capacity BOK Center. World-class museums like the Philbrook Museum of Art and the Gilcrease Museum allow visitors of all ages to take in the impressive cultural collections Tulsa has to offer. Tulsa is home to 23 public golf courses, 135 tennis courts, and 88 playgrounds. The Tulsa Drillers baseball team (AA affiliate of the Los Angeles Dodgers) draws legions of fans to ONEOK Field. The Tulsa Zoo and Living Museum, located in Tulsa's 2,800-acre Mohawk Park, one of the largest municipal parks in the country, features more than 1,500 animals representing 436 species.

In recent years, Tulsa has expanded its cultural amenities with the addition of the Woody Guthrie Center, the Bob Dylan Center, and Greenwood Rising: Black Wall Street History Center. Work has begun in Congress to establish the Greenwood district as a National Monument. The Gilcrease Museum is currently being reconstructed. The museum houses a comprehensive collection of the art, culture, and history of North America and is managed through a partnership between the city and the University of Tulsa.

1 visittulsa.com/things-to-do/arts-and-culture

gatheringplace.org

bobdylancenter.com

woodyguthriecenter.org

gilcrease.org

The Gathering Place, a new 66.5-acre park located along the Arkansas River near downtown Tulsa, opened to the public in September 2018. The park's second phase of development resulted in the relocation of Tulsa's Children's Museum, Discovery Lab, to the southern edge of the Gathering Place, expanding the appeal and resources offered within the park.

In 2023 Tulsans approved a $814M capital improvement package consisting of sales tax- and bond-funded projects focused on maintaining and improving assets such as the Tulsa Zoo, Cox Convention Center, Tulsa Performing Arts Center, and the BOK Center (event venue). This demonstrates the City's ability and desire to support arts and culture and to maintain public assets.

Development Since 2019

An effective way to reduce future losses is to avoid development in known hazard areas and to enforce the development of safe structures in other areas. In other words, keep people, businesses, and buildings out of harm's way from the beginning. Tulsa's Comprehensive Plan was updated in June 2023. Information on this plan and others, and how mitigation was incorporated, is included in Chapter 3, Capability Assessment. Environmentally sensitive areas, such as those within FEMA and Tulsa regulatory floodplains, were evaluated when the Future Land Use Map and various land use policies were updated in the Comprehensive Plan update process. In addition, a new land use category and overlay district were created to address development along the Arkansas River within the City. New land use goals within the Comprehensive Plan address both growth and resilience.

> **Goal 4:** Redevelopment, revitalization, and enhancement programs are focused in areas that have been economically disadvantaged.

Goal 10: Future growth is balanced with the ability of the City to provide public services, utilities, and infrastructure.

1.4.4 Natural Environment

Environmental assets and natural resources are important to Tulsa's identity and quality of life and support the economy through agriculture, tourism and recreation, and a variety of other ecosystem services, such as clean air and water. The natural environment also provides protective functions that reduce hazard impacts and increase resiliency. For instance, wetlands and riparian areas help absorb flood waters, soils, and landscaping contribute to stormwater management, and vegetation provides erosion control and reduces runoff. Conservation of environmental assets may present opportunities to meet mitigation and other community objectives, such as protecting sensitive habitat, developing parks and trails, or contributing to the economy. Tulsa manages 135 parks covering roughly 6,500 acres. The Arkansas River Corridor is a destination for bird migration. The Gathering Place is home to over 1.2 million plants with 6,000 trees and includes a wetland pond and garden.

In 2016, Up with Trees commissioned an Urban Forest Master Plan for the City of Tulsa. "This Urban Forest Master Plan (UFMP) provides a guide for managing, enhancing, and growing the tree resource over the next 20 years along with long-range objectives for building an urban forest that is resilient, safe, and connected to the community."[1]

Maintaining a healthy urban forest is an important step in hazard mitigation. Sufficient tree coverage can mitigate heat impacts, wind conditions, erosion, and improve water quality. However, when trees in the city are not in good health, they can cause greater damage and become problematic in high wind and tornado events and fire hazards.

1 upwithtrees.org/Tulsa_UFMP_Final.pdf

CHAPTER 2
PLANNING PROCESS

2.1 Hazard Mitigation Planning and the Community Rating System

Planning for the City of Tulsa followed a ten-step process, based on the guidance and requirements of the FEMA Community Rating System. The ten steps are described on the following pages. The Local Mitigation Plan Review Guide, Local Mitigation Planning Handbook, and CRS Coordinator's Manual, Activity 510, were used to ensure Local Mitigation Planning requirements and CRS Floodplain Management requirements were met.

2.1.1 Step One: Organize to Prepare the Plan

The City of Tulsa secured funding for this update through the Hazard Mitigation Grant Program. The planning process was formally initiated by City Council Resolution #20258 on June 25, 2023. The resolution designated the Tulsa Stormwater Drainage and Hazard Mitigation Advisory Board (SDHMAB) to serve as the Tulsa Citizens' Advisory Committee to oversee the planning effort. The SDHMAB decided to use the Program for Public Information Committee (PPI) as the Steering Committee for this project. Since adoption of the 2019 Hazard Mitigation Plan, the PPI Committee has and will continue to meet monthly to evaluate

Planning Process

progress and recommend changes to the plan.

The PPI Committee consists of citizens, community leaders, government staff personnel, and professionals active in disasters. SDHMAB Committee and PPI Committee members and affiliation are included in the lists of planning team members in Appendix A.

The SDHMAB and the PPI Committee met eight times each during the planning process at City of Tulsa offices to review preventative measures, property protection, natural resource protection, emergency services, structural flood control projects, and public information. This review led to the development of the plan and recommended goals and objectives, mitigation measures, and priorities for mitigation actions. Staff from multiple City of Tulsa Departments were actively involved in the plan update process. Meeting dates and locations were posted by the City Clerk on the City of Tulsa website.

2.1.2 Step Two: Involve the Public

Throughout the progression of the 2024 Hazard Mitigation Plan update, the City of Tulsa maintained a dedicated webpage with comprehensive information about the plan and a public survey. This webpage (available at cityoftulsa.org/residents/public-safety/hazard-mitigation.aspx) provides insight into Hazard Mitigation and its planning framework. It invited the public's feedback through online surveys and email submissions, showcased past Multi-Hazard Mitigation Plans, and featured a GIS map depicting hazard data across the city. Feedback from these surveys and public commentary significantly shaped the capabilities assessment in Chapter 3, hazard assessments in Chapter 4, and the mitigation actions in Chapter 5. In alignment with the update, the PPI Committee undertook significant engagement efforts. The City of Tulsa took the initiative by designing postcards equipped with a QR code that led to the public survey. These were distributed by the Mayor's Office of Resilience and Equity during "Welcoming Week 2023," a national event from September 8-17, 2023, acknowledging the unity of immigrants, refugees, and long-term residents. The city used this event to celebrate its vibrant immigrant community. The online survey, a part of this effort, was designed to be user-friendly, even offering a Google Translate option. Printed versions of the survey were also available during this event.

The city held three public meetings specifically to address the hazard mitigation plan and gather feedback. The first public meeting we held on July 28, 2023, centered around discussions on Tulsa hazards and potential resolutions for the plan. The planning team attended a town hall meeting in City Council District 2 on December 18, 2023. This council district has a higher flood risk than others. During this meeting, the multi-hazard plan was introduced, handouts were provided, and attendees were invited to ask questions and discuss their concerns and experiences related to hazards. A meeting in August 2024, facilitated public review and feedback on the draft plan before its finalization.

As an added outreach strategy, a mitigation handout was developed and shared across city offices, libraries, and at various community events, ensuring the public had ample opportunities to understand and contribute to the planning process. All SDHMAB and PPI Committee meetings were publicly announced and open, in accordance with the Open Meetings Act.

2.1.3 Step Three: Coordinate with Other Agencies and Organizations

The project team reached out to 45 different groups, encompassing neighboring commu-

nities, tribes, various levels of government agencies, businesses, and both private and non-profit entities, now termed as "Stakeholders." For a full list of stakeholders, please see Appendix D.

Communication methods included emails, letters, and phone calls. Each Stakeholder was personally spoken to, delving into their pre-existing research, reports, and detailed data, along with their ambitions and designs for the region.

Throughout the planning phase, three workshops were conducted. In these sessions, Stakeholders in attendance dissected the current Tulsa Multi-Hazard Mitigation Plan, discussing its relevance, examining the hazards mentioned and their consequent issues, brainstorming suitable mitigation steps, refining the plan's goals, and drafting a plan of action. Of these Stakeholders, 31 members took part in at least one of these workshops. Feedback was also channeled via emails from other representatives. A dedicated website was established to host the draft plan, allowing for review and comments during plan development.

Input also facilitated creating and prioritizing mitigation strategies into the Action Plan. Details regarding the Stakeholders approached, invitations to workshops, and attendance records can be found in Appendix C. The discussions from public and stakeholder sessions were important in understanding the city's susceptibility to each hazard, influencing the risk assessment. This input was critical in shaping and prioritizing the mitigation strategies within the Action Plan. Public meetings are summarized in Table 2-1.

2.1.4 Step Four: Assess the Hazard

The project team collected data on the hazards from available sources, the 2019 Tulsa Multi-Hazard Mitigation Plan, and the 2019 State of Oklahoma Hazard Mitigation Plan. The Hazard Identification and Risk Assessment, Chapter 4, includes a description of the type, location, and extent of natural hazards that can affect Tulsa. The Plan includes information on previous occurrences of hazard events and the probability of future events.

The Simple Planning Tool for Oklahoma Climate Hazards, produced by the Southern Climate Impacts Planning Program (SCIPP, www.southernclimate.org), was used for the hazard assessment. The Southern Climate Impacts Planning Program is one of 11 National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Sciences and Assessments (RISA) teams. Hazards from the 2019 plan were reviewed and updated in June.

2.1.5 Step Five: Assess the Problem

The hazard data was then analyzed considering what it means to public safety, health, buildings, transportation, infrastructure, critical facilities, the natural environment, endangered species and the economy. Findings from this analysis are included in Chapter 4: Risk Assessment for each of the hazards documented in this plan.

Building footprints and property parcels were used to estimate potential losses from the site-specific hazards identified in Chapter 4 of the plan update. Building footprint polygons within the City of Tulsa were selected from computer-generated building footprints covering all 50 US states released publicly by Microsoft in 2018. Polygons representing current parcel records from the Tulsa, Osage, and Wagoner County Assessors offices were obtained from INCOG. The following methodology was used to estimate the total number of structures impacted and the total market value of the properties impacted by each hazard. Property damage estimates were not calculated for the general area hazards.

Building footprint polygons that intersected spatially with each hazard were identified.

The identified building footprints were then matched with their spatially coincident parcel record polygons. The total number of matching property parcel records was calculated to estimate the total number of properties impacted. The sum of the market value provided in the property parcel records was calculated to estimate the total value of properties impacted. Specific problem statements, or observations, are included for each hazard in Chapter 4.

2.1.6 Step Six: Set Goals

Project and community hazard mitigation goals and objectives for Tulsa were developed by the stakeholders and project team during the January 2024 Stakeholder Workshop to guide the development of the plan. The hazard mitigation goals are listed in Chapter 5.

2.1.7 Step Seven: Review Possible Activities

There were twenty-nine mitigation actions identified in the 2019 mitigation plan. An annual report is prepared by the City in collaboration with the PPI Committee on the status of existing Hazard Mitigation Plan mitigation actions and presented to the Tulsa City Council. A review of the 2019 mitigation actions, along with the latest annual report, was completed by the planning team. Actions were evaluated with the intent of carrying over any not started, or continuous for the next five years. Actions with the same intent were combined into a general action item. The list of actions was expanded to include several additional tasks in response to this plan update. Specific observations and problem statements, resulting in the actions listed in Chapter 5, are included at the end of each hazard section in Hazards, Chapter 4. Wide varieties of measures that can affect

Table 2-1: Meeting Schedule

MEETING	DATE	PURPOSE
Stakeholder Workshop 1	June 29, 2023	Introduce planning process and organization. Collect information on Tulsa's existing mitigation practices and capabilities.
Public Meeting 1	July 25, 2023	Collect public comments on natural hazards, possible mitigation solutions, and related issues.
Stakeholder Workshop 2	Nov 2, 2023	Conduct a risk assessment for the City for each natural hazard.
Public Meeting 2	Dec 18, 2023	Council District #2 Town Hall; Provide an overview of the plan, planning process and opportunities to offer feedback and participate in the community survey.
Stakeholder Workshop 3	Jan 25, 2024	Discuss mitigation goals and strategies including specific actions for each natural hazard. Final discussion and comments for draft plan.
Public Meeting 3	TBD	Introduce Mitigation Action Plan, provide an overview of the complete draft Multi-Hazard Mitigation Plan and collect public comments.

hazards or the damage from hazards were examined. A more detailed description of each category is in Chapter 5: Mitigation Strategies, and an overview of mitigation actions considered is in Appendix B.

2.1.8 Step Eight: Draft an Action Plan

The planning team reviewed observations from the risk assessment and results of the capability assessment when considering different actions. The planning team evaluated and prioritized the most suitable mitigation actions for Tulsa to implement. The mitigation strategy analyzes actions and projects considered to reduce the impacts of hazards identified in the risk assessment and identifies the actions and/or projects that Tulsa intends to implement.

2.1.9 Step Nine: Adopt the Plan

The Draft City of Tulsa Multi-Hazard Mitigation Plan Update 2024 was submitted to the Oklahoma Department of Emergency Management and FEMA Region VI for review and approval. The SDHMAB approved the final plan, adopted it as an amendment to the Comprehensive Plan, and submitted it to, and was approved and adopted by the Tulsa City Council.

2.1.10 Step Ten: Implement, Evaluate, and Revise

Adoption of the Multi-Hazard Mitigation Plan is only the beginning of this effort. Community offices, other agencies, and private partners will proceed with implementation. The SDHMAB and the PPI will continue to meet on a regular basis to monitor progress, evaluate the activities, and periodically recommend revisions to the Plan and Mitigation Action Items. These findings and recommendations will be included in the annual report prepared under the direction of the PPI Committee. The plan will be formally updated a minimum of every five years, as required by FEMA.

Table 2-2

DOCUMENTS/ PLANS REVIEWED	AGENCY OR DEPARTMENT	HOW IT WAS INCORPORATED (IF APPLICABLE)
PlaniTulsa Comprehensive Plan	COT Planning	Reviewed FLU for future development patterns that were accounted for in the Risk Assessment. Reviewed for alignment opportunities, included in Capabilities Assessment.
Kirkpatrick Heights / Greenwood Master Plan	Partner Tulsa, COT Planning Office	Reviewed for Mitigation Strategies and overall alignment with long range planning and economic development policies.
Capital Improvement Plan	COT Public Works	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Resilient Tulsa Strategy	COT Mayor's Office of Resilience and Equity	Reviewed for Capabilities Assessment, Mitigation Strategies, overall alignment
Tulsa Urban Forest Master Plan	Up with Trees	Reviewed for Mitigation Strategies
Economic Development Plan	COT Planning Office COT Development Services; Partner Tulsa	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Emergency Operations Plan	COT Public Works, TAEMA, LEVEE District 12, USACE Tulsa District	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Continuity of Operations Plan	COT Planning, Development Services, Water and Sewer, Public Works, TAEMA, Levee District 12, USACE Tulsa District	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Transportation Plan	COT Planning	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Stormwater Management Plan	COT Public Works, USACE Tulsa District	Reviewed for Capabilities Assessment.
Zoning Ordinance	COT Planning and Development Services	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Subdivision Ordinance	COT Development Services	Reviewed for Planning and Regulatory assessment in Capabilities Assessment.
Floodplain Ordinance	COT Development Services, Public Works, USACE Tulsa District, INCOG	Reviewed for Capabilities assessment and for Flooding Risk Assessment.
Flood Insurance Rate Maps (FIRM)	COT Development Services, TAEMA, USACE Tulsa District, INCOG	Reviewed for Capabilities and Risk assessment.
Dam Failure Emergency Action Plan	COT Water and Sewer, Public Works, TAEMA, USACE District 12	Reviewed for Flooding and Dam/Levee Assessments and Mitigation Strategies.
Levee Failure Emergency Action Plan	TAEMA, Levee District 12, USACE Tulsa District	Reviewed for Flooding and Dam/Levee Assessments and Mitigation Strategies.
State Hazard Mitigation Plan	OEM	Reviewed for Mitigation Strategies
NFIP		Incorporated in Capabilities Assessment

CHAPTER 3
CAPABILITIES ASSESSMENT

Communities have multiple methods of preventing or mitigating the impacts of natural disasters. Such actions range from instituting regulatory measures (e.g., building and zoning codes) and establishing Emergency Operations Plans (EOP) and Emergency Operations Centers (EOC), to purchasing fire trucks and ambulances and constructing large and small infrastructure projects like levees and safe rooms. The City of Tulsa has already made considerable investments in these critical areas. The sections that follow in this Chapter review the regulations, plans, programs, and infrastructure that the City of Tulsa has employed to avoid or mitigate the impacts of natural hazards.

The Planning Team involved numerous stakeholders from neighboring communities, tribes, counties, agencies, and non-profit organizations to determine if they had studies, plans, or information that would have bearing on Tulsa's HMP. See Chapter 2 for a list of these stakeholders. In addition to local capabilities, there are several national hazard mitigation programs developed by FEMA and other agencies that are designed to help communities organize their mitigation activities. This section looks at Tulsa's participation and progress in these programs.

3.1 Types of Capabilities

The primary types of capabilities for reducing long-term vulnerability through mitigation planning are the following:

- Planning and Regulatory
- Financial
- Administrative and Technical
- Education and Outreach

3.1.1 Planning and Regulatory

Planning and regulatory capabilities are based on the implementation of ordinances, policies, local laws, and state statutes, and plans and programs that relate to guiding and managing growth and development. Examples of planning capabilities that can either enable or inhibit mitigation include comprehensive land use plans, capital improvements programs, transportation plans, small area development plans, disaster recovery and reconstruction plans, and emergency preparedness and response plans.

3.1.2 Financial

Financial capabilities are the resources that a jurisdiction can access or is eligible to use to fund mitigation actions. The costs associated with implementing mitigation activities vary. Some mitigation actions such as building assessment or outreach efforts incur little to no costs other than staff time and existing operat-

ing budgets. Other actions, such as the acquisition of flood-prone properties, could require a substantial monetary commitment from local, state, and federal funding sources.

Some local governments may have access to a recurring source of revenue beyond property, sales, and income taxes, such as stormwater utility or development impact fees. These communities may be able to use the funds to support local mitigation efforts independently or as the local match or cost-share often required for grant funding.

3.1.3 Administrative and Technical

Administrative and technical capability primarily refers to the community's staff and their skills and knowledge. It also includes tools that can be used for mitigation planning and implementation and the ability to access and coordinate these resources effectively.

3.1.4 Education and Outreach

This type of capability refers to education and outreach programs and methods already in place that could be used to implement mitigation activities and communicate hazard-related information.

3.2 National Flood Insurance Program (NFIP)

Tulsa joined the National Flood Insurance Program in 1971. All residents of Tulsa are eligible to purchase federal flood insurance. In 2020 the City of Tulsa attained a Class 1 in FEMA's Community Rating System (CRS) program.

The City of Tulsa is committed to fulfilling the minimum requirements set by the NFIP and surpassing them. This will be achieved through the enforcement of local Regulatory Floodplain Ordinances and active participation in the CRS program.

Qualified City staff are available at the Permit Center to discuss options and to help citizens plan and build a safe project while complying with City floodplain and watershed development policies. The City of Tulsa's permitting process is designed to ensure that all construction in Tulsa is safe. A permit is required for all new construction and, most of the time, a permit must be obtained for repairing or replacing existing features.

In addition to regular building permits, special regulations apply to construction in floodways and the Regulatory Floodplain. No construction, including filling, is allowed in the mapped floodway without an engineering analysis that shows the project will not increase flood damage elsewhere. Any activity outside the floodplain but within a natural or man-made watercourse also requires a permit.

A floodplain watershed development permit must be obtained from the City of Tulsa before commencing construction, landfill, grading, berming, diking, or excavation within city watersheds. New buildings in the floodplain must be protected from flood damage so our building code requires that new buildings be elevated at least one foot above the elevation of the City of Tulsa Regulatory Floodplain.

Elevation or floodproofing may be required prior to constructing a substantial improvement (the cost of the improvement or add-on is 50 percent of the value of the existing building). Permits also are required for a repair if it's more than just cleanup after a storm.

3.2.1 The Community Rating System

The CRS is a part of the National Flood Insurance Program that helps coordinate all flood-related activities of the City. Tulsa has participated in the CRS since 1991. The CRS is a voluntary program that seeks to reduce flood losses, facilitate accurate insurance rating, and

promote awareness of flood insurance by creating incentives for a community to go beyond minimum floodplain management requirements.

Tulsa advanced to a Class 2 community on October 1, 2003 and a Class 1 on April 1, 2022. The Class 1 rating allows Tulsa's residents a forty five percent reduction in their flood insurance premium rates. All rates are based on where the structure is located in FEMA's Flood Insurance Rate Maps (FIRMs). New Digital Maps (DFIRMs) became effective in October 2012. A summary of City of Tulsa flood insurance policies, according to NFIP, as of 2022, is included in Table 3-1. Tulsa has 155 Repetitive Loss properties. Information about Repetitive Loss properties is included in Chapter 4.

3.3 Flood and Stormwater Management

Tulsa has a long history of dealing with floods. Distinct from many other places, Tulsa implements stricter regulations in three key areas within the "100-year" floodplain zones, aiming to minimize future flood damages. Generally, the FEMA Special Flood-Hazard Area (SFHA), or "100-year" floodplain, represents a zone with a 1% annual chance of flooding. These SFHA floodplains are marked on FEMA's Flood Insurance Rate Maps. The SFHA sets the base standard for the National Flood Insurance Program, capturing only the current development conditions at the time of the assessment and usually only considering areas where the drainage basin is at least one square mile. Tulsa's regulations exceed NFIP's standard in several important ways, as listed in the City of Tulsa Stormwater Management Plan and highlighted below.

In 2024 the City Council passed a resolution adopting the September 12, 2024, FEMA Flood Insurance Study (FIS), corresponding Flood Insurance Rate Maps (FIRMs) and City of Tulsa Floodplain Map Atlas revisions for Tulsa County and Incorporated Areas as identified in FEMA's Letter of Final Determination dated March 12, 2024. The City also amended local regulations (Title 11A TRO Stormwater Management and Hazard Mitigation Program) to add definitions to Section 301 and revise Section 304.E.3 to clarify language as requested by the Community Rating System (CRS) ISO auditor. The City's Title 11A (Stormwater Management and Hazard Mitigation) regulations, the recently approved ordinance and the resolution adopting the FIS are provided available on the City's online code source.

3.3.1 Ultimate Watershed Urbanization

Insurance purposes require the NFIP floodplain maps to be based on existing watershed devel-

Table 3-1: City of Tulsa Flood Insurance Policies

FLOOD INSURANCE	AMOUNTS
Flood Insurance Policies in Force	1,043
Values of Insurance in Force	$420,646,800
Premiums in Force	$1,135,814
Total Losses	2,443
Flood Losses Paid	**$37,519,545**

Source: NFIP Claims Data, 2022

opment. Tulsa regulates to a higher standard in three categories of so-called "100-year" floodplain areas in order to reduce future flood losses. As a minimum standard, the FEMA Special Flood-Hazard Area, or "100-year" floodplain, is an area that has a 1% chance of flooding in any given year. FEMA SFHA floodplains are designated on FEMA's Flood Insurance Rate Maps. The SFHA identifies the NFIP minimum national standard, which reflects only existing development conditions at the time of the study typically stopping where the contributing drainage area is down to one square mile or less.

The City of Tulsa regulatory floodplain areas are calculated by a different standard. They consider "100-year" flooding that would occur when contributing watersheds are fully developed and extend upstream to a contributing drainage area of 40 acres rather than FEMA's standard of 1 square mile. Therefore, Tulsa regulatory floodplain areas may be wider than the FEMA floodplains and may extend farther up creeks and waterways. Floodways, generally the most dangerous center strip along a water course, is where water is apt to run faster and deeper. Tulsa applies more stringent regulations in floodways because of their higher risk. Throughout this report, "floodplain" will mean specifically the City of Tulsa regulatory floodplain, unless otherwise noted.

The SFHA deals with existing conditions and does not take the impacts of future urbanization into account in its modeling or floodplain map delineations. Tulsa regulates to a higher standard, requiring that no insurable structure will be built that has its lowest finished floor less than 1 foot above the Base Flood Elevation (BFE).

Piping and paving for future urbanization and development can cause an increase in urban stormwater runoff and flood depths. In some instances, it could cause discharges to double and can widen the floodplain and cause increases in the BFE. Tulsa requires upstream detention of excess flows and compensatory storage to mitigate this problem.

3.3.2 Master Drainage Planning

From 1980 to 2000, Tulsa established comprehensive drainage plans for each major watercourse, forming the basis of its floodplain management strategies and initiatives.

The inaugural citywide master drainage plan, titled the Flood and Stormwater Management Plan 1990–2005, was a key document that organized and prioritized flood defense projects outlined in Tulsa's 29 master drainage plans. The latest update to this plan was on September 7, 2001. It focused on two main areas:

- The Capital Improvement Program
- A priority list for Non-Structural Mitigation and Acquisition

Subsequently, the City introduced the Flood and Stormwater Management Plan 1999-2014, which was released on September 10, 1998. This plan was formulated in line with the guidelines from the Community Rating System, Flood Mitigation Assistance (FMA), and the Hazard Mitigation Grant Program (HMGP). While its primary focus was on flood management, the 1999-2014 plan also took into account other natural hazards and recommended various stormwater capital improvement projects. To support these endeavors, Tulsa instituted a stormwater utility fee specifically allocated for stormwater maintenance and mitigation project funding.

To further support Tulsa's stormwater management goals, in 2017, the City adopted a Stormwater Management Criteria Manual to standardize the content and review of public and private drainage designs and reports.

3.3.3 Watershed Development

Regulating floodplains is one element of the city's flood-management programs which is more broadly focused on protecting all designated watersheds. Water gathers and drains throughout entire watersheds, from uplands to lowlands. Each watershed is an interactive element of the whole. A change at one place can cause changes elsewhere, whether planned or inadvertent. The city maintains master watershed plans for all areas of Tulsa that provide localized guidance and inform the city's larger regulatory framework.

Tulsa requires a watershed development permit to be issued before developing, redeveloping, building, excavating, grading, regrading, paving, landfilling, berming, or diking of any property within the city.

There are five types of watershed development permits: floodway, floodplain, stormwater drainage, stormwater connection, and earth change permits. Individual residential lots outside the floodplain are exempted. Tulsa's regulations are based on adopted floodplain maps (both Tulsa Regulatory and NFIP), watershed-wide master drainage plans, and development permits based on specific performance standards.

3.3.4 Stormwater Detention

One method Tulsa uses to avoid increased flooding downstream from new development is to provide stormwater detention basins throughout regional watersheds within dedicated parkland or protected open space areas. New or substantially improved developments must detain the excess stormwater on site - unless they are exempted in master plans or allowed to pay a fee in lieu of on-site detention. Water from detention basins is released slowly downstream. In-lieu fees are allocated for regional detention facilities. In most instances, the City has found regional detention basins to function more satisfactorily than smaller, scattered on-site facilities.

3.3.5 Floodplain Compensatory Storage

Flood water cannot be compressed. It requires space. Encroachments into a channel or floodplain can dam, divert, or displace flood waters. Tulsa requires compensatory excavation if a development - including a flood control project - would reduce valley storage. Preserving or recreating floodplain compensatory storage is a keystone of the City's program.

3.3.6 Freeboard

NFIP regulations require finished floors of new development to be at or above the base flood elevation, based on existing watershed conditions. Tulsa includes freeboard as another margin of safety, requiring finished floors to be at least 1 foot above the regulatory flood elevation, based on a fully urbanized floodplain.

3.3.7 Development Review

A review of both public and private development activities is conducted to ensure compliance with adopted regulations that address flooding and other natural hazards. This task is assigned to the Floodplain Administrator and is also monitored by the SDHMAB through monthly reports documenting reviews, permits and other issues that occur within the FEMA and Tulsa Regulatory Floodplains. The Watershed Development Regulations outlined in Title 11A Stormwater Management and Hazard Mitigation Program of the City's code of ordinances paired with the City's Subdivision and Development Regulations, where applicable, establish the review criteria for watershed permits. Substantial improvement is defined in Section 301 of Title 11A and administered by the

Floodplain Administrator through the policies within this Title.

Excerpt from Title 11A:

Substantial improvement means any repair, reconstruction or improvement of a structure, the cost of which equals or exceeds fifty percent (50%) of the market value of the structure, either before the improvement or repair is started or, if the structure has been damaged and is being restored, before the damage occurred. For purposes of this definition, "substantial improvement" is considered to occur when the first alteration of any wall, ceiling, floor or other structural part of the building commences, whether or not that alteration affects the external dimensions of the structure. The term does not, however, include any projects for improvement of a structure to comply with existing state or local health, sanitary or safety code specifications which are solely necessary to assure safe living conditions, or any alterations of a structure listed on the National Register of Historic Places or State Inventory of Historic Places.

Additional controls are provided in the City's adopted Subdivision and Development Regulations pertaining to the creation or adjustment of parcels of land within the jurisdiction.

Excerpt from City of Tulsa Subdivision and Development Regulations:

5-090 PROTECTION FROM FLOODING AND OTHER NATURAL HAZARDS

5-090.1 All proposed land divisions, new development and redevelopment in a flood hazard area must be reviewed by the floodplain administrator to verify that:

A. The proposal is consistent with the need to minimize flood damage;

B. All public utilities and facilities, such as sewer, gas, electric and water systems, are located and constructed to minimize or eliminate flood damage;

C. Adequate drainage is provided to reduce exposure to flood hazards; and

D. The proposal complies with all applicable federal, state and local flood-related building codes and watershed-floodplain development regulations.

5-090.2 The requirements of this subsection (5-090.2) apply to all land divisions, new development and redevelopment in a flood hazard area.

A. All plats, lot line adjustments and lot splits must show:

(1) Flood hazard area boundaries (including floodways);

(2) Design flood elevations; and

(3) Current effective map panel information.

B. All new building lots must be provided with adequate buildable area on naturally high ground outside of the flood hazard areas.

C. All new building lots must be accessible by emergency vehicles during flood events by transportation routes with reasonably safe and dry access.

D. The design of utilities and facilities must comply with all applicable floodplain regulations, building codes and drainage standards.

E. Floodplain permits must be obtained before any development occurs in a flood hazard area.

F. All flood hazard areas must be placed in a reserve area or overland drainage easement and preserved as open space.

5-090.3 Steep slopes or lands subject to subsidence or other natural hazards may not be platted or developed in such a way as to present a danger to life or property, or to the public health, safety, or general welfare.

5-100 STORMWATER MANAGEMENT Developers are responsible for designing and installing stormwater management facilities in accordance with all applicable city and county requirements.

Table 3-2: Summary of Plans/Programs by Agency

	AGENCY OR CITY OF TULSA (COT) DEPARTMENT								
	COT PLANNING	COT DEVELOPMENT SERVICES	COT WATER AND SEWER	COT PUBLIC WORKS	TAEMA	LEVEE DISTRICT 12	USACE TULSA DISTRICT	INCOG	PARTNER TULSA
Comprehensive Plan	•							•	
Capital Improvement Plan			•	•					
Economic Development								•	•
Emergency Operations				•	•	•	•		
Continuity of Operations	•	•	•	•	•	•	•		
Transportation	•			•				•	
Stormwater Management				•			•		
Brownfields				•					•
Dam Failure Emergency Action Plan			•	•	•		•		
Levee Failure Emergency Action Plan					•	•	•		
Debris Removal				•	•				
RL/Open Space				•					
2015 ICC Building Code		•		•					
Zoning Ordinance	•	•						•	
Subdivision Ordinance	•	•						•	
Floodplain Ordinance		•		•			•		
Flood Insurance Rate Maps (FIRM)		•		•			•		

3.4 Planning and Regulatory Capabilities

This framework analyzes Tulsa's existing Plans, Ordinances, Codes, and other Regulations used to guide growth and development. Examples of such documents include Comprehensive Plans, District or Neighborhood Plans, Resilience Plans, Economic Development Strategies, Emergency Operations Plans, Development Regulations, and Building Codes, among others.

During the planning process, the project team evaluated each of these materials to understand how they influence the City's ability to mitigate, address, and recover from hazards. Where tools already exist, mitigation strategies and recommendations employ existing resources and processes to streamline implementation. Opportunities for alignment with the Multi-Hazard Mitigation Plan are identified in this section. Continued coordination between the agencies that administer these regulatory tools and programs is encouraged to further support the City's mitigation efforts.

The following matrix lists the programs, plans, and ordinances and the department or agency that maintains them. A more detailed description of each plan or ordinance follows in Table 3-2 and the following section.

3.4.1 Comprehensive Plan

Qualitative Assessment

Tulsa's Comprehensive Plan, PlaniTulsa, contains ten chapters, of which seven—Land Use, Transportation, Economic Development, Housing and Neighborhoods, Communities, Parks and Recreation, and Environment and Natural Resources—provide action items and guidance that, if implemented, could advance Tulsa's capacity to mitigate several types of hazards.

An update to the plan was adopted in 2023, which restructured and expanded plan content. Each chapter now includes a section that identifies potential considerations regarding health and wellness, social equity and resilience, funding priorities, and how Tulsa fits into the larger region. The planning team met with staff planners responsible for this update to understand how the Multi-Hazard Mitigation Plan can both support and benefit from long-range planning efforts like PlaniTulsa.

Alignment Opportunities

Updates to PlaniTulsa, or future Comprehensive Plans, could benefit from including sections or language about hazard mitigation within each salient chapter, and discussing mitigation and resilience throughout the recommendation process. Considering the potential impacts of apparently unrelated action items and recommendations on mitigation capabilities could help prevent adverse effects. For example, recognizing the possible worsening of stormwater issues resulting from land use recommendations that increase density, due to the proliferation of impermeable surfaces. Future Comprehensive Plans should maintain these recommendations, while also providing guidance on how to implement them without incurring negative outcomes by employing strategies like Green Infrastructure.

The planning team met with the Tulsa Planning Office planner responsible for the 2023 update of PlaniTulsa on May 31, 2023 to discuss alignment opportunities with the Multi-Hazard Mitigation Plan. In each chapter of the updated comprehensive plan, considerations (or contexts) are provided regarding social equity and resilience in addition to health and wellness. The 2019 Multi-Hazard Mitigation Plan was one tool used to develop these contexts and make connections between the City's comprehensive plan and mitigation goals.

3.4.2 Resilient Tulsa

Qualitative Assessment

Resilient Tulsa offers robust analysis of the City's current hazard context and outlines several goals which, if achieved, could contribute to Tulsa's hazard mitigation efforts.

The Plan's Hazard Vulnerability Analysis model identifies Tulsa's greatest susceptibilities, the three most prominent of which are extreme heat, tornados, and winter storms. Flooding is ranked fifth, and dam or levee failure are both placed within the highest risk category.

The City Resilience Framework (CRF) outlines four categories of urban resilience and provides twelve action-oriented and implementable "drivers" to achieve success in these categories. Those include Health and Wellbeing, Economy and Society, Infrastructure and Environment, and Leadership and Strategy.

Vision 2 of the Resilient Tulsa Plan recommends the creation of Resilience Hubs implemented through the Map Your Neighborhood program and promotes the use of Emergency Mobility Plan Technology.

Alignment Opportunities

Resilient Tulsa does well to provide hearty, data-driven analysis of what hazards Tulsa faces, advance specific definitions of resilience in certain categories, and recommend strategies to improve resilience and response, with equity and social justice at the center of these recommendations.

Future iterations of the Plan should first update this analysis as needed and maintain or reexamine the categories of the CRF. With contemporary data and an updated understanding of the CRF, Resilient Tulsa should strive to expand the scope of its recommendations, address more types of hazards, and explain what the City and affiliate agencies can do to strengthen resilience to these hazards. It should also work to solidify the connection between this strong data and analyses and actionable policy guidance.

During the 2024 mitigation plan update process, representatives from the Mayor's Office of Resilience and Equity participated in multiple stakeholder meetings and in meetings with various stakeholders during the planning process. One recommendation from the meetings was to develop a hazard mitigation or climate resilience equity indicator in future updates of the CRF.

3.4.3 Capital Improvements Program

Qualitative Assessment

The Capital Improvements Program (CIP) allocates funding to City Departments and Projects over a five-year period. Tulsa's current CIP began in fiscal year 2025 and extends through fiscal year 2029.

Across this five-year period, the City anticipates allocating over $3.1 billion to Public Works projects which may have a strong and direct impact on hazard mitigation capabilities. These projects include $95 million for flood control and over $521.5 million for street projects which ensure robust mobility for emergency management before, during, and after a disaster event. The CIP also provides for a combined allocation of over $75.7 million to the Parks and Recreation Department and to River Parks projects.

The Tulsa Authority for Economic Opportunity, also known as Partner Tulsa, has been allocated $14.7 million to support implementation of adopted plans and programs which are largely focused on providing improved opportunities to under-served neighborhoods such as the Greenwood/Kirkpatrick Heights Master Plan.

The maintenance and expansion of facilities under the purview of these entities is invalu-

able for stormwater management and reduction of the urban heat island effect. The program also allocates millions of dollars for several creek rehabilitation and relief projects.

Alignment Opportunities

Continuing to develop responsive and timely public investment plans through the CIP will be of paramount importance to ensuring Tulsa's infrastructure and governance systems are prepared to conduct hazard mitigation procedures.

As the risk and severity of disasters increase, allocating funding to capital projects specifically oriented toward improving Tulsa's resilience to hazards before they occur, and capacity to respond while and after they occur, may become increasingly necessary. The question of precisely what these investments should target will have to be answered as issues and opportunities become understood, and the priorities of elected officials and appointed professionals are established. The process of developing future CIPs should include extensive discussion about how allocations will impact the City's hazard mitigation capabilities.

Capital projects focused on improving resiliency are included within this plan. Continued efforts to align funding programs like the CIP with long range mitigation goals will improve the City's ability to accomplish difficult tasks that result in improved outcomes for residents.

3.4.4 Code of Ordinances

Qualitative Assessment

Title 11-A of the City of Tulsa's Code of Ordinances establishes a Stormwater Drainage and Hazard Mitigation Advisory Board and lists the following as hazards within its consideration: dam failure, drought, earthquakes, expansive soils, extreme heat, floods, hailstorms, hazardous material events, high winds, levee failures, lightning, severe winter storms, terrorism, tornados, transportation events, urban fires, wildfires, and other natural or man-made disasters.

This title also affords the Board all necessary assistance from other personnel and agencies of the municipal government. Title 11-A also calls for the creation of funding mechanisms for the work of this board, outlines the permitting process for NFIP-compliant watershed development, and recommends a specific public involvement process for drainage plans and other capital projects.

Title 35 governs the construction and alteration of thoroughfares, drainageways, channels, detention facilities, storm sewers, and sanitary sewers; it also outlines street tree requirements, including maintenance.

Title 42 contains the City's Zoning Code and advocates for the use of Low-Impact Development (LID) techniques among its other tree preservation and installation requirements.

Finally, Tulsa's Subdivision and Development Regulations require that all proposed land divisions, new development, and redevelopment in a flood hazard area must be reviewed by the floodplain administrator to ensure various safety and infrastructure protection standards are met.

It also requires developers to install appropriate stormwater infrastructure and encourages the incorporation of LID best practices.

A customized River Design Overlay District is in effect for properties within the Arkansas River corridor. The purpose of the overlay is to address the appearance of the corridor while also ensuring development is sensitive to the area's natural resources and environmental qualities This type of regulation is important for addressing potential impacts of hazards throughout the city and similar applications may be appropriate in other locations.

Alignment Opportunities

The Code of Ordinances is an expansive document, and its policies often affect development over not just years, but decades. As Ordinances are revised or rewritten, new regulatory language should not only be responsive to contemporary development issues, but also account for projected changes in hazard frequency and severity. These provisions should also be optimally responsive to changing state or federal positions on hazard mitigation to ensure compliance with the broader regulatory environment and best position the City to pursue and procure resources from higher governments.

All cities in Oklahoma must adopt local building and trade codes in accordance with the OUBCC (Oklahoma Uniform Building Code Commission). The current suite of adopted building codes consists of the 2018 ICC's (International Code Commission) International Building Code (IBC), International Residential Code (IRC), International Existing Building Code (IEBC), and International Fire Code. Cities can make local amendments to these codes that require more stringent criteria, however they cannot relax the minimum standards. For instance, in 2014 the city of Moore, OK was the first municipality in the country to adopt building codes that require new homes to be able to withstand winds of 135 mph instead of the previous 90 mph. Strengthening standards through building codes may improve resiliency and the City's ability to recover more quickly from future high wind and tornado events.

3.4.5 Emergency Operations Plan

Qualitative Assessment

TAEMA's Emergency Operations Plan (EOP) outlines how Policy Groups for Tulsa County and the City of Tulsa are formed and delegates specific tasks and responsibilities to different emergency operations positions, such as the Emergency Management Director, the Fire Chief, and volunteer groups when committed. It also provides protocols for ensuring Continuity of Government and the protection of essential records.

The Plan also contains provisions for communications strategies and responsibilities during emergency events, for the acquisition and storage of materials and equipment needed for emergency infrastructure repairs, and for increasing terrorism preparedness.

FEMA also supports local governments through its Lifelines program. Lifelines are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function. FEMA has developed a construct for objectives-based response that prioritizes the rapid stabilization of Community Lifelines after a disaster. The integrated network of assets, services, and capabilities that provide lifeline services are used day-to-day to support the recurring needs of the community and enable all other aspects of society to function.

Alignment Opportunities

The Emergency Operations Plan is a thorough and detailed compendium of protocols in which officials and agencies in the Tulsa area can find guidance for disaster response and preparation. The partners involved in its creation and updating should ensure that the document remains current and responsive to changing trends in disaster frequency and severity, in infrastructure and governance issues, and in emerging technologies.

Regular review and alignment of the EOP with this Multi-Hazards Mitigation Plan will support effective response to hazards and the ability to mitigate adverse impacts before hazards occur.

3.5. Administrative and Technical Capabilities

This framework analyzes the resources and skills available to City staff to develop and implement projects, policies, and programs in pursuit of hazard mitigation. Administrative capabilities stem primarily from the assignment of mitigation efforts to City Departments, Boards, and Commissions, and if those entities have sufficient personnel with the right skills to fulfill those responsibilities. Technical capabilities are assessed by reviewing the level of knowledge and technical skill housed within City Departments, such as competence with GIS, skills in public outreach, experience with grant writing, and so on.

The City of Tulsa has the following capabilities.

Table 3-3: Summary of Administrative and Technical Staff by Agency

	AGENCY OR CITY OF TULSA (COT) DEPARTMENT								
	COT PLANNING	COT DEVELOPMENT SERVICES	COT PUBLIC WORKS / WATER & SEWER	COT IT	TAEMA	LEVEE DISTRICT 12	USACE TULSA DISTRICT	INCOG	SDHMAB
Planning Commission	•							•	
Mitigation Planning Committee			•		•				•
Maintenance Programs to Reduce Risk			•	•	•				
Mutual Aid Agreements					•	•	•		
Chief Building Official		•							
Floodplain Administrator		•							
Emergency Manager					•		•		
Community Planner	•							•	
Civil Engineers		•	•				•	•	
GIS Coordinator	•		•	•			•	•	
Warning Systems/Services			•		•		•		
Hazard Data & Information	•	•	•	•	•		•	•	
Grant Writers	•		•		•				
HAZUS Analysis			•				•		

These include staff and their skills and tools that can be used for mitigation planning and to implement specific mitigation actions.

3.5.1 Planning Commission and City Council

Qualitative Assessment

Tulsa elects a Council of nine members, each representing a District, as well as the Mayor. Tulsa's charter calls for a strong mayor-council system, as opposed to a weak mayor-council system in which the City Manager has much more authority.

The Tulsa Metropolitan Area Planning Commission (TMAPC), a cooperative effort by the City and the County, is responsible for adopting the Comprehensive Plan, and adopting subsequent planning and development policies for the City.

Recommendations

The City Council and the Planning Commission, and other key elected officials and groups, should receive timely and thorough information about hazard conditions in Tulsa and about ongoing and projected mitigation efforts. Technical experts and officials should maintain communication with these governing bodies and should strive to educate them about hazard mitigation planning and implementation regularly and robustly to ensure they are able to render policy decisions effectively even in the absence of immediate access to technical expertise.

3.5.2 City of Tulsa Stormwater Drainage and Hazard Mitigation Advisory Board (SDHMAB)

Qualitative Assessment

The purpose of the Stormwater Drainage and Hazard Mitigation Advisory Board (SDHMAB) is to provide policy guidance to the managing city departments and the City Council. Title 11-A establishes the SDHMAB as part of the city's Comprehensive Stormwater and Hazard Mitigation Program. The Public Works Director is the authority over all hazard mitigation, even beyond flooding. The SDHMAB has developed a phased implementation program for projects identified in the City's watershed master plans, to be funded by stormwater fees, sales tax revenues, or bond issues.

Through the Program for Public Information (PPI) Subcommittee, the Board oversees updates to Tulsa's Hazard Mitigation Plan, and ensures coordination between stakeholders and local jurisdictions during the Plan development process.

Recommendations

The Board currently reviews an extensive list of hazards with which Tulsa may contend and is authorized to coordinate hazard mitigation efforts throughout the City. The Board should remain attentive to the changing hazard landscape and evolving mitigation practices.

Continuing to employ the PPI Subcommittee to update the Hazard Mitigation Plan will remain a best practice, given its capacity to obtain a Class 1 CRS Rating from FEMA, and the accompanying NFIP rate benefits.

Beyond adherence to FEMA requirements, the Board should strive to see continuous improvement in Tulsa's Hazard Mitigation Plans, making sure they remain thoroughly researched and well-written and become continuously more actionable and measurable with each iteration.

3.5.3 Risk Reduction Programs

Community Rating System (CRS)

The Community Rating System is a voluntary

program for flood loss reduction in which communities that go beyond the minimum floodplain management requirements earn flood insurance discounts for residents. The Federal Emergency Management Agency in the U.S. Department of Homeland Security administers the program. Tulsa's Class 1 rating for the National Flood Insurance Program corresponds to the city's number one ranking for fire protection by the Insurance Services Office (ISO), also administered by FEMA. Tulsa achieved the number one ISO rating citywide in 2019.

Qualitative Assessment

The Tulsa Fire Department, in conjunction with the Tulsa Community Foundation, maintains a Tulsa Fire Community Risk Reduction effort.

The Streets and Stormwater Department investigates known problem areas in creeks and drainage systems after all significant rainfall events.

Recommendations

The appropriate departments and agencies should continue to administer existing risk reduction programs, and seek to expand their reach and impact.

The City and other local jurisdictions should also strive to develop and administer risk reduction programs which can equip the public to respond intelligently to other hazards in addition to fires and drainage system failures. Given the findings of Resilient Tulsa's Hazard Vulnerability Analysis model, addressing the risks posed by winter storms and extreme heat events should likely take the highest priority in developing new risk reduction efforts.

3.5.4 Mutual Aid Agreements

Qualitative Assessment

The Oklahoma Intrastate Mutual Aid Compact assures intergovernmental cooperation in the event of an emergency by automatically enrolling all jurisdictions within the State of Oklahoma into the mutual aid system. Additional agreements and compacts may be formed between jurisdictions, and jurisdictions may opt out of the system if they wish.

Oklahoma has also adopted the Emergency Management Assistance Compact (EMAC) as law, granting the state access to national resources and aid during emergencies. Additional compacts between the City of Tulsa, or its departments, and other jurisdictions in the region exist as well, providing the City with access to emergency response resources from neighboring communities.

Recommendations

The City of Tulsa should create and maintain a centralized list of existing mutual aid agreements into which it has entered independently of the Oklahoma Intrastate Mutual Aid Compact. It should also continue to seek new agreements which can augment its mitigation capabilities and remain receptive to proposed mutual aid agreements from other jurisdictions. The City should also consider integrating any jurisdictions with which it has mutual aid agreements into the hazard mitigation planning process, and into the emergency operations planning process where appropriate.

3.5.5 Staff

Qualitative Assessment

Tulsa's Chief Building Official (CBO) is a Certified Floodplain Manager (CFM) and receives CECs annually. All infrastructure development permits are reviewed by Development Services and inspected by Field Engineering.

The Floodplain Administrator (FPA) is also a CFM and receives CECs annually. The FPA reviews all private and public development plans

within the floodplain.

TAEMA, while trained in emergency management and tasked with coordinating partners in disaster response, is understaffed per FEMA's Emergency Operations Center course number IS-775 suggested staffing levels for a community the size of the Tulsa metro.

All of the City's civil engineers responsible for stormwater review and planning are CFMs and receive CECs annually.

Recommendations

Tulsa should continue to staff the CBO and FPA positions with CFMs and ensure that these staff members are able to pursue and obtain CECs. The City should also continue hiring CFMs for stormwater review and equipping them to receive CECs.

TAEMA should continue any ongoing efforts to reach sufficient staffing per FEMA IS-775. The City should also utilize its connections and resources to assist TAEMA in this effort when appropriate.

Throughout the hazard mitigation planning process, it became clear in almost every meeting that there is a lack of federal mitigation funding expertise beyond state and local resources. The federal government provides various funding options for mitigation and resilience. The City has often had to rely on consultants to navigate these federal funding sources, indicating a lack of a consistent strategy for seeking funds like FEMA's Hazard Mitigation Assistance.

Although the costs of hiring consultants are often covered by grants, it would be more advantageous for the city to have this expertise in-house to coordinate city-wide efforts. Having dedicated staff for this purpose would enhance the City's ability to consistently apply for hazard mitigation assistance, increasing the chances of developing projects with broad hazard resilience and mitigation benefits and improving the likelihood of successful funding applications.

3.5.6 Technical Resources

Qualitative Assessment

Given that the City and its affiliate agencies pursue hazard mitigation funding through grants, the City maintains a Grants Department and has received numerous Hazard Mitigation Assistance grants. TAEMA also has a finance and grant coordinator who writes Hazard Mitigation Assistance (HMA) grants.

Recommendations

The City and affiliate agencies should continue to pursue grant funding for actions and projects identified in this Multi-Hazard Mitigation Plan. Maintaining strong partnerships, developing and sharing performance metrics and communicating on a regular basis will support successful grant applications.

3.5.7 Warning Solutions

Qualitative Assessment

TAEMA maintains a network of sirens which can alert over 90% of the population of Tulsa County. These sirens are tested weekly by the City of Tulsa IT Department. The City utilizes several other warning systems when appropriate, such as the barricade of streets when flooded, or the use of vehicular public announcement systems by the Police Department to alert a specific area.

Recommendations

The City, in cooperation with TAEMA, should continue to ensure that all emergency alert systems remain functional, and that they reach as much of the regional population as possible.

The City and TAEMA should also seek to utilize or develop new methods of alerting the population to hazard events as emerging technol-

ogies and methods become established as best practices. This may include continuing and expanding use of the Tulsa Ready mobile app, employing other alert systems which reach people directly via their cell phones, and social media presence. Other means of alerting the population which do not depend on access to electricity, internet, or cellular service should also be developed.

Alert systems of all types should continue to expand their impact through distribution in multiple languages and through approaches which overcome disability and sensory barriers. These efforts may require partnerships with local accessibility advocacy groups or affiliate agencies.

3.6 Financial Capabilities

This framework evaluates the budgetary ability of the City to act on policy and implement projects. By first identifying the different revenue streams and funding sources at Tulsa's disposal, and subsequently assessing how those funding mechanisms have been used and can be used to realize hazard mitigation goals, an understanding of Tulsa's ability to fund hazard mitigation work can be gained.

3.6.1 Local Funding Sources

Qualitative Assessment

As mentioned in the Planning and Regulatory Section, the CIP allocates funding to several initiatives which can improve stormwater and flooding outcomes, as well as emergency response capabilities.

General utility fees are used to maintain and expand utility services. New development impact fees, specifically fees in lieu of on-site detention, fund drainage improvements in basins where new developments are located. Tulsa also collects a stormwater utility fee, which funds maintenance and expansion of the stormwater drainage system.

The City also passes bonds to fund specific projects. The most recent iteration of Improve Our Tulsa allocates over $300 million to street projects and citywide facility maintenance, which could improve hazard response and resilience.

Recommendations

Tulsa should be responsive to emerging and projected capital funding needs related to hazard mitigation as it develops new CIPs, as mentioned in the Planning and Regulatory Section.

Tulsa should also continue diligent scheduling of its general utility fees to ensure consistent service, maintenance, and expansion when needed, and the same is true of stormwater utility fees and impact fees.

The City should continue to responsibly utilize strategic funding initiatives such as bonds and Improve Our Tulsa to obtain funding for hazard mitigation projects without reliance on state or federal resources.

3.6.2 State and Federal Funding Sources

Qualitative Assessment

The City utilizes Oklahoma Water Resource Board (OWRB) loans to fund water and sewer projects, when possible, via the Tulsa Metropolitan Utility Authority.

Tulsa also pursues Community Development Block Grants (CDBGs), which are typically used to fund projects addressing functional needs populations. Hazard Mitigation Assistance Grants from FEMA are also utilized whenever possible, and Federal Highway Administration funding is applied to eligible transportation projects when available.

Recommendations

Tulsa should continue to pursue state loans and grants whenever possible. The City should remain prepared to apply for any state funds that may become available by maintaining a robust foundation of local data and analyses, planning documents, and financial information needed to draft successful grant applications or secure loans.

The City should also take advantage of the current period of unusually abundant federal funding for infrastructure projects, programs which promote equity, and initiatives which recognize the changing landscape of hazard events. The City should adopt a highly proactive approach to securing these federal funds for hazard mitigation purposes while they are available.

3.7 Education and Outreach Capabilities

This framework assesses Tulsa's existing outreach programs, public information and communication methods, and community partnerships that can be used to educate and inform the public of hazard mitigation activities and opportunities. In determining how these contribute to the City's capabilities, this section seeks to describe not only what programs and partnerships exist but to assess their current utilization and success.

3.7.1 Outreach Partnerships

Qualitative Assessment

In the City of Tulsa Hazard Mitigation Plan, several key organizations play vital roles in disaster resilience and education.

As mentioned several times throughout this document, the City of Tulsa Program for Public Information was established in 2014 and identified appropriate city employees to serve on the PPI committee and recruited strategic community representatives that brought an interest in local flooding outreach and education. The Tulsa PPI Committee includes thirteen City of Tulsa employees and fifteen non-local government representatives from public and private sectors.

Several PPI committee organizations conduct annual outreach across the City of Tulsa to educate the public about various hazards, their impact, and hazard reduction.

The Disaster Resilience Network, encompassing the Disaster Resilient Business Council, Cross-Cultural Council, and Housing Council, focuses on empowering communities to minimize disaster impacts.

The Tulsa Ministerial Alliance offers support to individuals with special needs, while the Tulsa Weather Coalition provides material aid like air conditioners for medical needs and educates about heat-related risks.

The 211 Helpline is a crucial resource for social services and disaster resources in emergencies. Child-focused programs like the Child Care Resource Center and the American Red Cross Pillowcase Project offer training, technical assistance, and education in natural hazards, safety, and emotional coping skills.

Recommendations

To enhance hazard mitigation, Tulsa is recommended to maintain and strengthen these existing partnerships, adaptively using these channels as resources and needs evolve, and to actively seek new collaborative opportunities for similar purposes.

3.7.2 Ongoing Efforts

Qualitative Assessment

Preparedness efforts are directly linked to the city's resilience—the ability to prepare for threats and hazards, adapt to changing condi-

tions, and withstand and recover rapidly from adverse conditions and disruptions. With the interconnected and ever-evolving nature of people, places, and systems, strengthening resilience requires a collective approach—one that includes all sectors and disciplines, all levels of governments, the private and non-profit sectors, academia, communities, families, and individuals, and that considers all facets of resilience such as climate, ecosystem, social, economic, infrastructure, and disaster resilience and their interdependencies. Strengthening resilience also requires that we build capacity and capability that benefit and protect communities, create integrated, multi-objective solutions that comprehensively address shocks and stressors, and position people, places, and systems to adapt and evolve in ways that support resilience for current and future generations.

Ongoing efforts include:

The Tulsa Fire Department hosts fire safety events at elementary schools.

The City has become StormReady Certified through its maintenance of a 24-hour warning point and emergency operations center, its provision of multiple ways to receive weather warnings, and its use of a local weather conditions monitoring system, among other techniques.

With a minimum of 8 and a maximum of 2,500 dwelling units per Firewise Community, the City in its entirety is not eligible for this designation but is home to several communities which have attained it.

TAEMA operates the Tulsa Ready mobile application, which can provide knowledge and guidance on disaster preparedness and alert users to emerging hazard conditions.

The City and County Health Departments administer Community Assessments for Public Health Emergency Response (CASPER), which indicate the potential resilience of area residents in the event of a disaster.

Recommendations

The City should maintain its Fire Department fire safety events and assess whether there are opportunities to expand the scope and impact of this program.

Tulsa should continue to maintain and invest in the emergency alert and information systems that have resulted in its StormReady Certification and learn about any other possible certifications or measurements which, if obtained, could improve mitigation capabilities.

TAEMA should continue to utilize the Tulsa Ready app and ensure it is kept up to date. The app should also be updated as needed to reflect contemporary best practices with regard to mobile app functionality and design.

The City and its affiliate agencies should leverage information obtained through CASPER to improve direct outreach and educational materials and best equip outreach partners.

CHAPTER 4
RISK ASSESSMENT

The risk assessment helps communicate vulnerabilities, develop priorities, and inform decision-making for both the hazard mitigation plan and for other emergency management efforts. Subject matter experts and community leaders obligated themselves to countless hours of stakeholder workshops, steering committee meetings, and data collection and analysis. The risk assessment provides the factual basis for developing a mitigation strategy for the city. This assessment is designed to provide the city with a deeper understanding of specific hazards. The results should be integrated into future emergency management planning and recovery and future development efforts. A web-based version of the risk assessment may be found online at cityoftulsa.org. The City of Tulsa has also created a web-based GIS mapping tool to assess diasaster threats to specific locations.

Developing the Risk Assessment

The risk assessment was updated and enhanced to provide the most current and robust data and information for quantifying the cost-effectiveness of potential hazard mitigation projects. A GIS Analysis was conducted to include any new/modified/updated information (including hazard, land use, and development trends), findings, research, and risk data. New, readily available, credible technical data was incorporated into the analysis as appropriate.

Hazard Identification

Tulsa considered a full range of hazards that could affect the city for the 2024 All-Hazard Mitigation Plan Update. The process included a review of the 2019 Tulsa Multi-Hazard Mitigation Plan, a review of the state hazard mitigation plan, a review of previous events and losses, as well as information on the frequency, magnitude, and costs associated with hazards that have struck Tulsa or could do so. Extensive outreach was conducted by subject matter experts to ensure the appropriate elements of each hazard were included and the best available data was used for the risk assessment.

Hazards of Concern

At stakeholder workshop meetings held on June 28, 2023, November 2, 2023, and January 25, 2024, a group of stakeholders considered the 12 hazards identified in the 2019 Tulsa All-Hazard Mitigation Plan and decided all hazards except Hazardous Materials remained valid and that some hazards should be combined to reduce redundancy. The planning team considered hazards addressed in the State of Oklahoma Hazard Mitigation Plan. The hazards of concern evaluated for the 2024 Hazard Mitigation Plan Update are presented below; the order of the listing does not indicate the hazards' relative severity:

- Dam & Levee Failure
- Drought

- Earthquake
- Expansive Soils, Subsidence and Erosion
- Extreme Heat
- Fire
- Flooding
- Hail
- Lightning
- Tornado/High Wind
- Severe Winter Storm

Hazards Summary

The classifications for probability and overall significance, as defined on Worksheet 5.1 in the FEMA Local Mitigation Planning Handbook, met Tulsa's needs and methods and were used in the 2024 risk assessment.

Definitions for Classifications:

Probability of Future Events

Unlikely: Less than 1 percent probability of occurrence in the next year or a recurrence interval of greater than every 100 years.

Occasional: 1 to 10 percent probability of occurrence in the next year or a recurrence interval of 11 to 100 years.

Likely: 10 to 90 percent probability of occurrence in the next year or a recurrence interval of 1 to 10 years ·

Highly Likely: 90 to 100 percent probability of occurrence in the next year or a recurrence interval of less than 1 year.

Chart 1: Summary of Hazard Probability and Overall Significance. The chart shows colors in the High/Med/Low fields to indicate the overall significance of a hazard. The colors of the symbols in these fields indicate the probability of future events as shown in the key below:

Unlikely **Occasional** **Likely** **Highly Likely**

		OVERALL SIGNIFICANCE		
		High	Medium	Low
HAZARDS	Flooding			
	Severe Winter Storms			
	Tornado / High Winds / Derecho			
	Dam and Levee Incidents			
	Extreme Heat			
	Wildfire			
	Hail			
	Drought			
	Expansive Soils			
	LIghtning			
	Earthquake			

Overall Significance

Low: The event has a minimal impact on the planning area.

Medium: The event's impacts on the planning area are noticeable but not devastating.

High: The criteria consistently fall in the high classifications and the event is likely/highly likely to occur with severe strength over a significant to extensive portion of the planning area.

Disaster History

Of the 225 federal disasters declared in the State of Oklahoma from 1955 to January 2024, Tulsa County received 34 major disaster declarations (DR) and 12 fire management assistance declarations (FM). The City of Tulsa Disaster Declarations chart below outlines each FEMA declaration in Tulsa County since 1955. It should be noted that declarations prior to 1964 do not contain county data, as it is not available (FEMA 2018). FEMA DR- 4587 and FEMA DR-4657 were declared in Tulsa County, and subsequently the City of Tulsa, since approval of the previous plan.

4.1 Flood

4.1.1 Hazard Description

A flood is the partial or complete inundation of water over normally dry land. Common impacts of flooding include damage to personal property, buildings, and infrastructure; bridge and road closures; service disruptions; and injuries or even fatalities. There are three common types of flooding in Tulsa: riverine flooding, flash flooding, and urban flooding.

Riverine flooding occurs from excessive rainfall in upstream areas that forces rivers and streams to rise and overflow their banks, inundating the adjacent floodplains. Riverine flooding is usually a gradual process, with several hours to several days of warning time for downstream communities. This type of event usually remains in flood for a longer period than flash or urban flooding, and often causes more damage due to the length of time structures are inundated, the velocity and depth of water, and floating debris.

Flash flooding is associated with large convective thunderstorms that frequent the region and can drop between 1 and 5 inches of rain in the course of an hour. When the soil is already saturated, rainfall from such storms can converge in creeks and streams suddenly, with little warning. Flash floods can reach peak flows within a few minutes. Waters from flash floods move with great force and velocity and can tear out trees, carry away houses and outbuildings, and destroy roads and bridges. These walls of water often carry large amounts of debris, sewage, and pollutants. Although potentially hazardous to life and destructive of property, flash flooding usually lasts only a matter of hours.

Urban flooding occurs when heavy rainfall runs off of structures, parking lots, and streets and converges in culverts and drainage ways often clogged with debris. This causes streets to flood and storm sewers to back up.

4.1.2 Location

Tulsa's 213 square miles contain 56 creeks and watersheds, which directly or ultimately drain into either the Arkansas River or into Bird Creek, a tributary to the Verdigris River. A major ridgeline runs diagonally through Tulsa, from northwest to southeast. Watersheds to the southwest of the ridge generally flow to the Arkansas River, and those to the north and east into Bird Creek. FEMA and Tulsa have identified those areas within the watersheds of Tulsa's streams that have a 1% (100-year) chance

Table 4-1: City of Tulsa Disaster Declarations[1]

DISASTER NUMBER	TITLE	YEAR OF DECLARATION DATE
314	HEAVY RAINS & FLOODS	1971
317	SEVERE STORMS & FLOODING	1972
392	SEVERE STORMS, FLOODING, TORNADOS	1973
419	HEAVY RAINS & FLOODING	1974
453	SEVERE STORMS & FLOODING	1974
441	SEVERE STORMS & FLOODING	1974
491	SEVERE STORMS & TORNADOS	1975
504	SEVERE STORMS & FLOODING	1976
709	SEVERE STORMS & FLOODING	1984
704	SEVERE STORMS & TORNADOS	1984
778	SEVERE STORMS & FLOODING	1986
987	SEVERE STORMS & TORNADOS	1993
991	SEVERE STORMS, TORNADOS, FLOODING	1993
3118	EXTREME FIRE HAZARD	1996
1272	TORNADOS	1999
3158	SEVERE WINTER AND ICE STORM	2000
1355	SEVERE WINTER ICE STORM	2001
1401	SEVERE WINTER ICE STORM	2002
3219	HURRICANE KATRINA EVACUATION	2005
1623	EXTREME WILDFIRE THREAT	2006
2628	SPERRY FIRE	2006
3280	SEVERE WINTER STORMS	2007
1735	SEVERE WINTER STORMS	2007
1678	SEVERE WINTER STORMS	2007
3272	SEVERE WINTER STORMS & FLOODING	2007
3308	SEVERE WINTER STORM	2010
1876	SEVERE WINTER STORM	2010
1985	SEVERE WINTER STORM & SNOWSTORM	2011
3316	SEVERE WINTER STORM	2011
2944	TURLEY FIRE	2011
4222	SEVERE STORMS, TORNADOS, STRAIGHT-LINE WINDS, FLOODING	2015
4438	SEVERE STORMS, STRAIGHT-LINE WINDS, TORNADOS, FLOODING	2019
4587	SEVERE WINTER STORMS	2021
4657	SEVERE STORMS, STRAIGHT-LINE WINDS, TORNADOS, FLOODING	2022

1 fema.gov

of flooding in any given year.

The City of Tulsa adopted a City of Tulsa Regulatory Floodplain based on a 1% or 100-year flood under the planned fully urbanized conditions that is anticipated within the drainage basin. These floodplains are extended upstream in the drainage basin to a point where there is approximately 40 acres of drainage, compared to the Special Flood Hazard Area (SFHA) floodplains, which only extend to a point where there is approximately one square mile of drainage area. Regulations for the City of Tulsa Regulatory Floodplain range from building elevation and flood-proofing requirements to other site and watershed considerations. Figure 4-1 maps the City's Regulatory Floodplain.

It is important to note that while FEMA digital flood data is recognized as best available data for planning purposes, it does not always reflect the most accurate and up-to-date flood risk. Flooding and floo-related losses often do occur outside of delineated special flood hazard areas. Figure 4-2 maps public comments related to flooding. Tulsa flood problems are widely dispersed and could be divided into several categories:

- Floods along major waterways with very large drainage basins, such as the Arkansas River and Bird Creek;
- Flash floods along tributary creeks and water ways that ultimately drain into the Arkansas River or Bird Creek;
- Floods that impact streets and transportation systems;
- Localized drainage and nuisance flooding problems.

The master drainage plans identified the "problem areas" within each basin, analyzed

Figure 4-1 City Regulatory Floodplain

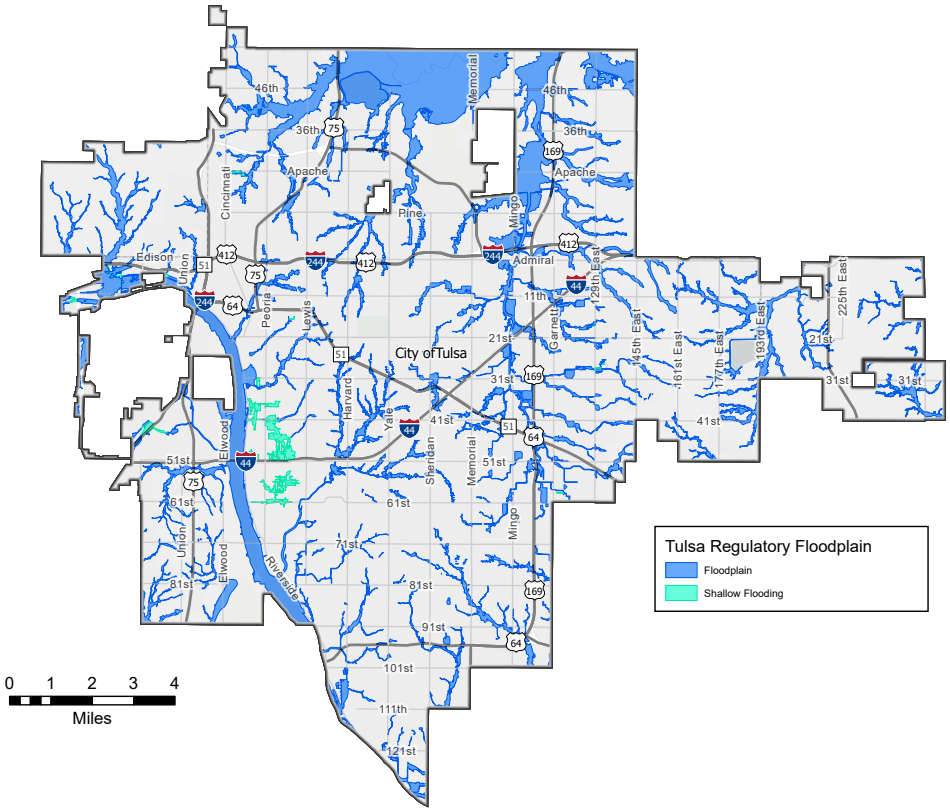


Figure 4-2 Public Flooding Comments

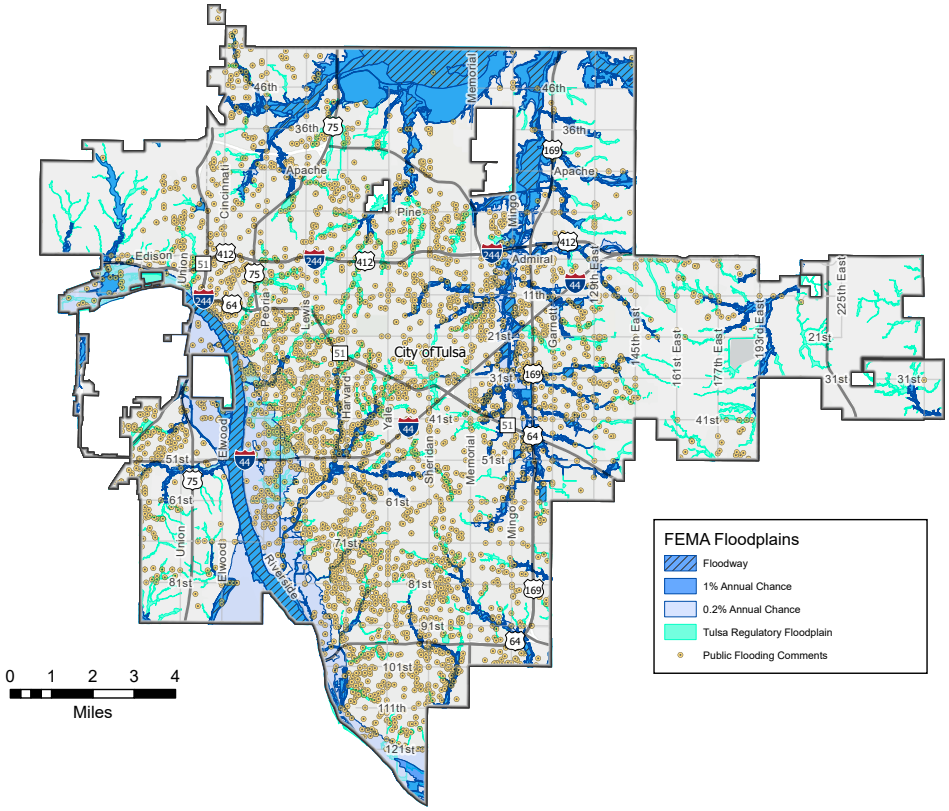
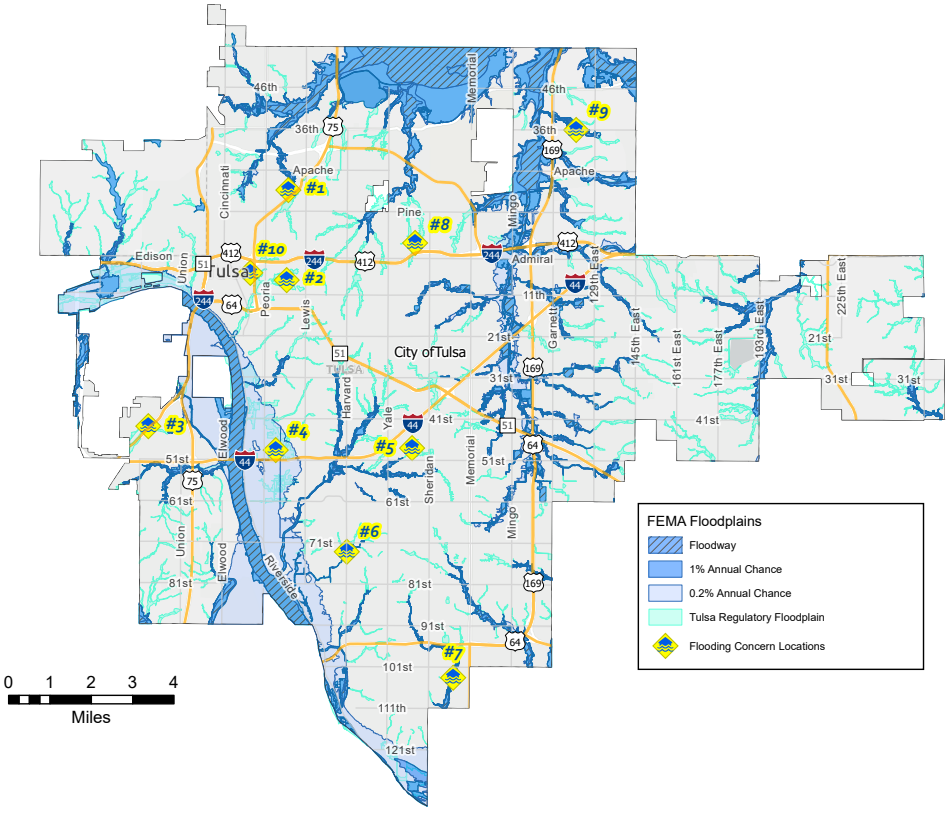


Figure 4-3 City of Tulsa Floodplains and Areas of Concern



alternative solutions to those problems, and provided recommended solutions, many of which are on the City's Capitol Improvement Plan list. As noted in this section, nearly all areas of Tulsa are at risk to the flood hazard. For this plan update, the planning team found it important to focus on mitigating flood risk in recurring problem areas. The areas are identified on the floodplain map in Figure 4-3 and described in Table 4-2.

4.1.3 Extent

Floodplain Management is based on the "1% or 100-year flood," which is a flood that has a one percent (1%) chance of occurring in any given year. FEMA has established the Special Flood Hazard Area (SFHA), more commonly referred to as the 1% or 100-year flood level, as the base flood elevation (BFE) for planning and development along waterways. As a part of its regulatory function, the National Flood Insurance Program (NFIP) has established zones which are used in Flood Insurance Rate Maps (FIRM).

These zones have a direct bearing on the flood insurance rates paid by the owner of a structure in the respective zones. Table 4-3 lists zones identified for use in regulating construction in the floodplain and for determining insurance rates for properties located in the floodplain. It is estimated that the average structure in the SFHA will experience 2 feet of flooding, which will result in 25% damage to the structure and 25% damage to contents. The maximum non-creek floodplain is 6 feet in depth, in an overland flow area of Joe Creek.

Table 4-2: Floodplain Hazard Locations

#	SOURCE	DESCRIPTION	LOCATION
1	Dirty Butter Creek, Tributary RB1	High level of flooding of public & private property. Apache Street overtopping.	NW Corner of Pine and Xanthus
2	Elm Creek	Flooding of residential and commercial properties and streets due to an undersized storm sewer system.	Elm Creek from E. 3rd St. to approximately E. 10th St. between Peoria Ave. and Lewis Ave.
3	Red Fork Creek	Flooding of Crystal City Shopping Center and surrounding buildings.	Between Southwest Boulevard and I-244 east of 33rd West Ave.
4	Perryman Ditch	Flooding of streets and residential properties.	East and West of Rockford Ave. north from I-44 to approximately E. 46th St.
5	Fulton Creek Basin	Regular flooding due to inadequate storm sewers.	East 43rd St. and South Sheridan Rd.
6	Fred Creek	Overtopping of Harvard Ave.	Harvard Ave. south of 73rd St.
7	Fry Ditch No. 2	Severe erosion threatening streets and residences.	From 101st St. between 76th E. Ave and 77th E. Ave., south to approximately 106th St.
8	Coal Creek	Involves the Hughes and Independence detention facilities, storm sewer replacement and acquisition of flooding homes.	From Maplewood to Irvington south of Independence
9	Little Creek	Flooding of 36th Street.	36th St. North between Garnett Road and 129th E. Ave.
10	East Village	Street Flooding in East Downtown.	4th St. and Kenosha Ave.

Table 4-3: FEMA Flood Insurance Rate Map Flood Zones[1]

	THE 100-YEAR OR BASE FLOODPLAIN. THERE ARE SEVEN TYPES OF A ZONES:	
ZONE A	A	The base floodplain mapped by approximate methods, i.e., BFEs, are not determined. This is often called an unnumbered A zone or an approximate A zone.
	A1-30	These are known as numbered A zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).
	AE	The base floodplain where base flood elevations are provided. AE zones are now used on new format FIRMs instead of A1-30 zones.
	AO	The base floodplain with sheet flow, ponding, or shallow flooding. Base flood depths (feet above ground) are provided.
	AH	Shallow flooding base floodplain. BFEs are provided.
	A99	Area to be protected from base flood by levees or federal flood protection systems under construction. BFEs are not determined.
	AR	The base floodplain that results from the de-certification of a previously accredited flood protection system that is in the process of being restored to
ZONE V AND VE	V	The coastal area subject to velocity hazard (wave action) where BFEs are not determined on the FIRM.
	VE	The coastal area subject to velocity hazard (wave action) where BFEs are provided on the FIRM.
ZONE B AND ZONE X (SHADED)	Area of moderate flood hazard, usually the area between the limits of the 100-year and the 500-year floods. B zones are also used to designate base floodplains or lesser hazards, such as areas protected by levees from the 100-year flood or shallow flooding areas with average depths of less than one foot or drainage areas less than one square mile.	
ZONE C AND ZONE X (UNSHADED)	Area of minimal flood hazard, usually depiction FIRMs as exceeding the 500-year flood level. Zone C may have ponding and local drainage problems that do not warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood.	
ZONE D	Area of undetermined but possible flood hazards.	

1 Understanding Your Risks, Identifying Hazards and Estimating Losses, FEMA 386-2

4.1.4 Previous Occurrences

In Tulsa, floods have accounted for many of the most frequent and most costly weather disasters. In the 15 years between 1970 and 1985, Tulsa County experienced nine major floods, serious enough to be declared federal disasters – the most federal flood disasters on record for any community in the nation at that time. Extent of the 1984 and 1986 floods are shown in Figure 4-4. Flood events have continued to impact Tulsa in recent years. The NCEI Storm Events Database includes reports of 27 flood events in the City of Tulsa since 2000, none of which were after approval of the previous hazard mitigation plan in 2019. Narratives of some previous flood events in the jurisdiction are included in Table 4-4.

4.1.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Likely. Based on the 27 flood events that occurred from 1998 through 2019, the City of Tulsa should expect an average of two or three minor flood events each year and major flood events on a less frequent basis. In recent years, Tulsa has experienced more short duration high intensity thunderstorms where rainfall intensity has exceeded the 1% storm intensities for brief time periods. This has resulted in more street and localized flooding.

Climate change also influences flooding patterns. According to the U.S. Global Change Research Program, even while record-breaking flooding events increased over the past 30 years, the Southern Great Plains experienced an overall decrease in flood frequency, possibly related to the decrease in total precipitation over the same period.

Figure 4-4: Tulsa Historic Flood Extents

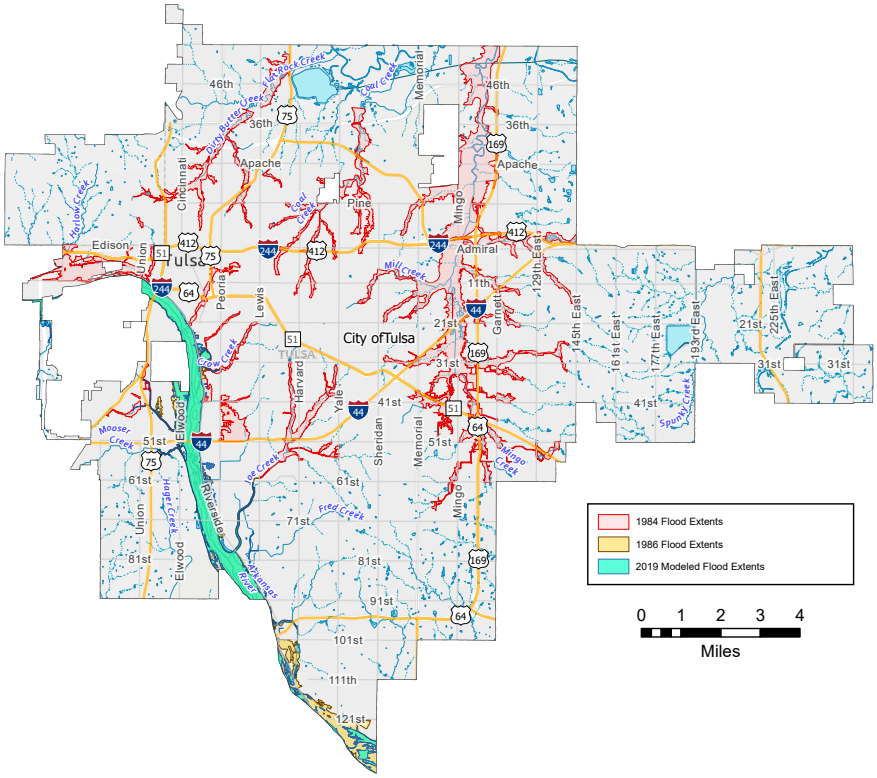


Table 4-4: Flood Event Narratives[1]

DATE	EVENT NARRATIVE
May 10, 1970	The Mother's Day Flood in Tulsa caused $163,000 in damages on rapidly developing Mingo and Joe Creeks.
Apr, May and Sept 1974	April and May floods left $744,000 in damages on Bird Creek. Violent storms and tornados June 8 caused widespread flooding on Joe, Fry, Haikey, and Mingo Creeks in Tulsa County, with more than $18 million in damage.
May 31, 1976.	On Memorial Day, a 3-hour, 10-inch deluge centered over the headwaters of Mingo, Joe, and Haikey Creeks in Tulsa, causing a flood that killed three and caused $40 million in damage to more than 3,000 buildings.
May 26-27, 1984	The 1984 Memorial Day Flood, the worst in the city's history, was Tulsa's watershed point. After a muggy Sunday afternoon, a stalled cool front produced some 15 inches of midnight rain, centered over Mingo Creek but also extending across most of the city. The results were disastrous. The 1984 Memorial Day Flood killed 14, injured 288, damaged or destroyed nearly 7,000 buildings, and left $180 million in damage ($556 million in 2024 dollars). Mingo Creek alone accounted for $125 million of the damage. The newly elected mayor and street commissioner had been in office for only 19 days, but both knew the issues well. In the darkest hours of the city's worst disaster, they pledged to ensure that such a disaster would never be repeated. Before daylight, they had assembled the City's first Flood Hazard Mitigation Team to develop the community's strategy. Within days, a new approach to Tulsa flood mitigation, response, and recovery was developed. As ultimately implemented, the program included the relocation of 300 flooded homes and a 228-pad mobile home park, $10.5 million in flood control works, and $2.1 million in master drainage plans. The total capital program topped $30 million, mostly from local capital sources, flood insurance claim checks, and federal funds.
Oct 1986	The 1986 Arkansas River Flood was a first test of the new stormwater management program. It also served as a reminder of the finite protection of Keystone Dam. Between September and October 1986, Keystone Reservoir filled to capacity, forcing the Corps to release water at the rate of 310,000 cubic feet per second. Downstream flooding was inevitable. At Tulsa, a private west bank levee failed, causing $1.3 million in damage to 64 buildings. The city fielded its hazard-mitigation team and cleared 13 substantially damaged structures.
May 29,1994	Heavy rainfall resulted in flash flooding in the west and south parts of Tulsa. Hager Creek overflowed its banks, and some homes were evacuated. Some structures near 81st Street South and Elwood Avenue had 2 to 4 feet of water in them, and houses were also flooded near 71st Street South and Harvard Avenue. A total of 8 to 12 homes were flooded in the city. Numerous roads were closed due to the flooding, including Interstate 44 from 33rd West Avenue to Union Avenue. Water was waist-deep on the access road to I-44, and 1 foot deep on the interstate itself.
Oct 5, 1998	Major street flooding in Tulsa included the areas of 31st and Yale, 96th and Sheridan, and two feet of water over the road at 28th and 129th East Avenue. Damages were estimated at $30,000.
Aug 26, 1999	More than 20 streets in Tulsa had to be closed. Tulsa police responded to 39 vehicles that were stalled in high water. Lower Mingo Creek overflowed, flooding undeveloped areas near 36th Street North. Lower Haikey Creek at 101st Street also escaped its banks. Northern Tulsa County had flooding along the Bird Creek. Damages for the countywide event were estimated at $40,000.
May 6, 2000	Over 6 inches of rain fell over Tulsa County, causing widespread flooding. Damage to roads, bridges and infrastructure was estimated at $200,000, while countywide it was about $3 million. One fatality occurred when a woman attempted to cross a street flooded by a nearby stream.

1 NCEI Storm Events Database

DATE	EVENT NARRATIVE
Oct 13, 2012	Three teenagers were playing near rain-swollen Coal Creek in north Tulsa. Two of the three teenagers got out of the water safely, but one was washed downstream and drowned by the flood waters. He was found the following morning about a mile and a half downstream from where they were playing. Several cars were reported stranded in high water from downtown Tulsa north to around Mohawk Park. Property damage was reported to be $20,000.
May 8, 2015	Sections of I-44 were closed due to water covering the roadway. Several cars were stalled in the flood water. Widespread heavy rainfall resulted in moderate flooding of Bird Creek near Sperry and Owasso.
May 20-23, 2015	Widespread flooding occurred in Mohawk Park with access roads inaccessible. Extensive flooding also occurred near Mingo Road and 56th Street North and 66th Street North. Portions of E 51st Street were flooded between Harvard Avenue and Yale Avenue. Portions of S Sheridan Road were flooded between E 41st Street and E 51st Street. Roads were flooded near the intersection of E 41st Street and S Yale Avenue. Major flooding in east Tulsa with three feet of water over 90th East Avenue and S 33rd Street. Roads and yards were flooded near the intersection of E 26th Street and S 139th E Avenue. The Broken Arrow Expressway underpass was impassable due to flooding near the vicinity of E 31st Street and S Yale Avenue. Portions of S Utica Place were flooded. Major flooding occurred at E 49th Street and S 72nd E Avenue. Flood water inundated a bridge on E 51st Street. Several retention ponds in the vicinity of Highway 51 and Highway 169 were nearly full and threatened to overtop their banks. Streets were flooded near N Delaware Avenue and E 46th Street N. Roads were flooded near the intersection of E 61st Street and S Utica Avenue. Flooding near E 21st Street and S Utica Avenue closed roads.
Dec 27, 2015	Eight to ten inches of rain fell across much of northeastern Oklahoma. This excessive rainfall caused moderate flooding of the Polecat Creek near Sapulpa, moderate flooding of the Caney River near Collinsville, and moderate flooding of the Bird Creek near Sperry and Owasso. Bird Creek near Owasso rose above its flood stage of 18 feet at 2:45 am CST on December 27th. The river crested at 23.51 feet at 5:30 pm CST on the 28th, resulting in moderate flooding. Extensive flooding occurred in Mohawk Park with access roads inaccessible. Mingo Road between 56th Street north and 66th Street North was closed. The river fell below flood stage at 10:30 am CST on the 29th.
July 2, 2017	Storms developed into eastern Oklahoma during the late afternoon and early evening. The strongest storms produced damaging wind gusts and locally heavy rainfall. Portions of S Lewis Avenue were flooded between E 61st Street and E 71st Street. A car was driven into the water, where it stalled. The roadway was flooded in and around the intersection of E 41st Street and S Sheridan Road. Several cars were driven into the water, where they stalled.
Aug 15, 2017	Thunderstorms developed during the afternoon of the 15th across northeastern Oklahoma in advance of a cold front that moved into the region. Heavy rain occurred across portions of Tulsa County, resulting in localized flooding. Portions of W 21st Street S were flooded between Chandler Park and the Arkansas River bridge.

DATE	EVENT NARRATIVE
May 2019	The City of Tulsa saw record rainfall, and as a result tremendous flooding in parts of Tulsa and surrounding areas. During the May 2019 event, water reached record levels at Bird Creek which is located in the North part of Tulsa County. As a result, Owasso residents were displaced because of the rapid Bird Creek flooding. On May 21, 2019, Verdigris River levels were rising and flooding impacts were expected in communities including Oak Grove, Okay, and Wybark. Wagoner County Emergency Management sent out voluntary evacuation orders for all low-lying areas near the Arkansas and Verdigris Rivers (which were impacted by the Bird Creek flooding). Tulsa County Emergency Management Director warned citizens there could be an extremely dangerous situation between North Tulsa and Owasso due to Bird Creek flooding. Bird Creek--near Owasso, Oklahoma—was expected to crest 29.5 feet late Wednesday night May 22, 2019. (Bird Creek reached 36.42 feet on May 22, 2019 and most of the town of Skiatook experienced flooding, along with many other areas). The Tulsa County Emergency Management Director also said that this flooding was going to be an extremely dangerous and life-threatening situation for anyone who lived in Bird Creek and the surrounding areas. The flood resulted in over $3 billion in damage along the Arkansas River, killing five people.

4.1.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: High: The criteria consistently fall in the high classifications and the event is likely/ highly likely to occur with severe strength over a significant to extensive portion of the planning area.

4.1.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Likely. Based on the 27 flood events that occurred from 1998 through 2019, the City of Tulsa should expect an average of two or three minor flood events each year and major flood events on a less frequent basis. In recent years, Tulsa has experienced more short duration high intensity thunderstorms where rainfall intensity has exceeded the 1% storm intensities for brief time periods. This has resulted in more street and localized flooding. Climate change also influences flooding patterns. According to the U.S. Global Change Research Program, even while record-breaking flooding events increased over the past 30 years, the Southern Great Plains experienced an overall decrease in flood frequency, possibly related to the decrease in total precipitation over the same period.

4.1.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: High: The criteria consistently fall in the high classifications and the event is likely/ highly likely to occur with severe strength over a significant to extensive portion of the planning area.

People

In Tulsa, 1,863 residential single-family structures, 200 residential multi-family structures, and 347 commercial structures are touched by the SFHA floodplains. In a citywide 1% or 100-year flood, over 31,000 individuals could be displaced by flooding within or near the inundation areas. Hazus model estimates the number of households that are expected to be displaced from their homes due to the flood and the associated potential evacuation. The model estimates 6,712 households will be displaced due to the flood. Displacement includes households evacuated from within or very near to the inundated area. Of these, 2,168 people (out of a total population of 412,637) will seek tem-

porary shelter in public shelters. Evacuation procedures are outlined in the City of Tulsa/ Tulsa County Emergency Operations Plan (EOP). The EOP includes actions, responsible agencies, and command hierarchy. Tactical decisions regarding evacuation routes would be made on the ground by first responders during the event. Agency actions and decisions would be coordinated through the Emergency Operations Center. From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67 percent, from 401,190 to 411,894.

Emergency Operations Center

People are affected by flooding in numerous ways. These include life, safety, and health problems as well as financially by damage to structures and personal property. More people die from flooding than any other natural disaster. The majority of these deaths are the result of driving through flooded areas. Early warning systems help reduce the number of these fatalities. There are both short- and long-term health risks associated with flooding. Flood waters are contaminated with e-coli and fecal coliforms from sanitary sewer overflows and animal waste as well as hazardous chemicals, which can cause immediate health problems. There is also a long-term health risk from mold remaining in flooded structures.

For the plan update, it was important to the planning team to take a closer look at who was specifically at risk to flooding. Knowing the size and geographical location of potential at risk populations (such as small children, the elderly, and the impoverished) are important to assessing areas of highest vulnerability and prioritizing actions for risk reduction.

Poverty-stricken neighborhoods in Tulsa experience flooding frequently. One example is Problem Area 1 in Figure 4-3, located at NW Corner of Pine and Xanthus in north Tulsa. In this area, there is a high level of flooding of public and private property and Apache Street overtops. According to 2020 Census information, approximately 40% of the population in this area live below the poverty level. Figure 4-5 maps floodplains and poverty levels by census tract. Tulsa should implement recommendations of the Master Drainage Plan to alleviate flooding in this area.

Economy

Flooding causes significant economic losses. Flooding can directly impact business operations by forcing closures or damaging equipment and facilities. Employers may not have the logistics in place to perform large-scale evacuations that rising flood waters can force. Disruption to transport causes business interruption, damage to business contents, vehicle damages, and extensive damage to infrastructure. Flooding of roads and key transportation routes can have significant impacts on the economy. Of the employers with more than 1,000 employees identified by the Tulsa Regional Chamber, only River Spirit Casino is located within floodplains inside the City limits, and it experienced flooding during the May 2019 event. This even caused the facility to close for an extended period.

The Tulsa International Airport (TUL) and the Tulsa Port of Catoosa, the nation's most inland seaport, connect the region with international trade and transportation. The Port of Catoosa suffered significant impacts as a result of the 2015 flood event when strong water flows and silt built up along the navigation system, called shoaling, which limits the required 9-foot depth of the channel for water transport. As a result, barges were unable to enter or leave the port for most of May and June. The cost to clear a single shoal was $1 million[1].

1 stateimpact.npr.org/oklahoma/2015/07/06/record-rains-leave-oklahomas-inland-seaport-damaged-and- dangerous/

Figure 4-5: Percent of Population Below Poverty Level and FEMA Floodplain

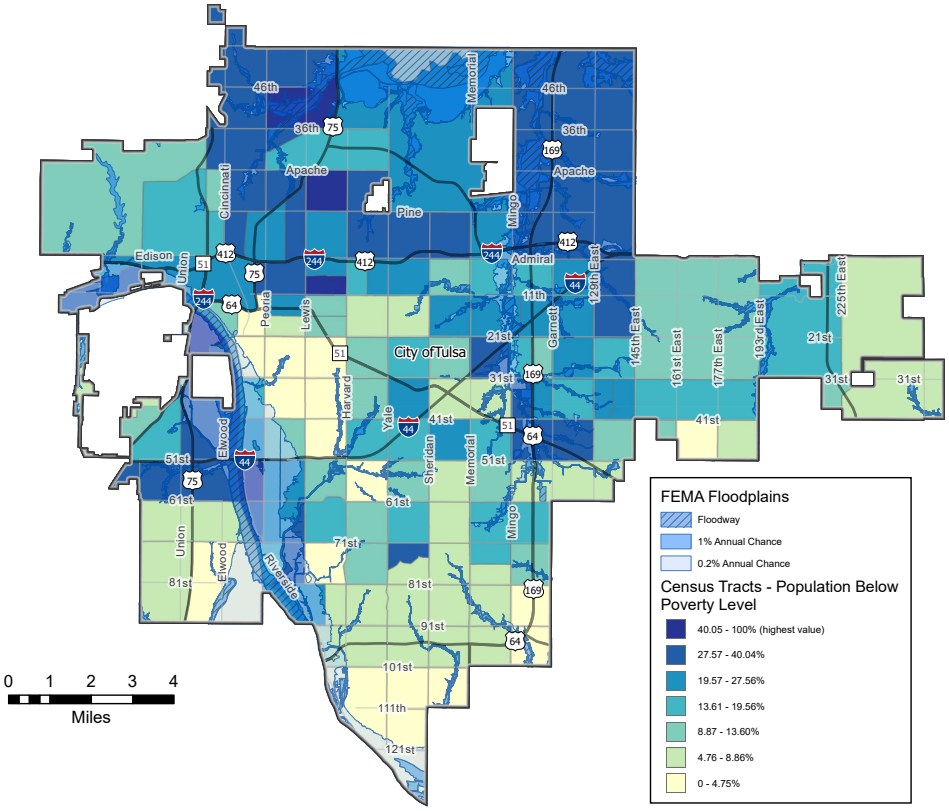


Figure 4-6: Percent of Households With Limited English in FEMA Floodplain

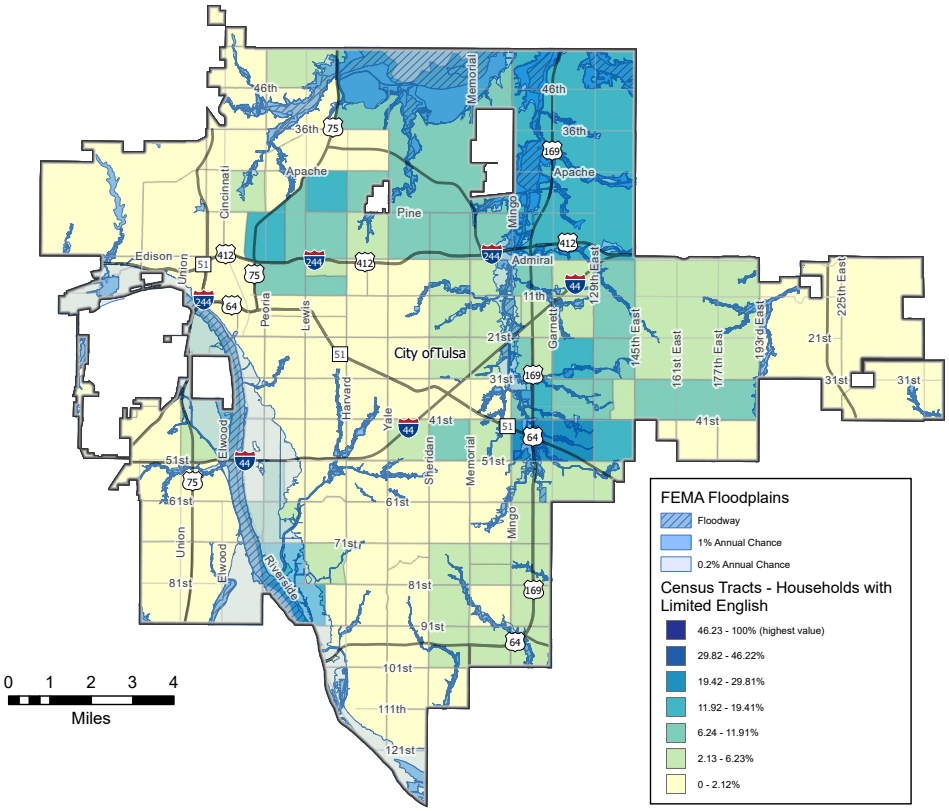


Figure 4-7: Percent of Population Age 65 & Older in FEMA Floodplain

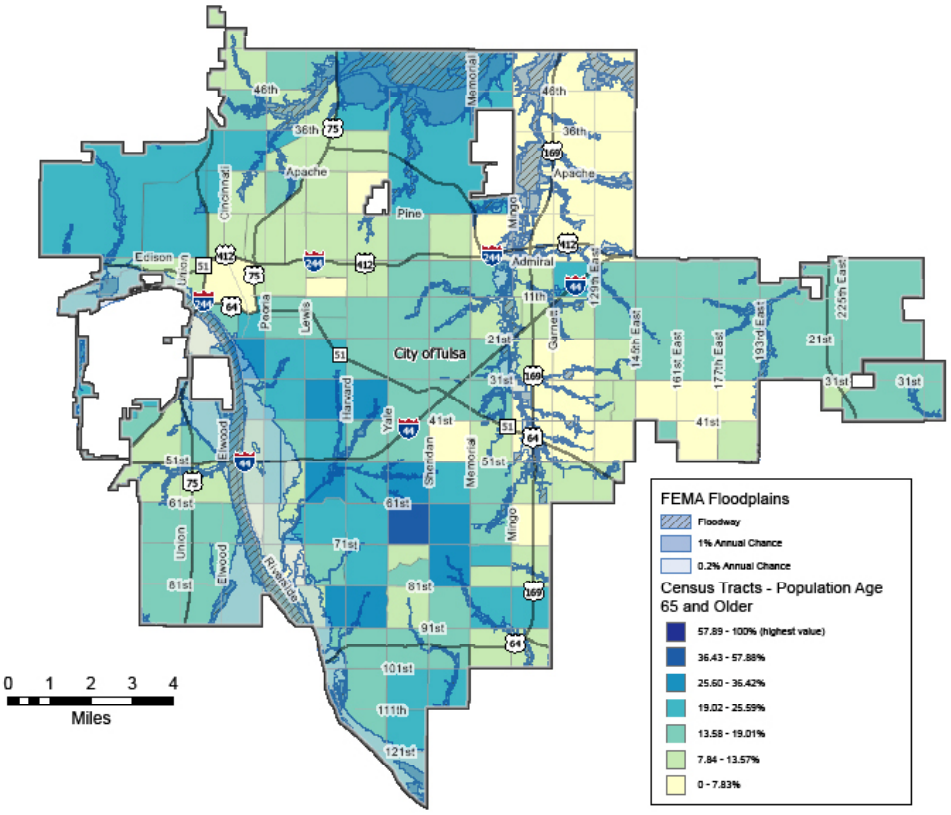
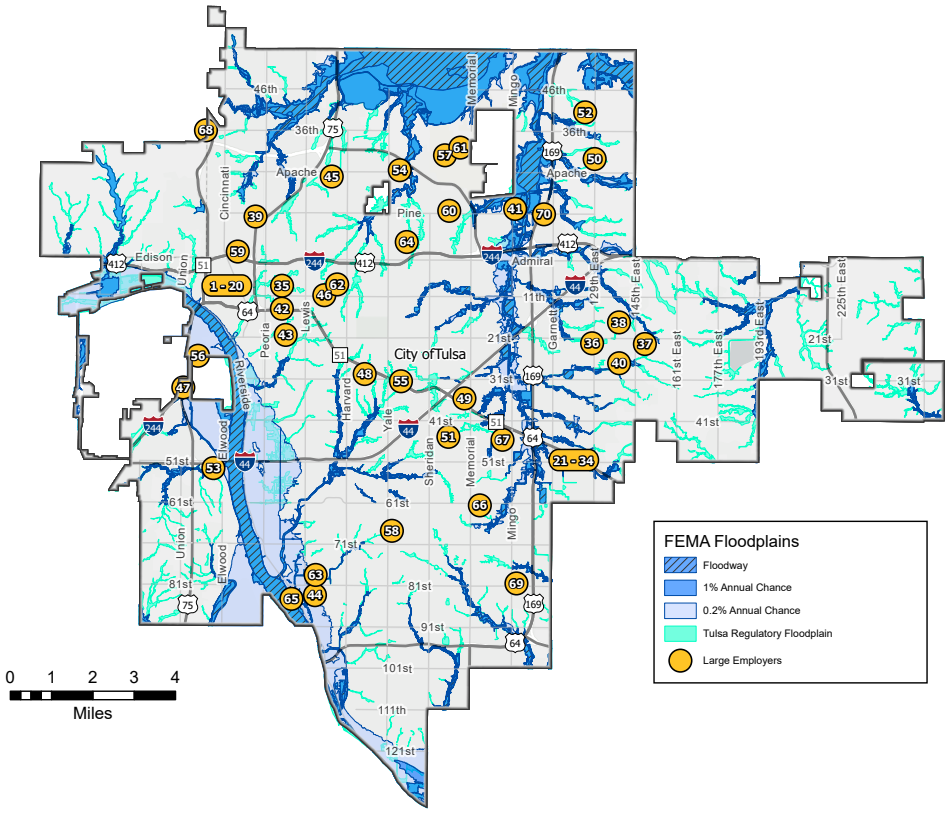


Figure 4-8: Major Employers (See list of major employers in Appendix E)



Built Environment

Existing Structures: In order to assess flood risk, a GIS-based analysis was used to estimate exposure to flood events using local tax assessor records in combination with building footprint data. The determination of assessed value at-risk (exposure) was calculated using GIS analysis by summing the improved values for parcels and structures that were confirmed to be located within an identified floodplain. Table 4-5 presents the potential at-risk property. Building footprint data allows for a significantly more accurate estimate of the structures inside the SFHA. As shown in Table 4-5 below, of the 7,669 parcels touched by the SFHA only 4,638 of these parcels have a structure touched by the floodplain. Structural values used in this assessment were from the Tulsa County Assessor's Office. It is estimated that the average structure will experience 2 feet of flooding, which will result in 25% damage to the structure and 25% damage to contents. HAZUS estimates that about 611 buildings will be at least moderately damaged. This is over 70% of the total number of buildings in the scenario. There are an estimated 14 buildings that will be completely destroyed.

There are 155 Repetitive Loss (RL) properties shown on Figure 4-9. 76 of those properties have been mitigated. 79 have not been mitigated: 42 single-family homes, five residential properties with two-to-four units, nine residential properties of more than four units, and 23 non-residential properties. These are areas with building flooding for which the owners have filed NFIP claims. To be a repetitive loss property, the owners must have filed at least 2 claims of $1,000 or more within any rolling ten-year period. In 2017, the City of Tulsa adopted RLA plans for each of the RLAs which evaluated the source of flooding and the appropriate mitigation actions for each. NFIP data and more information on the RLA plans is contained in Chapter 3, Capability Assessment. The City continues to mitigate these RLAs through acquisition or structural measures, which has resulted in a reduction from 93 unmitigated properties in 2019 to 79 currently. Development trends and population growth from 2019 to 2023 have not increased Tulsa's vulnerability to floods.

Infrastructure

Tulsa's most likely ongoing threat from flooding would be a flash flood event. During a storm event that is producing a large amount of rainfall over a short period of time, it is highly likely that several roadway intersections will become inundated and impassable.

Table 4-5: 2023 Structures and Parcels Touched by SFHA[1]

IMPROVEMENT TYPE	NUMBER OF BLDGS	EST. MARKET VALUE	NUMBER OF PARCELS	EST. MARKET VALUE
Residential	2103	$318,521,890	5,179	$887,822,839
Commercial	523	$203,114,513	893	$1,816,973,776
Other	168	$233,947,442	1,597	$1,119,958,397
Total	**2,794**	**$755,583,845**	**7,669**	**$3,824,755,012**

Among special flood hazard areas (SFHA), the drainage basin with the largest total property value flood insurance claims is Middle Mingo, exceeding $2.5 million. The drainage basin with the largest share of city properties is Central Tulsa, with flood insurance claims in excess of $800,000.

1 2023 Tulsa County Assessor Data

Table 4-6: National Flood Insurance Program Claims[1]

DRAINAGE BASIN GROUP	SFHA PROPERTY	SFHA LOSS VALUE	CITY REGULATORY PROPERTY	CITY REGULATORY LOSS VALUE	0.2% FLOOD CLAIMS	0.2% FLOOD CLAIM PAYMENTS
North Tulsa	55	$757,316	28	$230,870	4	$41,955
Downtown	0	$0	25	$283,441	0	$0
Middle Mingo	145	$2,628,820	33	$513,961	576	$13,235,412
Central Tulsa	111	$1,875,341	86	$802,008	28	$160,419
East Tulsa	4	$10,151	0	$0	0	$0
South Tulsa	7	$36,345	4	$15,441	4	$1,504
Lower Mingo	20	$1,373,293	15	$73,379	8	$386,045
SW Areas	3	$21,907	1	$1,638	0	$0
Arkansas River	0	$0	0	$0	2	$11,873
West Tulsa	29	$238,152	12	$87,700	8	$35,949
Riverside	2	$74,994	69	$609,663	45	$359,102
SE Tulsa	0	$0	7	$30,335	2	$33,742
Upper Mingo	27	$387,960	0	$0	74	$940,686

1 City of Tulsa - Program for Public Information, Update July 2023 City of Tulsa Stormwater Drainage & Hazard Mitigation Advisory Board

With this in mind, plans being developed or implemented for street and/or roadway improvements within the jurisdiction should consider mitigation measures to reduce flooding of these roads and intersections. The City's Watershed Master Drainage Plans (MDPs) were developed for all of the watersheds affecting the City of Tulsa to identify flood risk within the City. They have recommendations, including stormwater detention facilities, roadway culverts and bridges adequately sized to safely store and/or convey the 1% (100-year) flood. Additionally, those MDPs have recommendations for changes or additions to the creek channels, storm sewer systems, and areas where floodplain buyouts are the best solution. All City of Tulsa infrastructure improvement projects are subject to recommendations within the respective master drainage plan for the area.

Critical Facilities

Tulsa has 26 critical facilities touched by or adjacent to the city's floodplains. Critical facilities located in the floodplains pose a problem for the community since, in the event of a flood, the impacts reach beyond the flooding of the facility Tulsa's currently adopted building code requires that all new critical facilities be protected to the 0.2% or 500-year level of flooding. HAZUS estimates five essential facilities will be moderately damaged, buildings will be at least moderately damaged; one will sustain substantial damage; and seven will have total loss of use. This is over 61% of the total number of buildings in the scenario. There are an estimated 188 buildings that will be completely destroyed.

Cultural Resources

There are no historic buildings that intersect with the 100-year floodplain. Of the Historic

Districts in the city of Tulsa, only one intersects with the 100-year floodplain, Ranch Acres Historic District, located between 31st and 41st street, from Harvard to Yale.

Future Development

As development in new areas and revitalization of existing ones continue, locations and building techniques should be closely examined. Development of new sites or redevelopment of existing sites that increase the impervious area will further strain aging infrastructure.

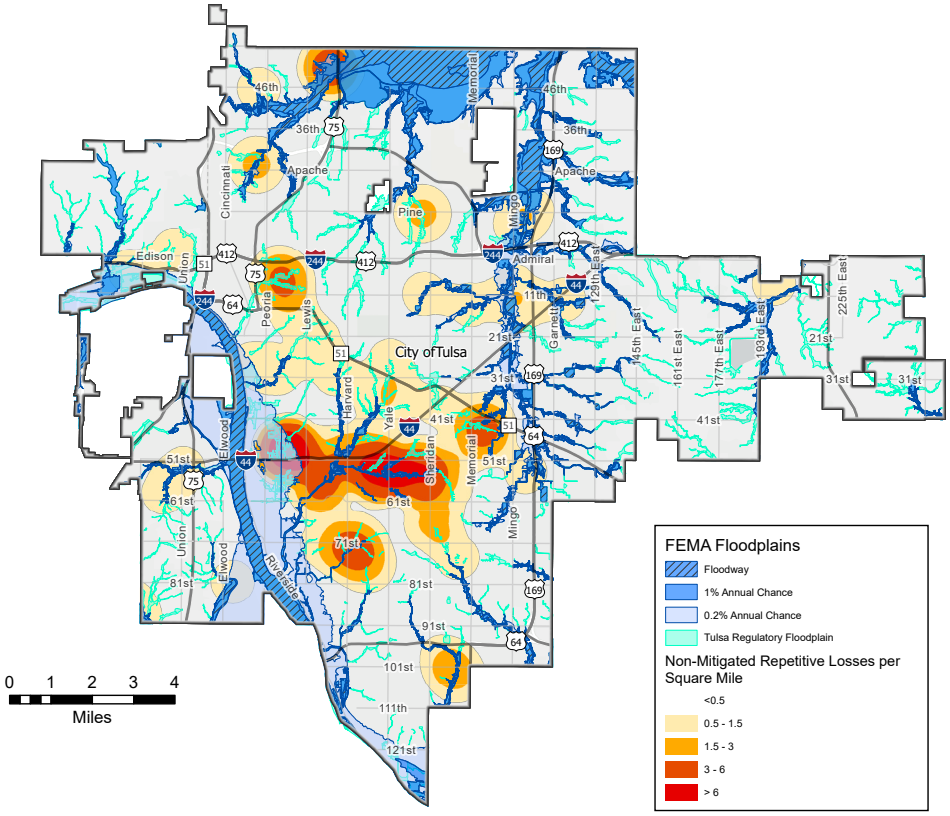
With Tulsa's strong commitment to maintaining current floodplain zoning guidelines, it is not anticipated that any new critical facility development will occur within flood-prone areas of the jurisdiction. Any renovations or improvements made to existing critical facilities in the 100-year floodplain should be evaluated to ensure the prescribed improvements will help mitigate potential damage from a future flood event. Plans being developed or implemented for street and/or roadway improvements within the jurisdiction should consider mitigation measures to reduce flooding of these roads and intersections.

Natural Environment

Flood events can provide both negative and positive impacts on the environment. As a natural occurrence, flooding helps trigger life processes such as migration and seed dispersal in flora and fauna. Negative impacts on the environment are generally a result of sedimentation and debris. Since the 1970s Tulsa has had an extensive Repetitive Loss acquisition program. Over 1,000 properties have been acquired to date.

Figure 4-9 shows the repetitive loss areas. All of the properties acquired are preserved as open space to prevent redevelopment and future flood losses. In some instances, especially

Figure 4-9: Repetitive Loss Areas



in the Mingo Creek Basin, entire neighborhoods were acquired. These large tracts of land are now utilized as parks and recreation areas.

The City also requires all new development to dedicate the entire floodplain in an overland drainage easement or reserve area with no habitable structures allowed. In addition to preventing flood losses, this serves as a buffer zone along the creeks, which improves water quality. The City owns and maintains over 2,700 acres of open space in a natural state to provide the natural and beneficial function of the floodplain.

4.1.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Tulsans rely on warning sirens as primary source of weather notifications.	Educate the public on purpose of outdoor warning sirens and promote NOAA weather radios.	30, 31
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8
Tulsa experiences flood events on an annual basis. As development continues and the frequency and severity of flooding increases, it is important for all citizens to understand the benefits and costs of flood insurance.	Tulsa should continue annual floodplain notifications and educate the public on the importance of flood insurance.	14
Tulsa prioritizes stormwater projects with a positive BCA, in the CIP and HMP for implementation.	Tulsa should review the CIP projects for opportunities to leverage available FEMA funding on an annual basis.	16, 57, 58, 59
Thousands of structures are located in the SFHA, and 155 RL properties remain.	The city should continue to acquire flood-prone properties using FEMA Hazard Mitigation Assistance Funds.	15
Multiple jurisdictions have authority for response and recovery during and after a flood, dam, or levee event in the Arkansas River Corridor.	The City of Tulsa should partner with neighboring jurisdictions and stakeholders, including state, tribal, and federal partners to develop a comprehensive response and recovery plan for the Arkansas River	20
Some areas of Tulsa appear to be out of range of an outdoor warning siren	Install, update, and maintain warning sirens.	30

4.2 Severe Winter Storms

4.2.1 Hazard Description

A winter storm is a winter weather event that produces impactful accumulations of freezing rain (ice), sleet and/or snow. Winter storms may include heavy snowfall, blowing and drifting snow, high winds, extreme cold, or ice storms. Among the most significant hazards associated with winter storms are traffic accidents. The most extreme instance is a blizzard, which is defined as winds greater than 35 mph, visibility less than ¼ mile, lasting at least 3

hours. New snowfall is not necessary for a blizzard; blowing snow can similarly obscure visibility. Winter storms are measured by snowfall accumulation or ice thickness. Winter storms occur in Tulsa between November and March and are usually created by large low-pressure systems. In Tulsa, ice storms are a greater threat than blizzards. Access to moisture from the Gulf of Mexico falling over shallow cold air near the surface can produce ice accumulations of two inches or greater with tremendous damage to power distribution

4.2.2 Location

The risk of this hazard is uniform over the entire City of Tulsa.

4.2.3 Extent

During the winter months, Tulsa occasionally experiences snowfall combined with high winds, freezing rain, or ice storms. Total seasonal snowfall averages around 10 inches. Greatest annual snowfall was 29.6 inches. The greatest daily snowfall was nearly 14 inches. In some years, Tulsa receives zero inches of snowfall. The snowfall season usually runs from November to April. Tulsa has experienced ice accumulation ranging from zero to 3 inches thick. ¼- to ½-inch accumulations can break small branches and weak limbs, while ½- to 1-inch accumulations can cause larger branches to snap off. The Sperry-Piltz Ice Accumulation Index, shown in Figure 4-10, is a tool used to predict the types of damage that may

Figure 4-10: The Sperry-Piltz Ice Accumulation Index, or "SPIA Index"

ICE DAMAGE INDEX	DAMAGE AND IMPACT DESCRIPTIONS
0	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
2	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulations.
3	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1-5 days.
4	Prolonged and widespread utility interruptions with extensive damage to main distribution feeder lines and some high voltage transmission lines/structures. Outages lasting 5-10 days.
5	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.

(Categories of damage are based upon combination of precipitation totals, temperatures and wind speeds/directions.) Copyright 2009.

occur to power utilities before a winter storm striking. The SPIA tool allows corporations and other entities to better prepare for potentially severe impacts of ice storms to electrical utilities days in advance of severe ice events.

Tulsa may experience a winter storm event with wind surface winds gusting over 30 mph and over a foot of snow accumulation. Tulsa may experience an ice storm with greater than 3 inches of ice accumulation and a rating of 5 on the SPIA.

4.2.4 Previous Occurrences

The NCEI Storm Events Database includes reports of severe winter storm events on a regional basis. Severe winter storms are, by nature, not isolated events – therefore it could be stated that winter weather events affecting Tulsa County also had some impact on the City of Tulsa. The NCEI database includes reports of 34 winter weather events between 1998 and 2023. Severe winter weather resulted in four Presidential Disaster Declarations in Tulsa. The most significant ice storm in Oklahoma took a devastating toll on Tulsa in 2007, and in 2011 record snowfall shut down the Tulsa World newspaper for the first time in its history. These events are summarized below.

HISTORICAL HIGHLIGHTS

DEC 2007

FEMA DR-1735

One to two inches of ice accumulated on trees and power lines. Tulsa began to lose power on Dec. 9, 2007. The peak of the outage was Dec. 10 at 5:15 p.m. when 262,128 homes and businesses had no power. That was half of the customer base. The Red Cross opened 34 shelters in Tulsa County with more than 1,800 people registering to spend the night. In Tulsa alone, there were 2.7 million cubic yards of debris. The event caused six fatalities (4 fire fatalities, 1 traffic fatality, 1 hypothermia fatality); Tulsa International Airport closed to incoming/departing flights for 24+ hours; three Tulsa hospitals were forced to rely on emergency generators. The total county-wide per capita impact for Tulsa County was $5.92 million. As a result of the storm, over 1,000 distribution poles and approximately 150 transmission poles were broken, approximately 9,000 meter enclosures damaged and approximately 1,000,000 miles of power lines repaired/replaced (not all in Tulsa). Additionally, 5,500 restoration workers were utilized (as opposed to 800 in normal operations) working nearly 80,000 man-hours per day, with support staff handling more than 512,600 calls pertaining to the event.

FEB 2011

FEMA DR-1985

Oklahoma was hit by the "Groundhog Day Blizzard" that dumped a record 14 inches of snow on Tulsa, with more snow following on Feb. 4 and 7. Tulsa International Airport was closed, as was I-44 between Stroud and Miami, along with the Creek, Indian Nations and Muskogee Turnpikes. In the early phase of the "back-to-back blizzards," temperatures dropped into the single digits and remained below freezing during the day. High winds dropped the wind-chill temperatures as low as 36 degrees below zero in some parts of the state. Water mains broke. For the first time in 111 years, the Tulsa World cancelled its print editions for three days. Tulsa's public schools were closed for eight days due to this series of winter storms. A Presidential disaster declaration was declared for Tulsa County, Tulsa's 14-inch snowfall broke the record for the most snow for the date, the most snow ever for February, and the most from a single storm. Schools, businesses, government agencies, and even interstate highways were closed.

FEB 2021

FEMA DR-3555

On February 17, 2021, a Presidential disaster declaration was issued in response to Winter Storm Uri. Tulsa recorded 10 inches of snow over the four-day storm, and temperatures plunged to a low of -13 degrees, the fourth coldest low on record. Electrical service was disrupted, water pipes burst and natural gas costs surged.

4.2.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Highly Likely

According to the SCIPP Simple Planning Tool, years consisting of a large number of snowfall days declined significantly across the southern United States between 1930 and 2023. Models suggest that although the number of snowfall events will likely continue to decrease given overall atmospheric warming when snow does occur, accumulations will be greater due to increases in atmospheric moisture (Krasting et al. 2013). There is significant uncertainty surrounding the future of ice storms in Tulsa. Observational data limitations and the complexity of the events themselves make it difficult to determine with much specificity whether patterns have and/or will change. Models show that by mid-century there will generally be a northward shift of the rain, sleet, and snow dividing line across the central United States. This shift will add to the complexity of determining precipitation type for winter events (rain, ice, or snow) in Oklahoma, however, the increase in atmospheric moisture may bring an increase to the amount of precipitation that does fall (Easterling et al. 2017).

Climate change also influences winter storm patterns. According to the U.S. Global Change Research Program, average annual precipitation projections suggest small changes in the region, with slightly wetter winters. However, the frequency and intensity of heavy precipitation are anticipated to continue to increase, particularly under higher scenarios and later in the century. In the Southern Great Plains region, winters will be warmer and spring will arrive earlier. The region has experienced an increase in annual average temperature of 1–2 degrees Farenheit since the early 20th century, with the greatest warming during the winter months. Warmer winters are likely to reduce heating demands and winter road maintenance costs.

Development trends and population growth from 2019 to 2023 have not increased Tulsa's vulnerability to winter storms.

4.2.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: High, the criteria consistently fall in the high classifications and the event is likely/highly likely to occur with severe strength over a significant to extensive portion of the planning area.

People

The entire population is exposed to severe winter storm events. From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67 percent, from 401,190 to 411,894. Thirty-two deaths were linked to the historic ice storm in December 2007: 19 related to traffic accidents, eight succumbed to hypothermia, and three caused by accidental falls on ice. The city of Tulsa works closely with VOADs to open shelters as necessary in the event of power outages. These shelters are different than social services offered to homeless populations year-round, addressed below.

Transportation Accidents: Snow packed hills and slick road surfaces increase the frequency and impact of traffic accidents for the general population, resulting in personal injuries. Trouble spots for Tulsa include the hilly terrain of South Tulsa, which causes a lot of trouble for drivers. Tulsa police identify three specific areas of concern: 61st and Sheridan, Yale between 81st and 91st, and 111th between Sheridan and Memorial. These roads have been closed for several hours in the past due to the number of vehicles stuck. There is potential for injury during every winter weather event. When winter precipitation is forecast,

Tulsa Police Department activates Operation Slick Streets. When activated, officers will not respond to non-injury accidents. If weather analysis forecasts sleet or a light mist before snow or ice, Tulsa will pre-treat the roads. Pre-treatment applies mostly to bridges and hills, with a few exceptions dependent on conditions. There is no pre-treatment with heavy rains before a storm transitions to snow or ice. Rain will wash away the salt material.

Hypothermia: Hypothermia is a potentially dangerous drop in body temperature caused by prolonged exposure to cold temperatures. Victims of hypothermia are most often elderly people with inadequate food, clothing, or heating; babies sleeping in cold bedrooms; and people who remain outdoors for long periods. Older adults are especially vulnerable. Being outside or in a cold house can cause an older person's body temperature to drop below 95 degrees and cause many health problems, even death.

Vulnerable Populations: Tulsans with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures. They may resort to alternate methods of heat such as space heaters or using the oven as a heat source. Additionally, subsidies are available through the Low-Income Home Energy Assistance Program (LIHEAP) to help low-income households meet the cost of home energy. All LIHEAP assistances are subject to available funding by the federal government.

Homeless populations face the risk of freezing to death in the absence of shelter, especially during winter weather events. There are several warming stations throughout Tulsa, including John 3:16 Mission, the Equality Center, Tulsa County Social Services, and the Salvation Army. Some are even open 24 hours per day. These facilities plan for overflow during winter weather events.

Economy

One of the biggest hits the economy takes during a winter storm event is in the form of lost wages and sales at places like restaurants and retailers.

Built Environment

Existing Structures: A direct threat to structures/buildings from a severe winter event is excessive snow/ice accumulation onto flat or low-grade sloped roofing surfaces. This is especially true of older structures that were not constructed to withstand this type of stress. Commercial structures face the same impacts of winter weather as residential properties. More indirect threats to structures/buildings would be from power outages causing interruption to heating and refrigeration (loss of supplies, food, sensitive equipment), frozen water pipes (excessive flooding causing damage to interior and sensitive electronic equipment if pipes break), and fires (caused by power lines being torn away from structure or power surges as lost power is restored).

Infrastructure

Electric: The most severe consequence of a winter storm on Tulsa's infrastructure is damage to power lines caused by the added weight and surface area of ice accumulation, combined with the additional stress of wind. These two factors can cause devastation to the power supply.

Gas: During winter events, Oklahoma Natural Gas (ONG) experiences a variety of challenges in meeting the needs of the Tulsa jurisdiction, including: damage to gas meters from ice accumulation, falling power lines or tree debris, inaccessibility to underground gas meters from falling debris, danger to field employees related to road conditions, downed power lines, and extreme temperatures.

Water/Wastewater: The most significant threat to the operation of Tulsa's four wastewater treatment plants during a winter storm would be power outages. All four plants and lift stations have either double feeds or generators.

Transportation: All manner of transportation would be at risk during a winter event in the Tulsa jurisdiction. Road closures due to ice/snow accumulation can result in loss of retail trade, wages, and tax revenue. Such closures often exceed $10 million/day in the eastern part of the country. The inability of public transportation to function after a winter event can also contribute to increased risk to the population if it hampers access to necessary medical care or safe shelter.

The City of Tulsa is responsible for clearing snow and ice from certain segments of the Tulsa expressway system and all arterial (main) streets. Other expressway segments in Tulsa are the responsibility of the Oklahoma Department of Transportation. Severe winter weather could result in the interruption of normal operations at Tulsa's International Airport and the city's private business airports. Significant ice or snow accumulations can impact runway safety and result in cancellation or major delays in regular flight schedules.

Critical Facilities: All critical facilities in the City of Tulsa are susceptible to the potential impacts of a winter storm event. Among other things, power outages interrupt vital services, and snow/ice accumulation or debris from damaged trees result in inaccessibility due to road closures or blockages. During the December 2007 ice storm, three of Tulsa hospitals were dependent on generator power for an extended time, and one nursing home was evacuated. Additionally, only one Tulsa Police substation had an operational fuel station. Tulsa Fire Department reported that 13 of their stations were without power (some without heat) and they were running low on oxygen bottles. Tulsa should ensure private medical facilities, such as urgent care and nursing homes, are educated on the importance of backup pow-

4.2.7 Summary of Conclusions and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
High percentage of low-income population are elderly and unable to afford adequate heating, leading to hypothermia.	Educate the public on locations of shelters and energy assistance programs.	1, 4
Nearly every hazard can cause power outages. During the 2007 ice storm, 13 fire stations lost power.	Tulsa should assess the need for generators at critical facilities and implement as funding becomes available.	6
Additionally, a hospital had to rely on backup power for a short period.		
The occurrence of an ice storm will result in substantial amounts of debris, blocking roads and isolating areas of Tulsa.	Tulsa should be prepared to remove debris post-disaster and be ready to request federal assistance when warranted.	
Tulsa Fire reports higher incidences of fires and carbon monoxide during winter weather due to improper use of alternate heating methods.	Educate the public on winter weather preparedness and safety.	1
Small businesses may not be able to afford the installation of a generator on site.	Develop a generator rebate program and fund through the FEMA Hazard Mitigation Grant Program.	12

er capabilities in the event of a power outage. Tulsa could also consider a generator rebate program, through the FEMA Hazard Mitigation Grant Program, to assist facilities with the cost of backup generators.

Cultural Resources: All cultural institutions in Tulsa are exposed to winter weather. The most likely effect of this hazard on cultural resources would be structural damages caused by heavy snow loads.

Future Development: All future development is exposed to winter storm events. Powerlines in areas of future development should be buried to avoid power loss. Generators should be installed at all critical facilities. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

Natural Environment: The City of Tulsa's urban forest includes over 5.2 million public and private trees. The Tulsa Urban Forest Master Plan includes strategies for a resilient urban forest that is safe and maintained. Tree loss is almost inevitable in ice events such as the 2007 storm. There is no official estimate on the number of trees lost to the ice storm. However, it is estimated about 1 million years in tree growth was lost to the storm. To insure integrity of the tree count, Re-Green Tulsa, a privately funded drive, was established to fund 20,000 trees.

4.3 High Wind and Tornado

4.3.1 Hazard Description

High Wind: Wind is the motion of air relative to the earth's surface. Extreme windstorm events are associated with cyclones, severe thunderstorms, and accompanying phenomena such as tornados and downbursts. High winds can result from thunderstorms, strong cold front

THE ENHANCED FUJITA SCALE

EF-O "MINOR" DAMAGE

65-85 MPH Winds. Shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.

EF-1 "MODERATE" DAMAGE

66-110 MPH Winds. More significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.

EF-2 "CONSIDERABLE" DAMAGE

111-135 MPH Winds. Roof torn off well-constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.

EF-3 "SEVERE" DAMAGE

136-165 MPH Winds. Entire stories of well-constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.

EF-4 "EXTREME" DAMAGE

166-200 MPH Winds. Well-constructed homes are leveled, cars are thrown significant distances, top-story exterior walls of masonry buildings would likely collapse.

EF-5 "MASSIVE/INCREDIBLE" DAMAGE

201+ MPH Winds. Well-constructed homes are swept away, steel-reinforced concrete structures are critically damaged, trees are usually debarked and snapped.

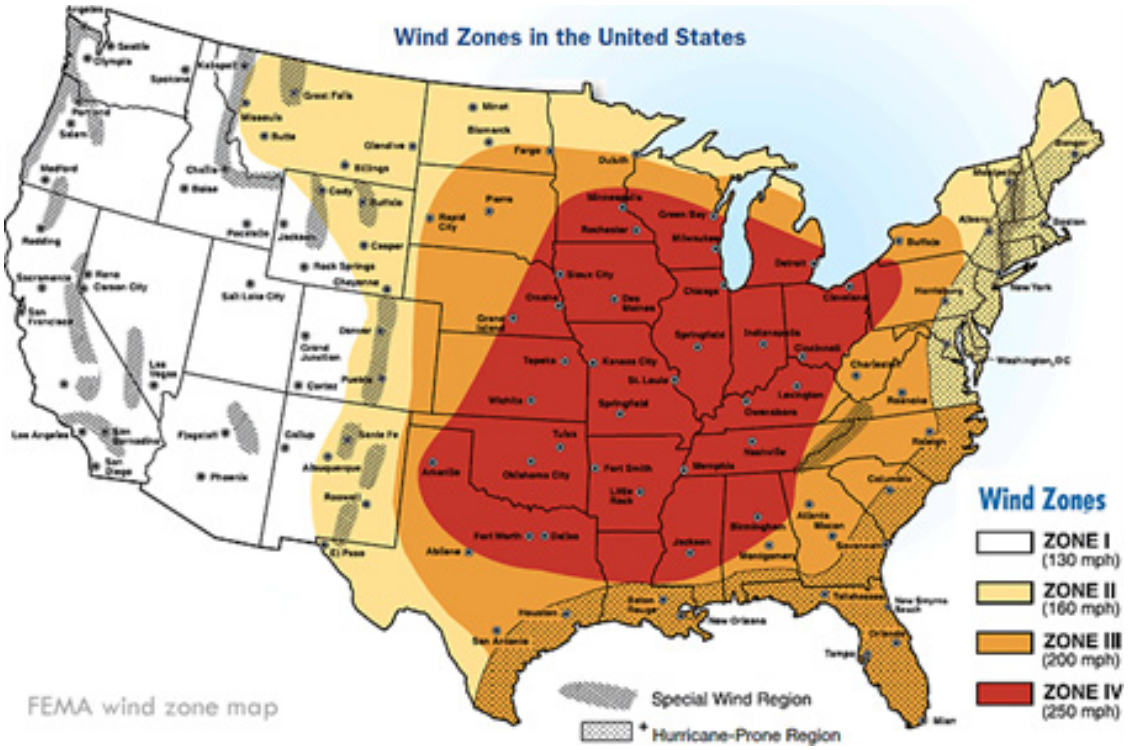
Source: weather.gov/oun/efscale

passages, or gradient winds between high and low pressure. Damaging winds are often called "straight-line" winds to differentiate the damage they cause from tornado damage. Downdraft winds are a small-scale column of air that rapidly sinks toward the ground, usually accompanied by precipitation as in a shower or thunderstorm. A downburst is the result of a strong downdraft associated with a thunderstorm that causes damaging winds near the ground. Damaging winds exceed 50-60 mph.

Tornado: According to the National Weather Service, a tornado is a violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. Tornados generally form from severe thunderstorms, mainly supercell thunderstorms – those that are isolated with the unimpeded inflow of moisture and enhanced by wind shear. Tornados may also develop along squall lines or in bands of storms associated with hurricanes. Tornados require moist air, instability (warm air rising), a source of lift such as a front, dryline, or heating, and wind shear (change in wind direction and speed with height). It is often difficult to separate windstorms and tornado damage when winds get above 73 mph.

A derecho is a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to the strength of tornadoes, the damage typically is directed in one direction along a relatively straight swath. As a result, the term "straight-line wind damage" sometimes is used to describe derecho damage. By definition, if the wind damage swath extends more than 240 miles and includes wind gusts of at least 58 mph or greater along most of its length, then the event may be classified as a derecho.

Figure 4-11: FEMA Wind Zone Map



4.3.2 Location

Both high wind and tornado events can occur in the City of Tulsa. Tornado events are usually localized. However, severe thunderstorms may result in conditions favorable to the formation of numerous or long-lived tornados. The risk of this hazard is uniform over the entire City of Tulsa.

4.3.3 Extent

The Enhanced Fujita Scale or EF Scale, which became operational on February 1, 2007, is used to assign a tornado a 'rating' based on estimated wind speeds and related damage. The EF Scale was revised from the original Fujita Scale to reflect better examinations of tornado damage surveys to align wind speeds more closely with associated storm damage. The City of Tulsa is located in Zone IV on the FEMA Wind Zone Map, Figure 4-11, and may experience wind speeds of zero to 250 mph or a tornado with a rating of EF5 on the Enhanced Fujita Scale. In some years, Tulsa experiences zero tornadoes.

According to the National Weather Service, sustained winds at 40-50mph can cause isolated wind damage. During strong thunderstorms, Tulsa may experience straight-line winds exceeding 100 mph.

4.3.4 Previous Occurrences

High Wind and Tornado events have occurred in the City of Tulsa. The NCEI Storm Events Database includes reports of 122 High Wind events with wind speeds of greater than 57 mph and 24 tornado events from 2003 to 2023. During the plan maintenance period, Tulsa experienced high wind events on an annual basis. The total damage from these events was almost $1,000,000 not including losses from tornado events during the same timeframe. The highest sustained wind speed during this period was 90 mph on March 25, 2015. The same storm system produced a tornado.

Before the 2015 Sand Springs tornado that crossed into Tulsa proper, few damaging tornados had touched down in the city limits of Tulsa. The most significant tornado in Tulsa's history was an F4 which ripped through Catoosa in 1993. In 1974, two F3 tornados damaged Brookside and parts of south and east Tulsa. This event damaged thousands of homes. The tornado traveled across the intersection of 71st and Memorial, one of the busiest in Tulsa. At the time, this area was not developed. If the 1974 tornado hit this area today thousands of homes would be affected, and a large portion of the Tulsa sales tax base. Since 1974, the Tulsa metro has increased from a sparsely populated total land area of 175.71 sq miles to 186.8 sq miles of relatively dense population. Increased development has made Tulsa a larger target for tornados. During the plan update period, Tulsa was affected by a damaging tornado on an almost annual basis. Summaries of damages associated with 2015, 2016, and 2017 tornados are shown in Figure 4-12.

On the night of June 17 to 18, 2023, a derecho with winds of around 100 miles per hour swept through Tulsa, causing significant damage. Over 200,000 people lost power, and nearly 70,000 were still without power four days later. Extreme winds scattered tree debris around homes, churches, and schools in north Tulsa. Stoplights, businesses, and neighborhoods north of East Pine Street were left without power. Tulsa Mayor G.T. Bynum described the power outages as catastrophic, similar to the 2007 ice storm. Damages were estimated to be $16.6 million.

4.3.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1 is "likely," with a 10 to 90 per-

cent probability of occurrence in the next year or a recurrence interval of 1 to 10 years. Based on previous occurrences, Tulsa should expect to experience damaging straight-line wind events on an annual basis. The probability of a tornado occurring within Tulsa was derived using the Tornado Risk Assessment Tool from the Storm Prediction Center[1]. A historical analysis was run to determine the annual probability of a tornado striking any single point within the City of Tulsa. This value is calculated by comparing the mean area affected by tornados each year with the total circular area of the search. The search area for this analysis was a 15km radius from the intersection of I-44 and State Highway 51. Based on this method, the City of Tulsa has a 0.308% chance of experiencing a tornado in any given year. The most likely month the City of Tulsa should expect to experience a tornado is the month of May.

The role of climate change in altering the frequency of the types of severe weather most typically associated with the Southern Great Plains, such as severe local storms, hailstorms, and tornadoes, remains difficult to quantify. According to the U.S. Global Change Research Program, indirect approaches suggest a possible increase in the circumstances conducive to such severe weather, such as tornadoes and high winds.

1 Source: Tornado Risk Assessment Tool, Storm Prediction Center, https://www.spc.noaa.gov/climo/online/probs/

HISTORICAL HIGHLIGHTS

MARCH 25, 2007

EF-0 AND EF-2 TORNADOS TOUCH DOWN IN NORTH TULSA

The tornado moved into Tulsa County at W Archer Road to the east of S 209th W Avenue. The roofs of several homes were damaged and trees were uprooted as it crossed S 193rd W Avenue. The tornado moved southeast crossing Highway 412, where it snapped or uprooted numerous trees and blew a tractor trailer off the road. A doughnut shop was destroyed at S 177th W Avenue, homes were damaged, and trees and poles were snapped. It crossed the Arkansas River and moved through the River Oaks Estates Mobile Home Park, where it destroyed 58 mobile homes and two permanent homes. One fatality and about 30 injuries occurred in this park. The tornado crossed the Arkansas River again as it moved east-southeast toward Sand Springs, uprooting numerous trees before dissipating on the south side of Sand Springs, south of Highway 412 and just west of Highway 97.

MARCH 30, 2016

EF-2 W/ WIND SPEEDS OF 100+MPH TOUCHES DOWN IN NORTH TULSA

Seven people reportedly were injured and multiple homes and other structures were damaged or destoyed on March 30, 2016 when a storm system spun up a tornado that caused damage from the northern part of Tulsa and eastward through Owasso, Verdigris, and Claremore.

JUNE 2023

FEMA DR-4721-OK

The Father's Day storm of 2023 caused mass power outages and road closures throughout Tulsa. The derecho produced wind gusts of 117 miles per hour, causing $16.6 million in damages, leaving over 200,000 residents without electrical service. At least three tornadoes were confirmed.

AUGUST 6, 2017

EF-2 TORNADO STRIKES MIDTOWN TULSA SHORTLY AFTER 1 A.M.

An EF-2 with winds up to 130 mph damaged dozens of businesses and homes over a 4.2-mile path through midtown and east Tulsa. The tornado touched down east of Harvard and south of 36th Street. Large tree limbs snapped and homes were damaged. As the tornado moved east-southeast crossing Yale, trees and power poles were snapped and businesses were damaged or destroyed between Yale and Sheridan along 41st Street. Roofs and exterior walls were torn off buildings and several vehicles were rolled. 26 injuries occurred in the area. The tornado continued toward Broken Arrow, causing roof, wall, and window damage between Sheridan and Hwy 169. Power poles and trees were downed. The storm turned easterly and moved along 51st Street and dissipated before 145th East Avenue.

Figure 4-12: City of Tulsa Tornado History and Summary of Recent Events

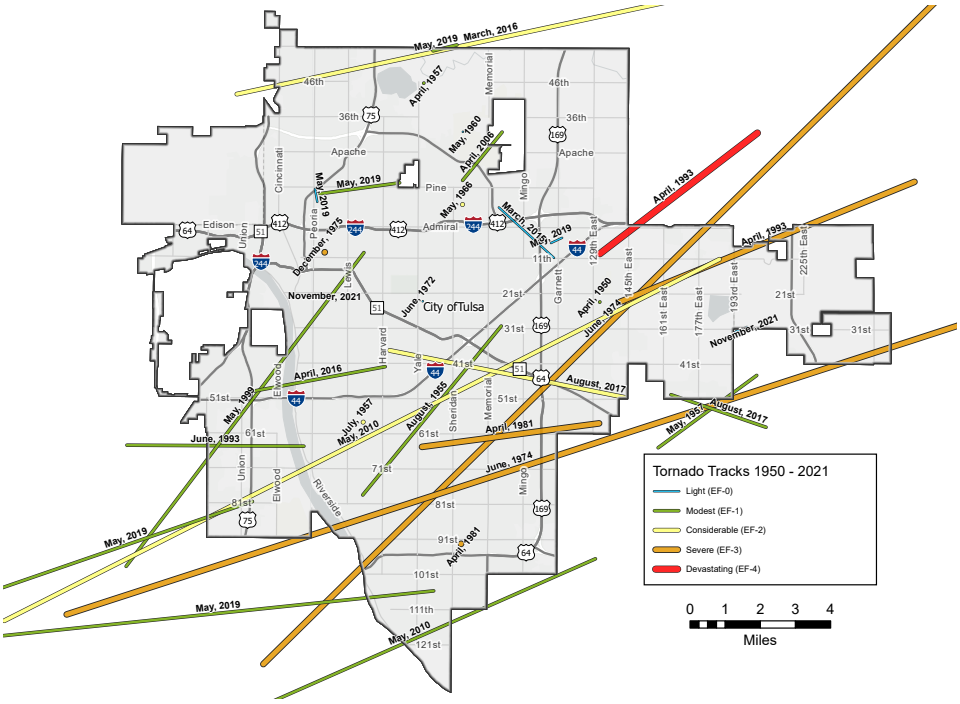
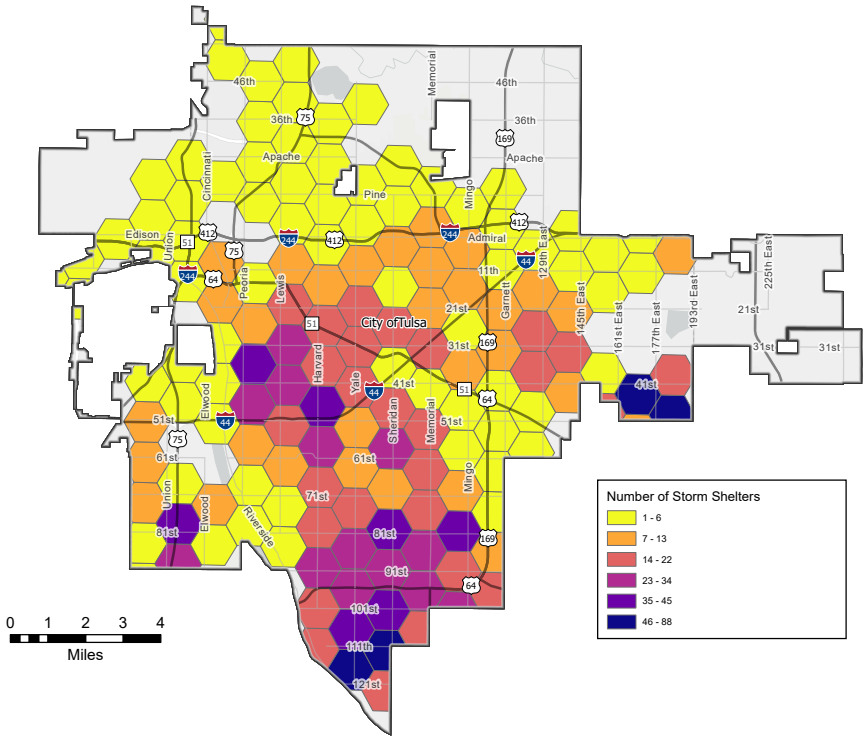


Figure 4-13: Registered Storm Shelters in Tulsa



Using data from the City of Tulsa's Storm Shelter Registry, a heat map was created to show areas of Tulsa with the highest concentration of safe rooms per 2023 data. A heat map was used for privacy reasons, Figure 4-13. Actual point data indicates a significant disparity in the number of individuals with safe rooms in north Tulsa compared to south Tulsa.

4.3.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: High, the criteria consistently fall in the high classifications and the event is likely/ highly likely to occur with severe strength over a significant to extensive portion of the planning area.

People

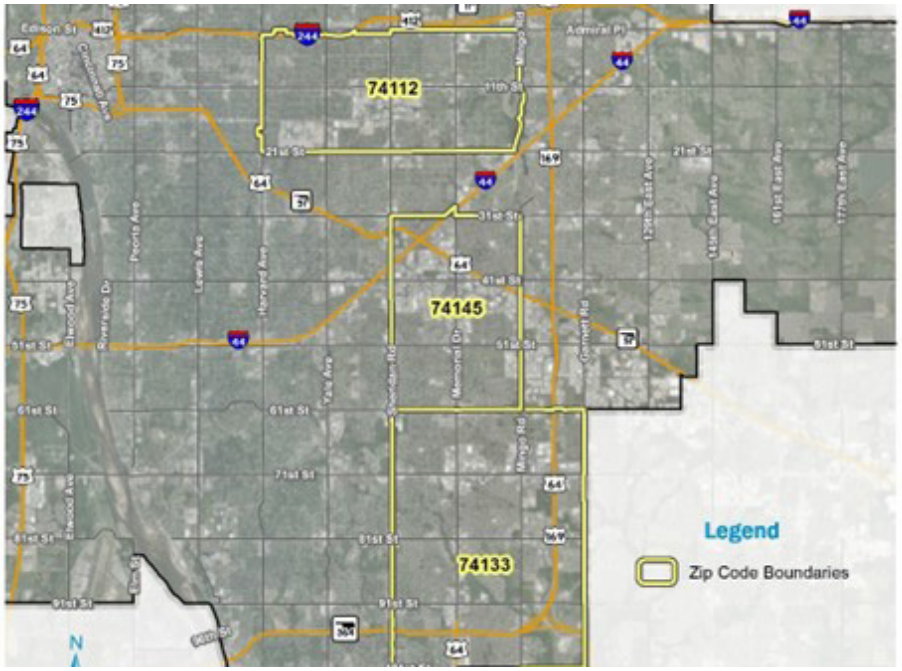
All the population of Tulsa is exposed and at risk for experiencing this hazard. From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67 percent, from 401,190 to 411,894. Adequate warning systems are essential to public safety during high wind and tornado events. Though the purpose of outdoor warning sirens is to provide a warning for people participating in outdoor activities, many Tulsans rely on them as their primary notification. Tulsa should educate the public on alternate means of severe weather alerts, such as NOAA radios, the TulsaReady App, and IPAWS notification.

Major determinants that play into effects of this hazard on the population include social vulnerability. Areas in Tulsa with a higher income disparity are more vulnerable to high wind and tornados than areas with a higher per capita income, as low-income residents are less likely to afford the cost of a residential safe room. Quality of housing, language barriers, and education level play a role in increased vulnerability to this hazard and the level of resilience post-event. The Resilient Tulsa Strategy focuses on the goal to equip all Tulsans to overcome barriers and thrive; this includes providing even the most vulnerable Tulsans with information and resources necessary to prepare for and respond to disasters. Focusing future mitigation grant money on low-income populations would assist in closing this gap.

Lessons Learned

Tulsa has gained experience and knowledge about the effects of tornados on their commu-

Figure 4-14: Primary Sources of Sales Tax in Tulsa



nity. In 2015, the City faced more challenges because it was the first time in recent years a tornado directly impacted the citizens. The Tulsa Long Term Recovery Committee, led much in part by local, state, and nonprofit organizations, assisted in the recovery efforts. A federal disaster was not declared for this area.

In 2016, when the tornado devastated an area in north Tulsa, partners were already lined up based on their experiences assisting with the recovery efforts from the prior year.

The area most impacted in 2016 had a poverty rate of two to four times the poverty rate of Tulsa County.

The City Council and Tulsa Development Authority authorized Tulsa's Working in Neighborhoods program to prioritize CDBG funds for recovery. Use of these funds for recovery was written into the CDBG grant request and is referenced by the State of Oklahoma as the most innovate existing programming at the local level.

The City of Tulsa/Tulsa County Emergency Operations Plan, advises citizens to plan and prepare for shelters in or near their homes. Local government facilities should not be relied upon for shelter. The best option is for Tulsans to install safe rooms in their home, which provide near-absolute protection to wind events of at least 250 mph.

One ongoing problem with safe rooms is the need for the public to understand not all safe rooms are created equal. Lack of adequate safe room design can cause the unit to fail. FEMA provides guidance for safe room design criteria in bulletin P-361[1] .

Economy

While forecasting and early warning have decreased the number of fatalities associated with wind events, little has been done to address economic losses. After the August 2017 tornado event, Tulsa distributed a point in time survey to business owners affected by the incident. Business owners did not complete a follow-up study, so data limitations on the actual impacts the event had on the businesses, aside from physical implications, are limited. High wind and tornado events will cause direct and indirect losses to the economy any time businesses are affected and closed for a period.

In November 2017 the Resilient America Program of the National Academies of Sciences, Engineering, and Medicine presented initial findings of research on sales tax revenue and discussed what these initial findings could indicate about resilience in Tulsa; specifically, as they relate to tornados. The analysis shows three main zip codes as the primary sources of sales tax revenue in the City of Tulsa: 74145, 74133, and 74112, Figure 4-14. Based on this information, one can assume damaging high wind or tornado events in these zip codes would cause a more significant economic loss than other areas of Tulsa. The findings of this report are based on early research and in need of more detailed study and analysis.

Built Environment

Existing Structures: The residential building stock in Tulsa is diverse in the type of construction, age, and size of the building. Mobile homes or manufactured homes are the most vulnerable and makeup 1.5% of housing units in Tulsa. The federal government established standards in 2007 requiring all new manufactured homes to meet the requirement for installation and anchoring in accordance with its structural design and windstorm standards. Even anchored mobile homes can be severely damaged when winds gust over 80 mph.

Damages to residential properties depend on

1 fema.gov/sites/default/files/documents/fema_safe-rooms-for-tornadoes-and-hurricanes_p-361.pdf

the tornado's wind-speed and the level of wind resistance the property has been constructed to withstand. Houses with crawl spaces are more susceptible to lift. The manner in which foundations and roofs are constructed can affect a structure's ability to withstand wind pressure.

Homes constructed to be more wind-resistant, meeting high-wind design requirements, such as the Insurance Institute for Business and Home Safety's (IBHS) fortified home construction recommendations, are less vulnerable to tornado damage. Homes constructed to this structural capacity can withstand winds up to 130 mph, which is 95% of tornados.

Older homes are especially vulnerable to tornado events. About 13% of residential structures in the City of Tulsa were built before 1969. These older homes in the jurisdiction are generally more vulnerable to tornado damage than more recently built homes constructed to higher standards. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

Infrastructure

Tornados in Tulsa can cause significant damage to infrastructure. Tulsa should be prepared to face the loss of power and damage to critical infrastructure (e.g., storage tanks, hydrants, residential plumbing fixtures, distribution system) due to hail, wind, debris, and flash flooding, resulting in loss of service and/or reduced pressure throughout the system. Restricted access to the facility due to debris and damaged roads is likely. Loss of power and communication lines will require alternate methods of communication until cellular service or landlines can be restored.

Critical Facilities

It is impossible to predict the geographical area of impact of high wind and tornados. As such, all critical facilities in Tulsa are exposed to this hazard. In anticipation of high winds and tornados, Tulsa should consider the purchase and installation of generators at critical facilities. Currently, the TAEMA Emergency Operations Center provides an underground storm shelter. Additional shelters should be provided at other critical facilities throughout the city.

Cultural Resources

Loss of structures listed on the National Historic Register, or of one of Tulsa's many museums, would be devastating. All are vulnerable to high wind and tornados. Structural mitigation measures should maintain the historical integrity of National Register eligible or listed properties. For example, impact resistant glass systems in windows and doors should match the period and style of a historic structure.

Future Development

The City of Tulsa adopted the ICC International Building Code, 2018, and the ICC International Residential Code for One- and Two-Family Dwellings, 2018 Edition. The City of Tulsa should be prepared to focus beyond the apparent clean-up and repair/rebuild post-event. Future development is assumed to be less vulnerable to high-wind events because of the higher building standards in place. In 2018, insurance companies began offering discounts on homes built or retrofitted to certain tornado-resilient standards since a law went into effect April 1 requiring them. The general public should be educated on the advantage of having a stronger home, such as more affordable insurance rates, higher resale value and a house that can withstand up to an EF2 tornado. Tulsa should work with the Oklahoma Insurance Department to educate the public, building professionals, and insurance agents about these benefits. Additionally, Tulsa should consider a program to train building officials as IBHS Home Evaluators. There is a shortage of evaluators in Tulsa and a need for them may be

evaluated, and homeowners may receive insurance discounts if their company offers them. Development trends and population growth from 2019 to 2023 have not increased Tulsa's vulnerability to high wind or tornadoes.

Natural Environment

The effects of damaging wind from high-wind events or tornados on the natural environment are not always obvious or immediately apparent. Debris from damaged or destroyed homes can result in asbestos being deposited. Hazardous household waste, such as cleaning and automotive products, becomes an issue to animals and plants in the area and can also contaminate water and soil. During severe thunderstorm events in Tulsa, flash flooding is a common occurrence. Household and industrial waste can spread into animal habitats, stormwater, rivers, and lakes. Tulsa should address these issues with the Department of Environmental Quality during the recovery period and plan for proper disposal of debris in advance of wind or tornado events.

4.3.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
City Council and Tulsa Development Authority authorized use of CDBG funds to assist with recovery in non-federal events	Plan to apply for HMGP funds and build to higher standards in future recovery efforts. CDBG can match HMGP.	2
Some areas of Tulsa are less equipped to prepare for or recover from high-wind and/or tornado events	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8
Essential facilities in Tulsa need back-up generators.	Tulsa should assess the need for generators at critical facilities and implement as funding becomes available.	6
Tulsans rely on warning sirens as primary source of weather notifications.	Educate the public on purpose of outdoor warning sirens and promote NOAA weather radios, IPAWS, and the TulsaReady App.	1, 30
Tulsa has an established Long- Term Recovery Program and plan in place.	Tulsa should continue to maintain the recovery plan for post-disaster recovery, including a process for efficient damage assessments, mitigation action items and funding opportunities.	2
Many Tulsans do not have adequate sheltering options in their homes. There is a disparity in the number of safe rooms in north Tulsa compared to south Tulsa.	Educate the public on importance of Safe Rooms and implement individual safe room program. Priority of safe room program could focus on low- income populations.	33
The TAEMA office is underground, but aside from this we were unable to determine which other, if any, critical facilities had adequate sheltering options for high-wind and tornado events.	Safe rooms that meet or exceed the requirements of FEMA P361 and 320 should be installed in new critical facilities to protect first responders and city officials from severe weather.	
The general public, and even insurance agents, are unaware of the benefits associated with disaster resistant construction and discounts on insurance premiums.	Tulsa should work with the State Department of Insurance to educate the public on better building practices.	5
Though interest in building to IBHS Fortified Standards is increasing, there are few fortified inspectors in Oklahoma.	Tulsa should work with the State Department of Insurance, IBHA, and the HBA to train home builders on disaster resistant construction techniques and encourage certification as fortified inspectors.	5
Critical facilities are at risk to all modes of severe weather, and possible impacts.	Hazard vulnerability should be considered when constructing new critical facilities. If damaged, critical facilities should be repaired to high building standards.	
Some areas of Tulsa appear to be out of range of a warning siren.	Install, update, and maintain warning sirens.	30
High-wind or tornado events may result in heavy amounts of debris, blocking roads and isolating areas of Tulsa.	Tulsa should be prepared to remove debris post disaster and be ready to request federal assistance when warranted.	

4.4 Dam/Levee Incidents

4.4.1 Hazard Description

Dam failure

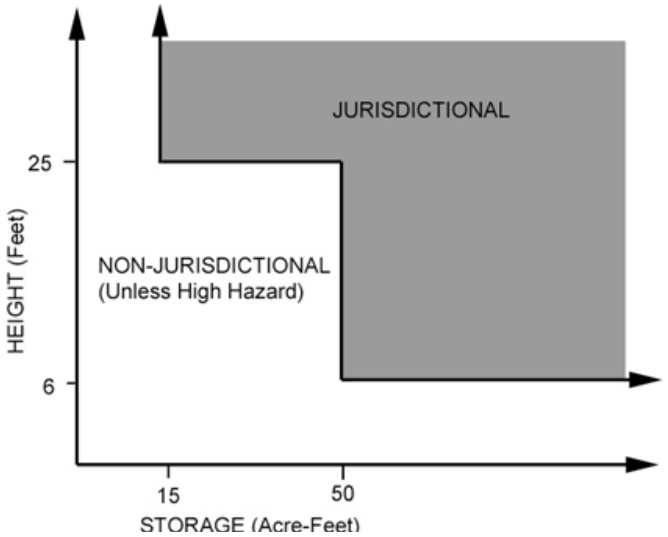
For dam failure, risk is the product of the annual probability of dam failure from a particular failure mode and the magnitude of the resulting consequences. A potential failure mode for a dam is defined as a way that dam failure can occur (i.e., the full sequence of events from initiation to failure) for a given loading condition (such as flood, earthquake, etc.). Credible failure modes must be determined for each individual dam. Further information on risk management for dams is available in the FEMA P-1025 Federal Guidelines for Dam Risk Management.

Flooding can occur downstream from a dam without the structure being breached. Sometimes, to prevent overtopping and catastrophic failure, dams are forced to make emergency releases of large amounts of water, which can cause downstream flooding.

Any dam that has a height of 25 feet or more from the natural streambed and/or 50 acre-feet or more of storage capacity is under the jurisdiction of the Oklahoma Water Resources Board (OWRB), as shown in Figure 4-15. The OWRB also classifies dams as high-hazard, significant-hazard, and low-hazard, depending on the downstream populations and infrastructure. The hazards are based on first, potential for loss of life from a breach and, second from the level of economic damage that will occur downstream from a breach. Table 4-7 identifies the risk and required inspection frequency for these dams[1].

A dam is considered small if it has maximum

Figure 4-15: OWRB Jurisdictional Sizes of Dams



storage of less than 10,000 acre-feet and a maximum height of less than 50 feet. Intermediate size dams are those which have a maximum storage of between 10,000 and 50,000 acre-feet and have a maximum height of between 50 and 100 feet. Large size dams are those which have a maximum storage of over 50,000 acre-feet and have a maximum height of over 100 feet.

An acre-foot is the volume of water that covers an acre of land to a depth of one foot, or approximately 325,000 gallons. An acre-foot is equal to 43,560 cubic feet.

Water discharge is measured in cubic feet per second (cfs). A cubic foot contains about 7.5 gallons of water. One cubic foot per second equals about 450 gallons per minute.

Of the 16 dams in or around the City of Tulsa, the OWRB has classified six as High Hazard and one as Significant Hazard. Not all of these dams would impact the city directly. The classification scheme simply reflects a dam's potential

1 Oklahoma Water Resources Board, Dam Safety, owrb.ok.gov/damsafety/index.php

Table 4-7: Dam Failure Hazard Potential Classification

HAZARD-POTENTIAL CLASSIFICATION	RISK INVOLVED WITH DAM FAILURE	INSPECTION FREQUENCY
HIGH	Probable loss of human life	Annually, by a registered professional engineer
SIGNIFICANT	No probable loss of human life but can cause economic loss or disruption of lifeline facilities	Every three years by a registered professional engineer
LOW	No probable loss of human life and low economic loss	Every five years

for doing damage downstream if it were to fail.

All high hazard dams must have an Emergency Action Plan (EAP) and must have an accompanying breach inundation map. This describes the locations where a breach of the dam will inundate an area by at least one foot during a sunny day (non-storm event related) breach or by a breach resulting in water surface elevations at least one foot higher than the water surface elevations from the spillway design flood without a breach, whichever is larger in area. These maps are on file with the Oklahoma Water Resources Board. See Appendix D. of this report, titled "2023 City of Tulsa High Hazard-Potential Dam Amendment" for supplemental information regarding Spavinaw Lake Dam and Eucha Dam.

Levee Failure

The Federal Emergency Management Agency (FEMA) has defined a levee in the National Flood Insurance Program (NFIP) regulations at 44 CFR as "a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding." Its primary function is flood protection.

Levee failures can cause catastrophic floods, releasing sudden walls of water that can sweep across lands thought to be protected by the structure. Thus, levees may create a false sense of security, increasing the amount of property at risk of flooding as people and businesses locate behind levees and floodwalls, believing they are totally safe. In addition, levees, dams, and other structural measures are extremely costly and can disrupt or destroy the natural environment.

See Appendix F of this report, titled "2023 City of Tulsa High Hazard-Potential Dam Amendment" for supplemental information regarding Spavinaw Lake Dam and Eucha Dam.

4.4.2 Location

Levees

There are three levees on the Arkansas River west of downtown on the north, south, and west sides of the Arkansas River protecting the refineries and some adjacent neighborhoods. A 0.2% (500-year) storm will overtop the levees. These levees are shown in Figure 4-22. The USACE designates these levees as:

- Levee A, the upstream left bank levee (the western levee, located north of the river in Sand Springs and Tulsa County);
- Levee B, the downstream left bank levee (the eastern levee, located north of the river, primarily within the jurisdiction of the City of Tulsa);
- Levee C, the right bank levee (the West Tulsa levee, within the Tulsa city limits, but also containing large unincorporated areas. These unincorporated areas, located in Tulsa County, contain oil refineries, oil

tank storage farms, and railroad switching yards.)

Tulsa and West Tulsa Levees A and B are on the Arkansas River in Tulsa County, Oklahoma. The levees are earth embankments averaging 15 feet tall and each being about five miles long and they are connected by concrete floodwalls built over a box culvert floodway structure that allows a major road and a railway to cross the mouth of Bigheart Creek. The levees were constructed by the U.S. Army Corps of Engineers, and after completion in 1944 ownership was transferred to Tulsa County Drainage District No. 12 for continued operations, maintenance, repair, rehabilitation, and replacement actions. The USACE designed the levees to contain and withstand a Keystone dam release of 350,000 cfs, with a minimum of 3 feet of freeboard.

Tulsa and West Tulsa Levee "C" is on the Arkansas River along an unincorporated portion of Tulsa County, Oklahoma. The levee is an earth embankment averaging 11 feet tall and is about eight miles long. The levee was constructed by the U.S. Army Corps of Engineers and after completion in 1945 ownership was transferred to Tulsa County Drainage District No. 12 for continued operations, maintenance, repairs, rehabilitation, and replacement actions.

Dams

Table 4-8 gives the pertinent data for each of the high hazard dams affecting the City of Tulsa, either as a breach flooding hazard or in affecting its ability to serve the City's water supply needs. Locations of the inundation areas in Tulsa are shown on the maps in Figure 4-16 through Figure 4-21. These can also be accessed at the City of Tulsa's Hazard Mitigation website.

4.4.3 Extent

Six High Hazard dams and the Tulsa West Tulsa Levee system would directly affect Tulsa during a breach or failure. For the purposes of this plan, only the impacts of high hazard dams are addressed unless otherwise specified. Specific extent statements for each dam and the levee system are included below, along with a map displaying the extent of flooding from a dam or levee event. The type of breach scenario is noted on each map.

Table 4-8: City of Tulsa High Hazard Dams

KEYSTONE DAM	
Location	On Arkansas River, 10 miles west of Tulsa
Source	Arkansas River
Drainage basin	22,351 sq. miles
Owner/operator	US Army Corps of Engineers
Year built	1964 (with an estimated useful life of 50 years)
Length/ Height	4,600 feet long, 121 feet high
Surface area	23,610 acres
Construction material	Masonry and earth-fill
Use of Dam	Water storage, flood control, hydroelectric, and recreation
Capacity	431,922 acre-feet (normal), 1,560,564 (maximum)
Results of failure/high releases	Inundation of Sand Springs, Tulsa, Jenks, Broken Arrow, Bixby
Emer Action Plan (EAP)	Yes

YAHOLA DAM	
Location	North of Tulsa on Lake Yahola
Source	Pumped storage
Owner/operator	City of Tulsa
Year built	1948
Length/ Height	17,500 feet long, 35 feet high
Surface area	431 acres
Construction material	Concrete and earth-fill
Use of Dam	Water supply for Tulsa
Capacity	6,445 acre-feet (normal)
Results of failure	Inundation of areas in North Tulsa
Emer Action Plan (EAP)	Yes

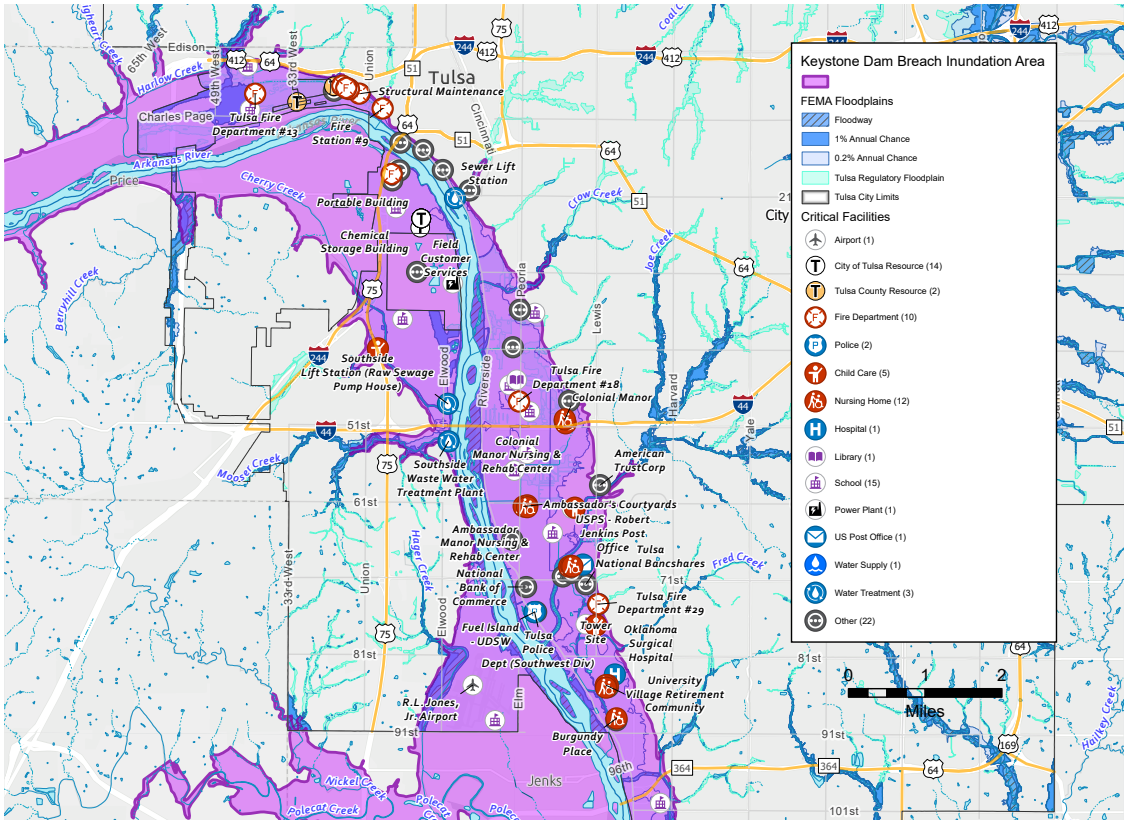
SKIATOOK LAKE DAM	
Location	18 miles north-northwest of Tulsa
Source	Hominy Creek
Drainage basin	354 sq. miles
Owner/operator	US Army Corps of Engineers
Year built	1984
Length/ Height	3,590 feet long, 143 feet high
Surface area	10,502 acres
Construction material	Concrete and earth-fill
Use of Dam	Flood control, water supply, fish and wildlife, recreation
Capacity	321,408 acre-feet (normal), 499,102 acre-feet (maximum)
Results of failure	Inundation of homes and infrastructure below dam
Emer Action Plan (EAP)	Yes

OOLOGAH LAKE DAM	
Location	27 miles northeast of Tulsa
Source	Verdigris River
Drainage basin	4,339 sq. miles
Owner/operator	US Army Corps of Engineers
Year built	1974
Length/ Height	4,000 feet long, 137 feet high
Surface area	29,500 acres
Construction material	Earth-fill and concrete
Use of Dam	Flood control, water supply, navigation, fish and wildlife, recreation
Capacity	549,209 acre-feet (normal), 1,509,721 acre-feet (maximum)
Results of failure	Inundation of low-lying homes and infrastructure below dam
Emer Action Plan (EAP)	Yes

LYNN LAKE DAM	
Location	
Source	Pumped storage
Owner/operator	City of Tulsa
Year built	1950
Length/ Height	13,300 feet long, 15 feet high
Surface area	420 acres
Construction material	Concrete and earth-fill
Use of Dam	Raw water storage
Capacity	325 acre-feet
Results of failure	Inundation of areas of East Tulsa and A.B Jewell Dam
Emer Action Plan (EAP)	Yes

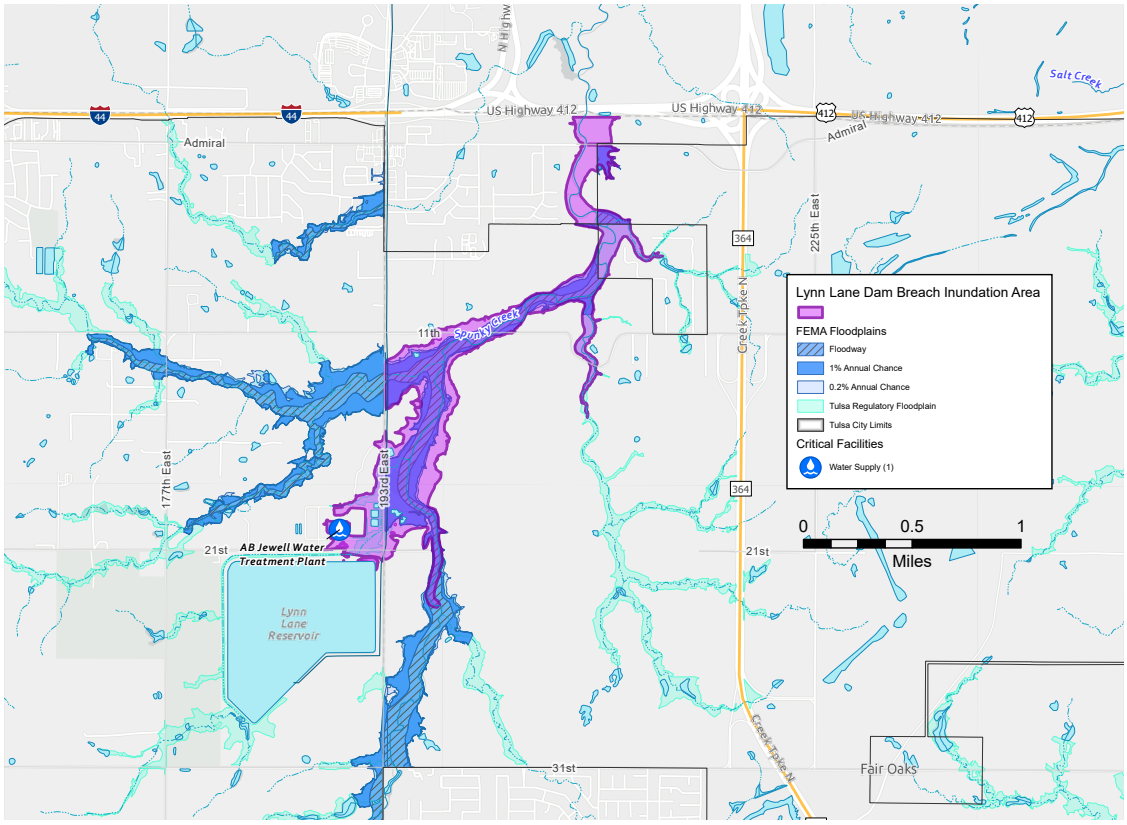
WARRENTON LAKE DAM	
Location	Near E. 67th St. and S. Kingston Ave.
Source	Tributary to Joe Creek
Owner/operator	Warren Medical Center
Year built	1936
Length/ Height	400 feet/ 37 feet
Surface area	4 acres
Construction material	Earth-fill
Use of Dam	Recreation
Capacity	41 acre-feet, 50 acre-feet maximum storage
Size	Small
Flood damage history	None
Results of failure	Downstream property inundation
Emer Action Plan (EAP)	Yes

Figure 4-16: Keystone Dam Breach Inundation Area



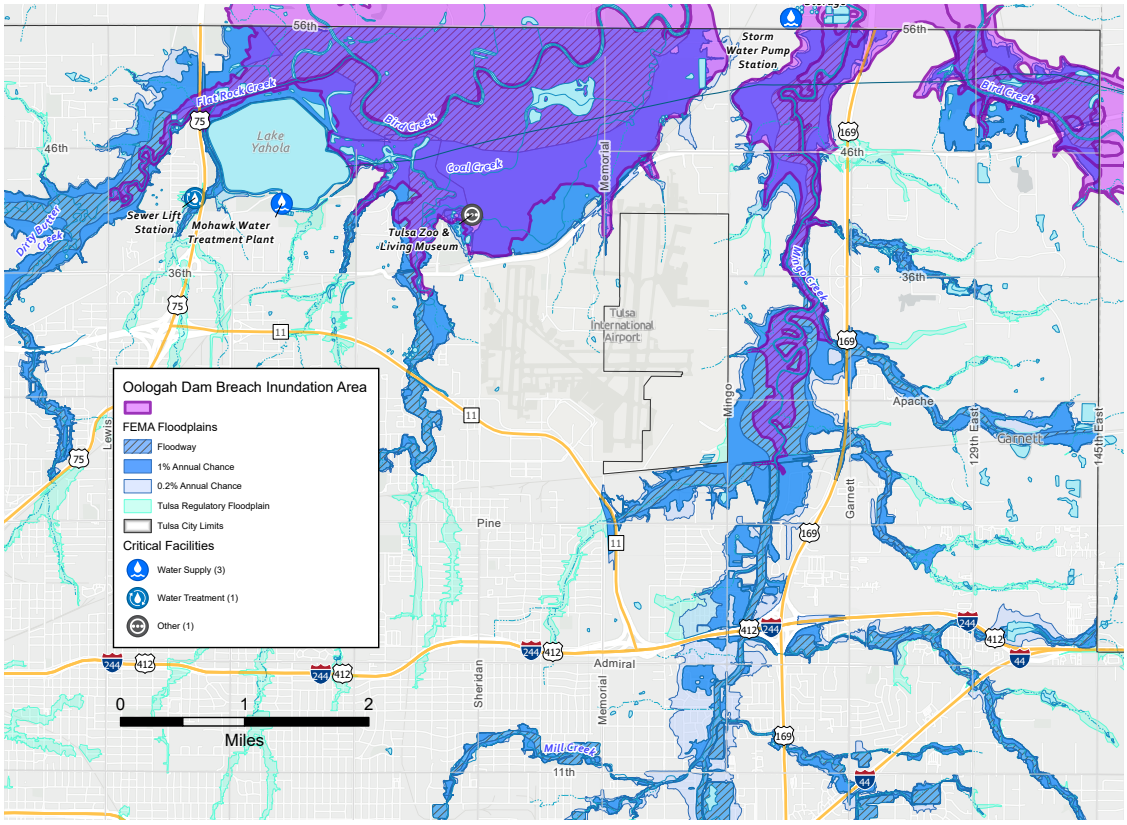
Warning time for breach or failure of Keystone would depend on the type of event. The USACE estimates a wave time arrival of 6 hours from the time of failure. A dam break would send a 20-foot-high wall of water rushing down the Arkansas River valley. The average building in the flood zone would have from 10 to 20 feet of water in the structure.

Figure 4-17: Lynn Lane Reservoir Sunny Day Breach Area



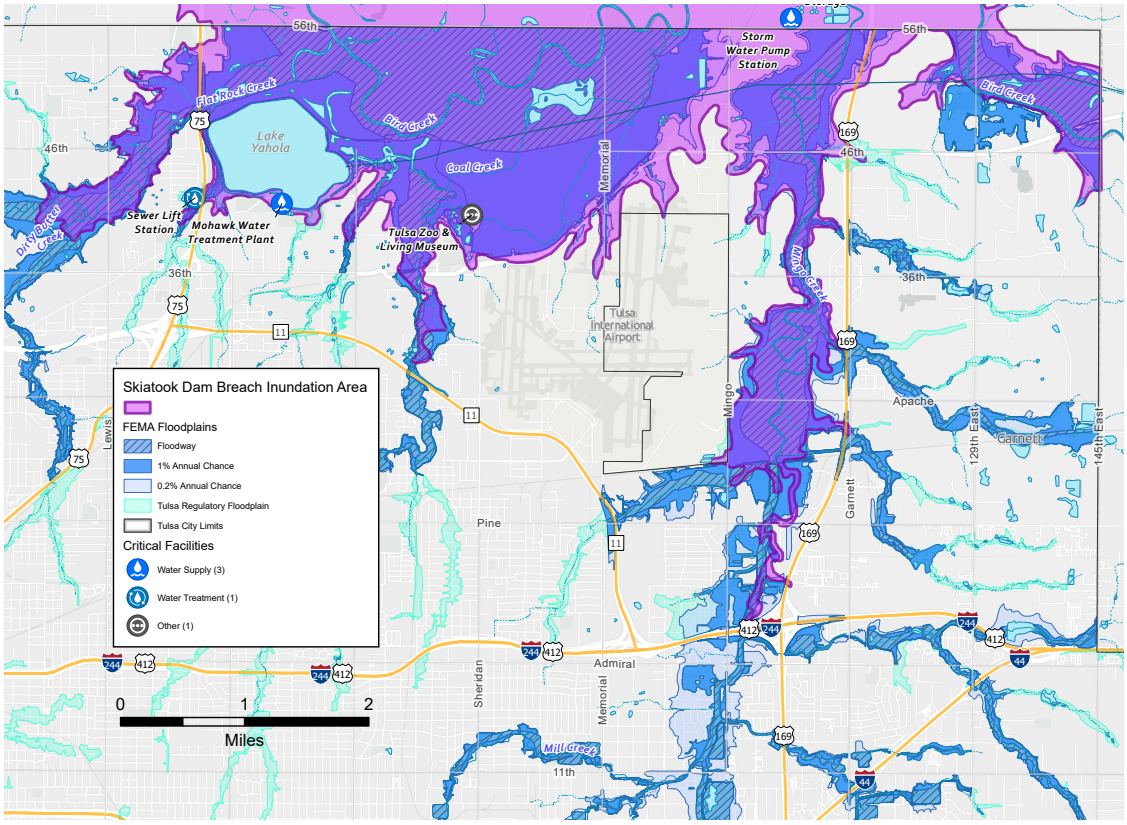
Lynn Lane Reservoir is a terminal storage reservoir and does not receive surface water runoff. It was therefore analyzed for sunny day failure only. A breach would require about 2 hours to completely form, impacting the water treatment plant area immediately downstream with water depths ranging from one inch to 8 to 10 feet above the creek bank. The breach flow would overtop 21st Street and 193rd E. Ave. by approximately 4 feet. The residential property downstream approximately 1.3 miles and north of 11th Street on the west side of Spunky Creek would experience flood depths of approximately 8 feet on the structure. No other buildings appear to be impacted south of Highway 412.

Figure 4-18: Oologah Dam Breach Area



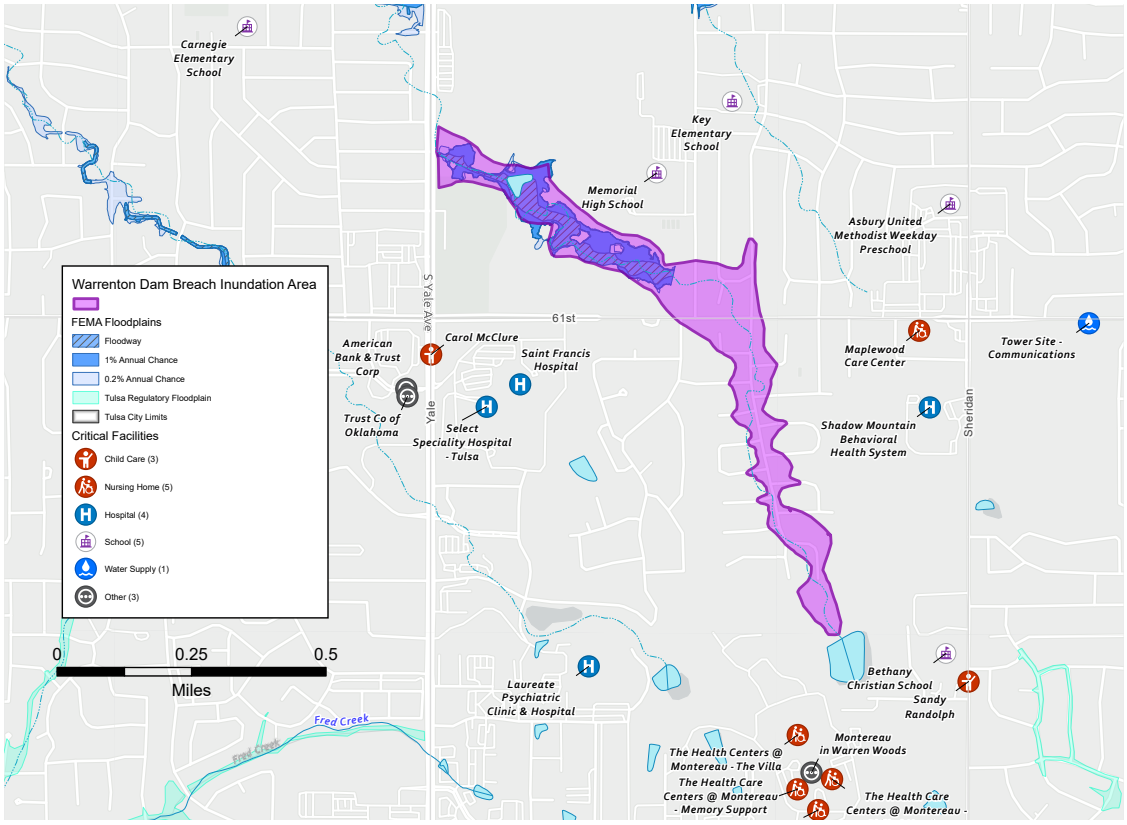
At 30 miles downstream of the dam near the Interstate 44 Bridge, the failure wave would arrive in Tulsa about 4.75 hours following the breach of the dam. The flood waters would quickly rise from one inch to over 30 feet of depth and would peak 20 hours later at an approximate elevation of 594.2 feet (NAVD 88), 33 feet above the top of bank. Flood waters would then begin to recede and would reach pre-failure levels about three days following the breach of the dam. Most of Tulsa lies southwest of the Interstate 44 Bridge crossing the Verdigris River. There would be major impacts from flooding to suburban and rural areas of Tulsa and bridges across the Verdigris River would be impacted. Homes and businesses near the river and in low lying areas along the Verdigris River and backwater creeks would be impacted. Critical infrastructure that could be impacted includes chemical processing facilities, electric substations, intermodal shipping facilities, airports, communications facilities, a hydropower facility, a bulk petroleum facility, a school and a wastewater treatment plant.

Figure 4-19: Skiatook Lake Dam Breach Area



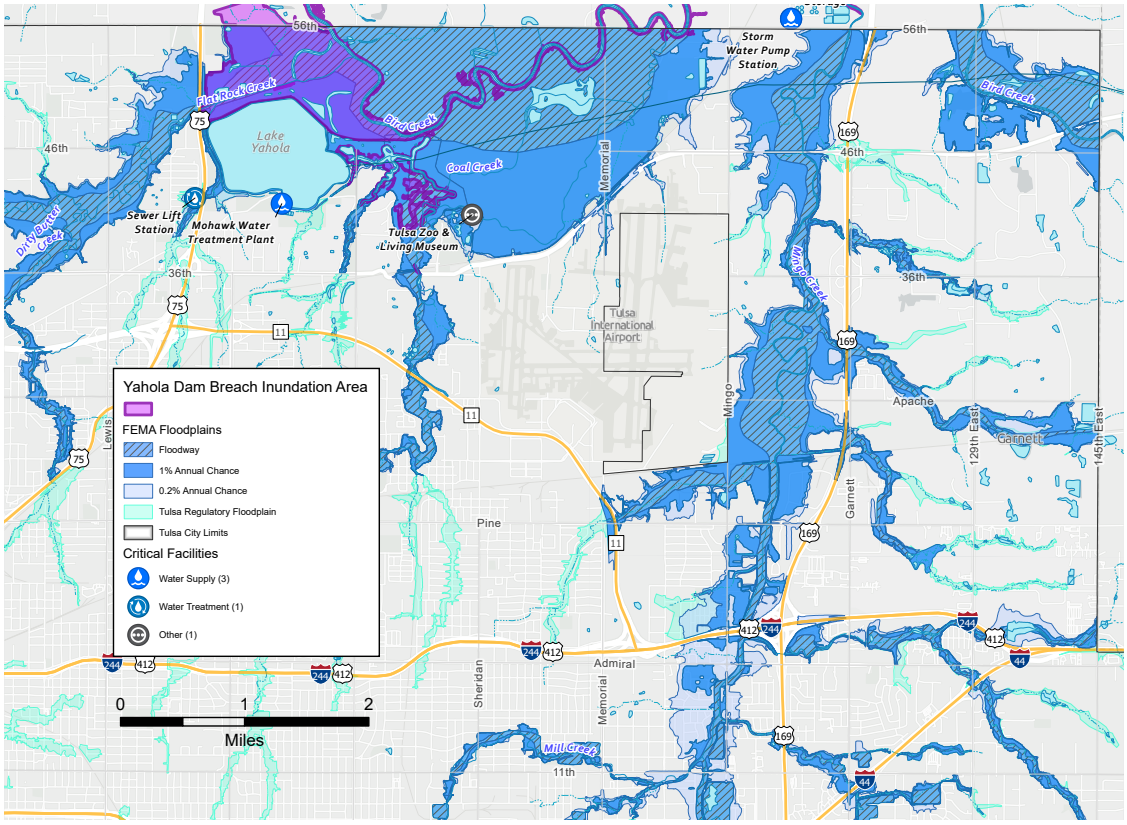
Failure wave would arrive within two hours following the breach of Skiatook Lake dam. The failure wave would peak 8.5 hours after the breach and would rise from one inch to a peak elevation of 620.8 feet (NAVD 88), 23 feet above the top of the stream bank. Flooding in north Tulsa would mostly be north of the Gilcrease Expressway. There would be backwater flooding up Coal Creek to the Gilcrease Expressway and up Mingo Creek to Interstate-244. Portions of North Port Road and East Port Road would be inundated.

Figure 4-20: Warrenton Dam Breach Maximum Failure Area



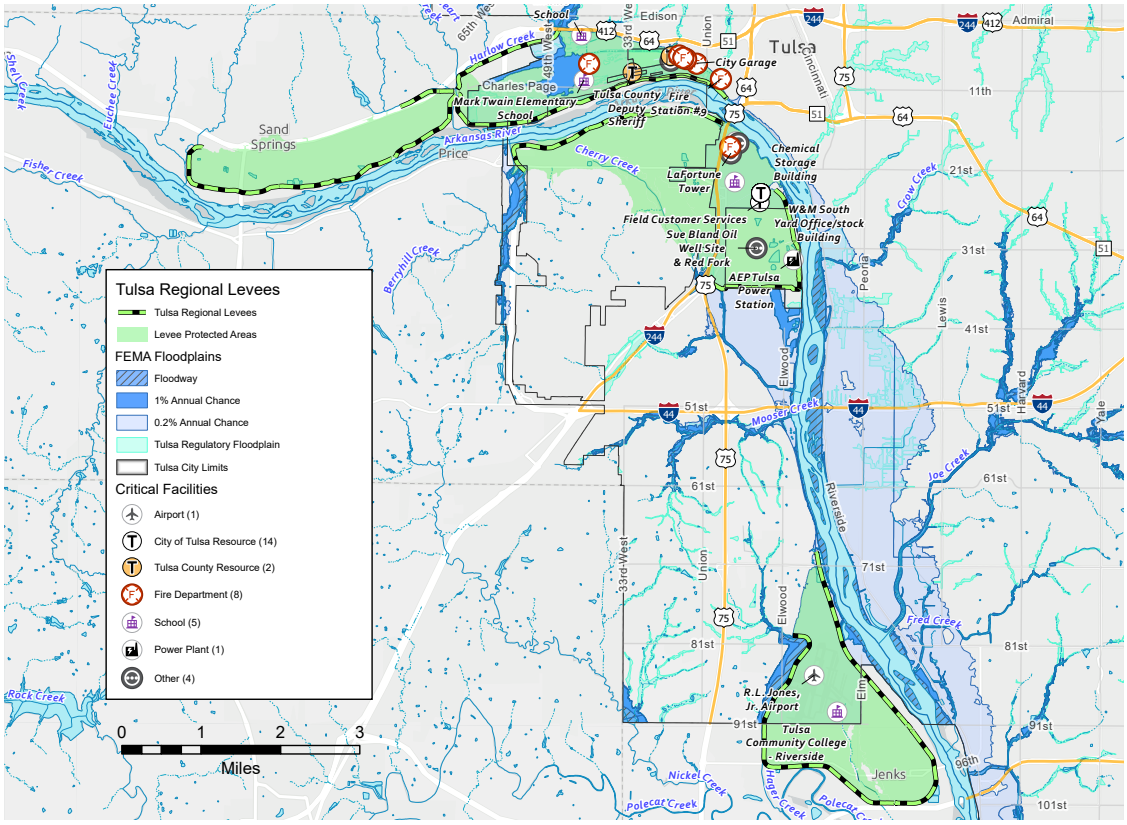
The EAP for Warrenton Dam estimates a wave time arrival of 1.2 minutes from the time of failure. The initial flood depth could range from one inch to just over 5 ft, at a location 504 ft from the dam. Max flood depth at 61st St. is 5.62 ft, 16.2 minutes from time of failure

Figure 4-21: Yahola Dam Breach Inundation Area



Yahola Reservoir is a terminal storage reservoir and does not receive surface water runoff. It was therefore analyzed for sunny day failure only. A breach would require about 2.5 hours to completely form, impacting 56th Street North, immediately downstream with water depths ranging from one inch to approximately one foot over the roadway. No buildings appear to be impacted. The breach flows are generally within the downstream channel at a distance of approximately 2 miles downstream.

Figure 4-22: Tulsa Levee System



Each levee protects significant development areas. The levees would overtop and probably breach during a 500-year storm. Due to the construction of the levees, a breach is highly likely when they are overtopped. The inundation would result in a loss of life and property. Failure might also result in environmental contamination from superfund sites and industrial uses. There is no known warning time or triggers for evacuations at this time. Flood levels could range from one inch to seven feet within Tulsa.

4.4.4 Previous Occurrences

The City of Tulsa has not experienced a dam break or failure up to 2023 (other than the 1986 forced-release event).

The levees have a history of poor performance. During the 1984 record rainfall event in Tulsa, Bigheart and Harlow Creeks overtopped levees causing extensive erosion and foundation failure of floodwalls. Dozens of residential structures were flooded, and many were demolished. Localized flooding occurred near an apparent overtopping area near Cherry Creek.

The 1986 flood of record on the Arkansas River loaded Levees A & B to about 80% of their total height and Levee C to about 75% of its total height. Breaches were barely contained by flood fighting efforts. Significant repairs were made after both the 1984 and 1986 flood events, but concerns remain with aging culverts, plugged toe drains and relief wells, and antiquated pumping stations that are all now more than 70 years old.

On-site assistance (USACE) was provided for the emergency repair of two breaches in the Tulsa-West Tulsa levee system during the 1986 flood on the Arkansas River. Several accounts of sand boils were also reported on the levees.

Additionally, the private west bank (Gar-

den City) levee failed, causing $1.3 million in damages to 64 buildings[1]. River water entered the Garden City community from the breach in a private levee, causing damage to 14 homes, 11 industrial buildings, and 39 mobile homes. Some of the houses flooded up to the rafters. The city fielded its hazard-mitigation team and eventually purchased 13 parcels, cleared seven homes, and rebuilt the damaged levee to provide at least limited protection to the extensive west bank industrial areas.

May 2019 proved to be a very rainy month for the state of Oklahoma, specifically for the northeast region of the state, and for the city of Tulsa. For the northeastern part of Oklahoma, it experienced the second-wettest May on record. Dams that played the biggest role in releasing water to prevent flooding were the Oologah Dam and Keystone Dam. Below is a graphic showing how much rainfall the state experienced. Tulsa County experienced 15.97 inches of rainfall, and it can be assumed the City of Tulsa experienced that much, if not more.

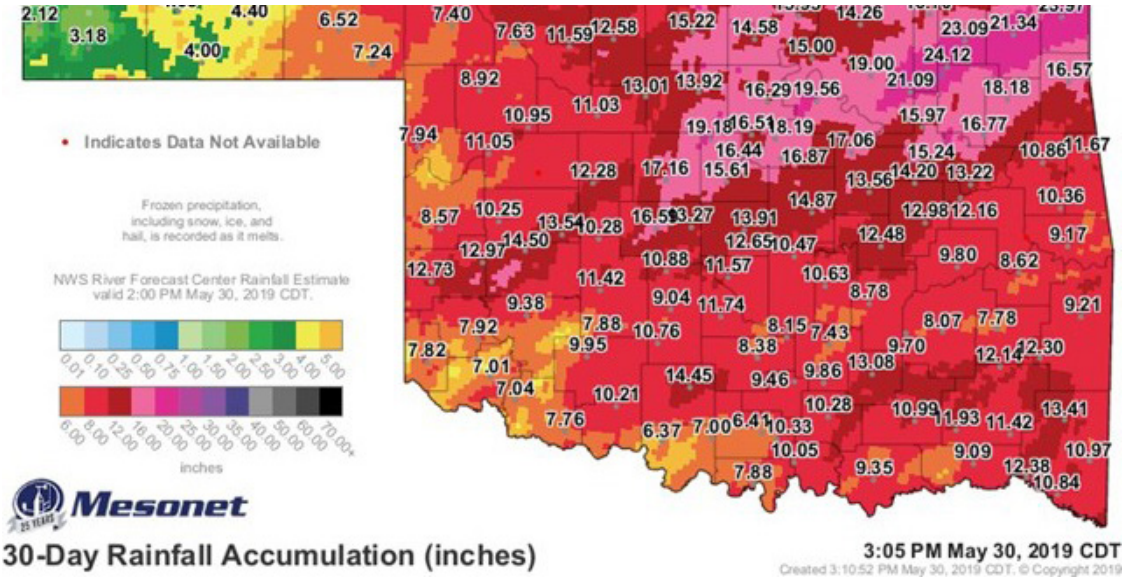
The Arkansas River crested at 23.5 feet, its second highest level since 1894. Resulting flooding caused $3 billion in damages within the Arkansas River basin. In Tulsa, the flood killed five people and left many neighborhoods inaccessible.

The Keystone Dam is constructed across the Arkansas River and helps to control the Arkansas River that runs through the City of Tulsa. During the 1986 flood, the Corps of Engineers released water downstream at a rate of 310,000 cubic feet per second (8,800 m3/s), which made downstream flooding inevitable. That amount is the most amount of water released to date.

During the May 2019 event, release rates from the Keystone Dam continued to hold at about 255,000 cubic feet per second, on May 24, 2019.

1 From Rooftop to River, Tulsa's Approach to Floodplain and Stormwater Management, City of Tulsa Stormwater Drainage Advisory Board and Public Works Department, May 1994

Figure 4-23: 30-Day Rainfall Accumulation



Floodwater releases at Keystone Dam increased to 265,000 cubic feet per second on Sunday May 26, 2019 and were set to rise to 275,000 by Monday, May 27, 2019, according to the Tulsa District U.S. Army Corps of Engineers. By Thursday morning, May 30, 2019, Keystone Dam release was reduced to 245,000 cubic feet of water per second. These releases had significant impact not only in the City of Tulsa but the surrounding communities as well.

During the 2019 event, the levee system operated as designed. The levees had a heavy load on them and several sand boils were reported. The USACE began monitoring the situation at 50,000 cfs and continued to work with local, state, and federal partners to repair any issues that arose.

Oologah Dam is about 30 miles northwest of Tulsa, near Rogers County, Oklahoma, and is on the Verdigris River. Because of the significant rainfall the Tulsa area experienced in 2019, the Corps of Engineers had to open the spillway gates to release water because the lake level had gotten too high to be released through the outlet works at the dam. On May 27, 2019 Tulsa District was releasing 65,000 cubic feet per second, or 455,500 gallons per second, from the dam and the auxiliary spillway.

4.4.5 Probability of Future Events

Overall Probability Rating of Dam Failure based on Classifications in Chart 1: Occasional, 1 to 10 percent probability of occurrence in the next year or a recurrence interval of 11 to 100 years.

Keystone Dam: The USACE believes there is a low probability that Keystone Dam would fail, because it is operated by the USACE and inspected at least once each year. The age of Keystone Dam is another issue of concern for Tulsa. When Keystone was built in 1964, the USACE estimated it would have a 50-year useful life. In addition, a great deal of silt has collected upstream from the dam, including in the flood pool. The Keystone flood pool filled completely in 1974 and 1986. In 2016 the flood pool was within 1.4 feet of filling the flood pool. In 2019 Keystone went into surcharge for the first time since 1993.

Even though a dam break is unlikely, there is a high probability that the USACE will once again be forced to make flooding releases from the dam. Even without a breach of the dam, forced releases of flooding from Keystone Dam, such as occurred in 1986 and 2019, could cause extensive property damage and disruption, as well as safety risks. The USACE and City of Tulsa have studied and mapped the areas that would be inundated from various releases ranging from 100,000 cfs through 450,000 cfs from the Keystone reservoir. Keystone Dam's maximum discharge could be as much as 939,000 cfs. A 1% (100-year) discharge is estimated at 270,000 cfs.

Skiatook and Oologah Dams: There is a low probability of failure of either of these dams, again because they are operated by the USACE and inspected at least once each year.

Lynn Lane Reservoir: There is a low probability of failure of this dam. The 2021 Dam Inspection Report showed that all aspects of the dam are "Satisfactory - No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines."

Yahola Reservoir: There is a low probability of failure of this dam. The 2021 Dam Inspection Report showed that the "General Conditions of Dam" are "Fair – No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety defi-

ciency. Risk may be in the range to take further action."

Warrenton Reservoir Dam: There is a moderate probability of failure of this dam. The 2021 Dam Inspection Report showed that the "General Conditions of Dam" are "Fair – No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action."

Overall Probability Rating of Levee Failure based on Classifications in Chart 1: Likely, 10 to 90 percent probability of occurrence in the next year or a recurrence interval of 1 to 10 years.

Tulsa West Tulsa Levees A and B are considered to be Very High Risk by the United States Army Corps of Engineers as determined by a risk assessment finalized in December 2016. This is because of: 1) levee overtopping is highly likely; 2) levee erosion and breach is expected during overtopping; and 3) rapid and deep flooding will cause extensive property destruction and loss of life. Tulsa West Tulsa Levee C is considered to be High Risk as determined by a risk assessment finalized in January 2017. This is because of: 1) levee overtopping is highly likely; 2) levee erosion and breach is expected during overtopping; and 3) rapid and deep flooding will cause significant property destruction and loss of life. The peak release rate during the 1986 flood of 305,000 cfs was less than one third of the design maximum release rate possible from Keystone Dam (939,000 cfs).

4.4.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: High, the event is likely/highly likely to occur with severe strength over a significant to extensive portion of the planning area.

People

People downstream of dams or in the area protected by a dam or the Tulsa West Tulsa Levee system could be subject to devastating danger and damage in the event of failure. The number of fatalities or injuries resulting from either hazard is strongly influenced by the number of people occupying the inundation area, the amount of warning they are provided, and the amount of pre-event public education and planning. People who might be at risk include those who are living, working, at school or play, or traveling through vulnerable areas. Tulsans are generally unaware of their risk to Dam or Levee overtopping. For example, a recent survey of the public living behind the Levee revealed some residents were unaware of their proximity or risk. Another example, Warrenton Dam is a high hazard dam and would inundate a busy intersection, and homes below the dam, with several feet of water. A breach of Warrenton Dam would have nearly zero warning time. The general public living below this dam, and others, are unaware of their risk.

The total number of people vulnerable to a maximum failure of Keystone, Oologah, and Skiatook Dams is accessible in the USACE Consequence Assessment Reports for each dam. The information is not available for public dissemination. Anyone in the inundation areas identified in the maps displayer earlier in this section are at risk of the impacts described herein.

Lynn Lane Reservoir: A breach or break of the Lynn Lane Reservoir could potentially impact an estimated 57 residents in Tulsa. Areas subject to inundation from the reservoir are mainly rural with scattered residents and several businesses. Most of the area downstream of the Reservoir is occupied single-family houses on large lots and there are two large baseball/softball complexes sitting adjacent to the reservoir. Therefore, the risk associated with

this dam breach or break is highly dependent on the time of which it occurs. If the breach were to occur on a weeknight or on a weekend, the extent to which life could be lost would be higher, due to the nature of the land use and activities near the dam.

Yahola Dam: Areas subject to inundation from a breach are predominately in Mohawk Park, Mohawk Golf Course, and nearby open field and wooded areas. The risk associated with a failure of Yahola Reservoir is highly dependent on the time of which it occurs. Normally, there would be more people in the golf course and park exposed to a failure during a weekend day in the spring, summer, or fall. If the breach were to occur in the middle of the night or in the winter, the potential damage would be less, since fewer citizens would be using the park and associated facilities. There are no permanently habitable structures downstream of the Yahola Dam.

Warrenton Dam: A major flood caused by a sudden breach of the dam is estimated to inundate the homes of 189 residents, businesses, a portion of La Fortune Park & Golf Course (Tulsa County) and city streets. These homes and business are within the Southmont Estates, Southmont Estates Extension, Hidden Valley Estates, Park Plaza, and Warren Center East Amended subdivisions, primarily located along S. Irvington Ave. in Tulsa, beginning at 6565 and 6566 S. Irvington Ave. and progressing north on both sides of the street.

Tulsa West Tulsa Levee: An estimated 3,000 people occupy the areas behind the Arkansas River Levees B and C.

Levees A and B have some significant problems, as identified by the USACE, Tulsa District[1]. Levees A and B were designed to provide significant protection from Arkansas River flooding. However, the tie back levees only provide approximately 4% - 3.33% (25-year – 30-year) protection from tributary flooding.

The toe drains and relief wells along the levees are over 75 years old, clogged and collapsed. These features prevent water pressure buildup in levees that can cause sudden failure.

Many of the culverts are over 70 years old and have not been structurally evaluated. Many modifications (generally abandonment) have not been documented over the years. Levee failure results from seepage around leaking culverts. This happened in 1986 on the Tulsa/W. Tulsa levees.

The pump stations have no alternate power source in an emergency. Pumps and switching gears in the pump stations are 70 years old and need to be replaced. Tributary flooding can occur because the levees were constructed to protect against Arkansas River flooding only. Figure 4-22 shows the 1% and 0.2% floodplains with Levee B overtopping from two locations from Harlow Creek, as well as interior flooding not related to the Arkansas River.

According to the U.S. Global Change Research Program, climate change could contribute to the failure of levees and dams in the future. As climate conditions continue to change, rare events such as 100-year floods (those that currently have a 1% chance of occurring in any given year) are likely to become more common. Future extremes may exacerbate flooding and wear and tear on existing flood control infrastructure and will necessitate revisions to design standards for flood infrastructure and a reevaluation of floodplains.

Economy

The most devastating economic event for Tulsa

1 From an OFMA presentation by Jaime Watts, USACE, September 15, 2014, entitled "Tulsa/West Tulsa Levees – Finding Shared Solutions"

would be failure of Keystone Dam. It is estimated total loss from the dam, downstream to Muskogee, would reach $9 billion. Failure of Oologah Lake Dam would affect a very small portion of Tulsa. It is assumed that about 1% of all losses would be attributable to the City of Tulsa, or approximately $4,703,000. Failure of Skiatook Dam was evaluated to a point about 180 miles downstream, with a total direct loss of $905,120,000. Only a portion of these losses would be within the City of Tulsa.

If a catastrophic levee failure occurs, economic consequences could include the loss of a major refinery and an electric power generating station.

Estimated economic losses for the other high hazard dams included in this risk assessment were not available at the time of this plan update. If this type of assessment is completed within the plan maintenance period, economic losses for those dams will be included in the next update.

Built Environment

Existing Structures: 2023 building footprint data was used to identify the number of structures located in the inundation area of High-Hazard dams in the Tulsa area. County assessor data was used to determine total estimated market value. A summary of this information is included in Table 4-9.

If the levee system were to fail to protect properties due to 1) planned releases from Keystone Dam in excess of the levee design protection, 2) from Keystone Dam failure, or 3) from flooding from internal sources, such as Harlow, Parkview, or Oak creeks, the damage to the City and County would be catastrophic. Infrastructure protected by the levee is valued at $4.8 billion; over 15,000 buildings, with an estimated value of $4.8 billion, are located in the area protected by the levee.

Infrastructure: Most significant impact to Tulsa's water treatment facilities during a dam or levee failure would be from loss of access to the facilities and loss of electrical power. Flooding in the watershed could impact water quality in the lakes that supply the city's water system. The impacts could range from minor to significant, depending on the nature of the flooding, pollutants released to the watershed and their location, and the impact on the City's intakes. Deposition of sediments, nutrients, and other contaminants by flooding can have a long-term effect on the City's water supply lakes. Wastewater treatment plants along the Arkansas River would be inundated by a dam failure

Table 4-9: Estimated Structure Count; Dam Inundation

DAM NAME	NUMBER	EST. MARKET VALUE
Heyburn Dam	1,127	$530,347,920
Keystone Dam	15,130	$4,890,568,041
Lynn Lake Dam	15	$1,706,775
Oologah Dam	91	$86,666,255
Skiatook Dam	330	$80,969,251
Warrenton Dam	93	$27,005,064
Yahola Lake Dam	3	$403,917
Total	**16,789**	**$5,617,667,223**

event, potentially releasing raw and treated wastewater into the Arkansas River.

Although the PSO electric plant that supplies the city is located on the west bank of the Arkansas River, the plant has a mitigation plan in place in the event of river flooding. The largest threat to the delivery of electrical service would be the destruction/damage of power poles/lines in the inundated areas. Gas-transmission pipelines could be breached both through trees being uprooted, affecting the lines, and ground being washed out, exposing the pipelines to damage.

Failure of Keystone Dam would affect Interstate 244, a major interstate highway, and the 21st Street Bridge, a major crossing over the Arkansas River, connecting West Tulsa to the rest of the city. The Cherokee Yard, a major intermodal regional transportation hub for the BNSF Corporation, and the railroad bridge at 11th Street would also be impacted by the failure. Failure of Skiatook Dam would inundate parts of US 75 and US 169 and State Highway 266. Failure of the Lynn Lane Reservoir would approach but would be unlikely to impact Interstate 44.

Fire, Police, and Medical Services would all be similarly at risk to effects of a dam or levee event. Emergency responders would be extremely taxed. With loss of vital utilities, emergency services would be heavily impacted. As with flooding, a dam or levee failure would create a larger call load for all emergency response agencies, presenting various challenges to the agencies, in addition to the posed hazards to emergency personnel performing these services. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

The failure of the Eucha, Oologah, or Spavinaw dams could have long-term impacts on the city's water supply. The city is reliant on these dams to meet current and future water demands.

Critical Facilities: There are 88 critical facilities located in the inundation area of Keystone Lake Dam. The failure may severely impact essential services or critical functions provided by these facilities. Few critical facilities would be affected by failure of other dams profiled in this plan. There are 27 critical facilities located in the inundation areas of the Arkansas River Levees. The Sun Oil Refinery, which could also be considered a critical facility, is also located behind the levees on the west side of the Arkansas River.

Cultural Resources: There are several cultural resources in Tulsa that would be affected by a dam or levee failure. Even high releases of Keystone Lake Dam would inundate parts of The Gathering Place and Southern Hills Country Club. Mohawk Park and Mohawk Golf Course are subject to inundation from Yahola Lake Dam.

Future Development: Given the inherent dangers along a river that drains nearly 75,000 square miles of land area, the future hazards along the Arkansas River will be determined by the balance of development and management that the community chooses. Various planning exercises offer possibilities for redefining local commitment to economic development, resource preservation, and hazard management along the river. Future development in the inundation area of dams addressed in this plan face the same risks as existing structures. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

Natural Environment: If Keystone Dam failed, the resulting release would devastate downstream habitat on the Arkansas River. Additional environmental consequences could result if the levee breached and resulted in

refinery products spilling into Arkansas River.

4.4.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Tulsans rely on warning sirens as primary source of weather notifications.	Educate the public on purpose of outdoor warning sirens and promote NOAA weather radios.	30, 31
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8
Multiple jurisdictions have authority for response and recovery during and after a flood, dam, or levee event in the Arkansas River Corridor.	The City of Tulsa should partner with neighboring jurisdictions and stakeholders, including state, tribal, and federal partners to develop a comprehensive response and recovery plan for the Arkansas River.	20
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Apply for HMGP funds and build to higher standards in future recovery efforts. CDBG can match HMGP.	2
Some areas of Tulsa appear to be out of range of an outdoor warning siren.	Install, update, and maintain warning sirens.	30
Tulsans are generally unaware of their risk to Dam or Levee overtopping. For example, a recent survey of the public living behind the Levee revealed some residents were unaware of their proximity or risk.	Educate the public of risks associated with living downstream of a dam or behind a levee.	1, 18
Failure of the Tulsa Levee System would flood many homes and businesses. As of August 2018, the USACE is studying the problem.	Tulsa should consider applying for FEMA HMA assistance if a viable solution to mitigate risk is found. Tulsa should implement recommendations of the USACE Study.	17

4.5 Extreme Heat

4.5.1 Hazard Description

Extreme heat is marked by unusual hot weather (maximum, minimum, daily average) over a region persisting for at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds (WMO 2015). Note: There is no universally recognized metric for what constitutes a heat extreme. The World Meteorological Organization recommends characterizing a heat wave by its magnitude, duration, severity, and extent.

4.5.2 Location

Tulsa is located in an area known for its hot, humid summers, with temperatures often reaching above 100°F for extended periods. Due to its location, extreme heat is a hazard that impacts the entire planning area.

4.5.3 Extent

The Wetbulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account temperature, humidity, wind speed, sun angle and cloud cover. This differs from the heat index, which takes into consideration temperature and humidity and is calculated for shady areas. Military agencies, OSHA and many nations use the WBGT as a guide to managing workload in direct sunlight. Figure 4-24 provides the impacts on the human body according to WBGT zone and recommended actions to manage heat.

Air temperature ranges from 80 to 110 degrees Fahrenheit, while relative humidity ranges from 40 to 100 percent. According to the State Climate Extremes Committee, Tulsa has experienced 115-degree temperatures in the month of August. Vulnerable populations are most impacted by extreme heat, as discussed in Section 4.5.6.

4.5.4 Previous Occurrences

The average high temperature for July and August in the City of Tulsa is 93.5 degrees Fahrenheit and high humidity levels, often putting the area in the "High" caution zone of WBGT. When temperature and humidity rise higher, as they often do in July and August, conditions can reach the "Extreme" category.

According to the NCEI Storm Events Database, 55 separate extreme heat incidents were reported for the City of Tulsa in the reporting period 1998 through 2023, a frequency of about two extreme heat events every year. The reported events caused 11 deaths and 1,141 injuries. Summaries of most notable events are included below, Table 4-9.

Figure 4-24: Wetbulb Globe Temperature and Heat Disorders Table

RISK	IMPACTS	ACTIONS
LOW (80-85)	Body stressed after 45 minutes	At least 15 minutes of breaks for each hour of work in direct sun.
MODERATE (85-88)	Body stressed after 30 minutes, heat cramps possible	At least 30 minutes of breaks for each hour of work in direct sun
HIGH (88-90)	Body stressed after 20 minutes, heat exhaustion possible	At least 40 minutes of breaks for each hour of work in direct sun
EXTREME (>90)	Body stressed after 15 minutes, heat stroke possible	Suspend all strenuous outdoor activities

4.5.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Highly Likely, 90 to 100 percent probability of occurrence in the next year or a recurrence interval of less than 1 year.

The City of Tulsa should expect extreme heat events on an annual basis.

Climate change will also influence future extreme heat events. According to the U.S. Global Change Research Program, the Southern Great Plains has experienced an increase in annual average temperature of one to two degrees Fahrenheit since the early 20th century. Climate change is expected to lead to an increase in average temperatures as well as frequency, duration, and intensity of extreme heat events. Extreme heat will become more common. By late in the 21st century, if no reductions in emissions take place, the region is projected to experience an additional 30–60 days per year above 100 degrees Fahrenheit than it does now.

4.5.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Medium: The event's impacts on the planning area are noticeable but not devastating.

People

From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67 percent, from 401,190 to 411,894.

Extreme heat can take its toll on all people in Tulsa, and even the most physically fit individuals can succumb to heat effects. However, certain segments of the population are at higher risk. These populations include the following:

- Individuals 65 years and older
- Children under five years old, especially infants
- Socially isolated individuals
- Mentally & mobility challenged individuals
- Obese individuals
- Individuals under the influence of alcohol or medications
- Individuals and families living below the poverty line
- Outdoor workers

Of particular concern are individuals over the

Table 4-9: Extreme Heat Event Narratives

DATE	EVENT NARRATIVE
Aug 6-12, 2007	The combination of hot temperatures and high humidity resulted in daytime heat index values from 105 to 113 degrees across much of eastern Oklahoma. Overnight temperatures remained above 75 degrees, which didn't allow much relief from the heat. Two men died in Tulsa as a direct result of the heat; both men were 65 years of age or older. EMSA treated two hundred other people in Tulsa for heat-related illnesses. Many of those victims were in attendance at the PGA Championship.
July 9-Aug 1, 2011	High temperatures climbed to above 100 degrees on all but two days during the remainder of the month at the Tulsa International Airport, and July 2011 went down as the second warmest July on record for that area since records began in 1905. Three senior citizens died in their homes as a result of the excessive heat. Nearly three hundred other individuals were injured.

Periods of excessive heat have occurred on an annual basis since 2011 but have not caused nearly the number of deaths or injuries as the events in 2007 and 2011.

age of 65 and below the poverty line. These are at the highest risk of loss of life due to extreme heat conditions. In the City of Tulsa, men aged 45 to 65 years of age account for the highest number of Tulsa Emergency Management Services Agency (EMSA) transports due to heat-related illness each year. Though this demographic accounts for a high number of transports, many can walk away unscathed after treatment. Elderly populations account for less EMSA transport but are less likely to recover once they have succumbed to the impact of extreme heat.

Urban residents, such as Tulsans, face unique heat-related risks due to the Urban Heat Island effect. Temperatures typically rise from the outer edges of the city and peak in the center. This phenomenon can have a significant health impact in urbanized areas. On sunny days during the summer, sunlight can heat dry and exposed urban surfaces, such as pavements and buildings, causing urban regions to become much warmer than their rural surroundings. As a result, an "island" of higher temperatures is formed in the landscape.

Economy

The biggest impact on the economy is the human toll associated with heat-related mortality and illness. Worker productivity decreases during heat waves. The slowdown is particularly acute in outdoor industries such as construction.

Built Environment

Existing Structures: Buildings are vulnerable to extreme heat in a limited way, such as in damage from expansive soils (see Section 4.13, Expansive Soils).

Infrastructure: High temperatures directly affect Tulsa's infrastructure. Flight cancellations, deteriorating roads and rail lines, and energy demands are among the impacts.

During extreme heat, AEP/PSO could experience any combination of the following challenges in meeting the needs of the Tulsa jurisdiction: Failure of vital delivery components due to exposure to high heat and excessive/simultaneous demand of supply, or insufficient field and office staff to effectively handle the workload.

Critical Facilities: Critical Facilities face the same issues as other structures and buildings above. In addition, a great many city facilities, such as City of Tulsa recreation centers, may be designated as cooling centers for vulnerable neighborhoods. As such, these facilities need to include this ability in their plans.

The many outdoor recreation areas in Tulsa are vulnerable to the effects of high temperatures. Community icons like Southern Hills Country Club, The Gathering Place, Philbrook, and Tulsa Botanical Gardens may be affected if water rationing is required.

Future Development: Urban planning and design that incorporates more trees and parks, white roofs and alternative materials for urban infrastructure can help reduce the effects of urban heat islands. The City of Tulsa has over 33,000 Tree Canopy Acres according to the 2016 Tulsa County Urban Tree Canopy Report. The report includes consideration of site design and environmental factors to prioritize planting sites on both public and private property with the highest potential for return on investment, as young trees mature and provide substantial stormwater, heat island, and environmental benefits. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

Natural Environment: Extreme heat causes concern for the agricultural community due to crop loss. High temperatures and dry air can lead to heat stress in trees.

4.5.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
During periods of extreme heat and drought, the City of Tulsa experiences water line breaks due to expansive soils.	Tulsa should replace broken pipes in areas of high soil expansion, with piping more resistant to breakage.	28
Extreme heat can cause power disruptions due to high energy demands. Essential facilities in Tulsa need back-up generators.	Tulsa should assess the need for generators at critical facilities and implement as funding becomes available	13,14
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	29

4.6 Fire

4.6.1 Hazard Description

Wildfire: A wildfire is any outdoor fire that is not controlled, supervised, or arranged. Wildfire probability depends on: local weather conditions; outdoor activities such as camping, debris burning, and construction; and the degree of public cooperation with fire prevention measures. Wildfires can result in widespread damage to property and loss of life. Wildfire vulnerability is found chiefly in wildland-urban interface (WUI) areas. Generally speaking, WUI refers to the zone of transition between unoccupied land and human development. It is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. To determine the WUI, structures per acre and population per square mile are used. The WUI in the area is divided into two categories: intermix and interface. Intermix areas have more than one house per 40 acres and have more than 50 percent vegetation. Interface areas have more than one house per 40 acres, have less than 50 percent vegetation, and are within 1.5 miles of an area over 1,235 acres that is more than 75 percent vegetated (Stewart et al., 2006).

Structure Fire: A structure fire is one that burns a home or other improved structure. Fire generates a black, impenetrable smoke that blocks vision and stings the eyes, making it often impossible to navigate through or evacuate a building on fire.

4.6.2 Location

All structures in Tulsa have some level of risk to the fire hazard. There are some factors that affect the risk of a fire occurring in a given location. Average age of structures, type of construction, and location relative to fire stations and open woods or grassland can all influence the likelihood or extent of damage of structure fires.

Wildfire vulnerability in Tulsa is located largely on the periphery of north Tulsa, rural area of east Tulsa into Wagoner County, and heavily wooded areas of Turkey Mountain, just west of the Arkansas River. Areas of greatest concern and historical occurrence, as identified by the Tulsa Fire Department during this planning process, are identified in Figure 4-26.

Area 1 Wildfire is a concern in this area because of development intermixed with heavy and unmaintained fuels. Additionally, the longest

response times for the TFD are located in east Tulsa.

Area 2 Station 12 coverage area stops at 41st West Avenue, where it meets the Berryhill Fire Protection District. Station 12 commonly responds to the west city limits of Tulsa, which is fenced at 57th West Avenue. This area is a mostly rural, residential area and includes Rice Hill, a residential area little known to most of Tulsa but significant to the Tulsa Fire Department. Rice Hill is one of very few areas in Tulsa without water mains, where most homeowners have potable water delivered to personally owned tanks.

Area 3, the Turkey Mountain Urban Wilderness area, is a 300-acre wilderness area with over 20 miles of trails where 15-20 times per year hikers or bicyclists become injured and require a search and rescue effort to rescue them. It has also been the scene of prolonged wildfires. The area is covered by TFD Station 3.

According to a representative from the Tulsa Fire Department, the northwest corner of Tulsa experiences the highest concentration of structural fires in a given year.

4.6.3 Extent

There are several tools available to estimate fire potential, extent, danger, and growth, including, but not limited to, the following: the Keetch-Byram Drought Index (KDBI), the Fire Danger Rating System, and the Burning Index (BI). The Keetch-Byram Index relates weather conditions to potential or expected fire behavior, using numbers from 0 to 800 to represent the amount of moisture that is present in soil and vegetation.

The Fire Danger Rating System, Figure 4-25, combines the combustibility of vegetation and weather conditions to derive the easily understood Green-Blue-Yellow-Orange-Red fire danger alerts. Tulsa may experience days of extreme fire danger on the Fire Danger Rating System and other days without any wildfire risk.. There is no scientific scale to measure the extent of a structural fire, however Tulsa may experience fires that cause total loss of a structure and contents. The most devastating events are those that cause loss of life.

According to the U.S. Global Change Research Program, periods of abundant precipitation followed by drought and high temperatures are linked to increased wildfire activity in the region. Model simulations indicate that wildfire risk will increase throughout the region as temperatures rise, particularly in the summer, and the duration of the fire season will increase.

4.6.4 Previous Occurrences

Since the previous plan was approved, structure fires have continued to occur on an annual basis. According to the Tulsa Fire Department, while fires nationwide have shown a downward trend since the urban renewal days (1960s through the early 1980s), the Tulsa Fire Department is still a very active structural firefighting department. Wildfire events are more rare. Since 2000, Tulsa has experienced three major wildfire events, as described in Table 4-11.

Figure 4-25: Fire Danger Rating System

Figure 4-26: Wildfire Areas of Concern

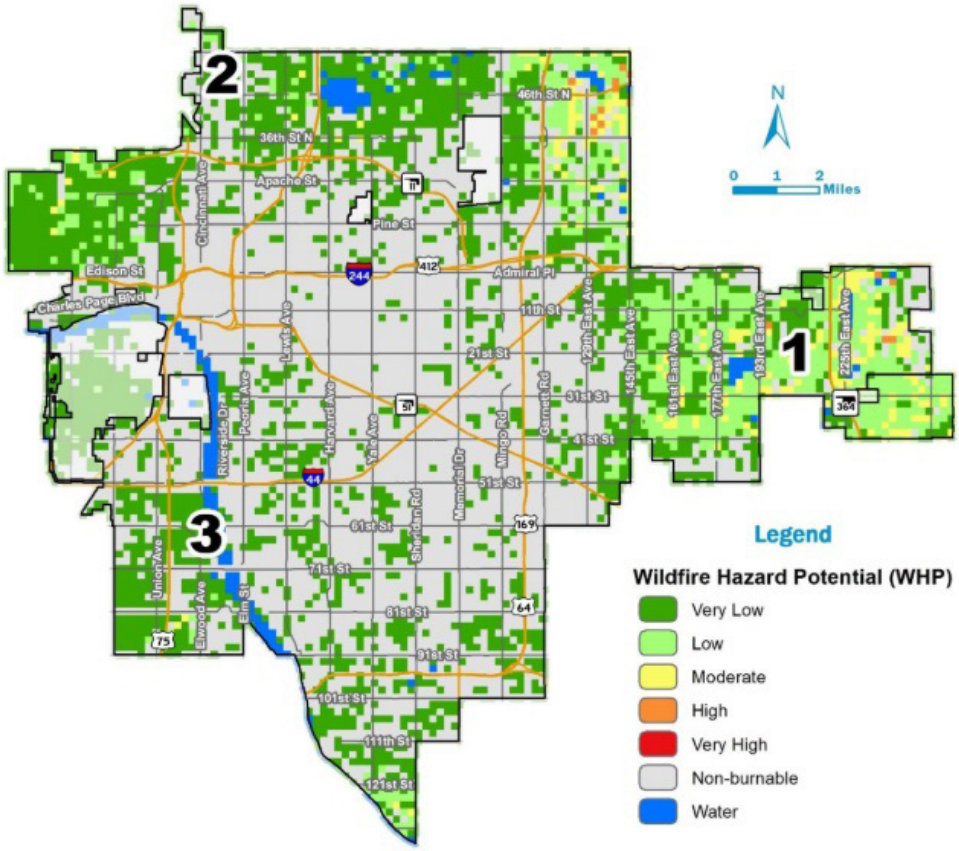
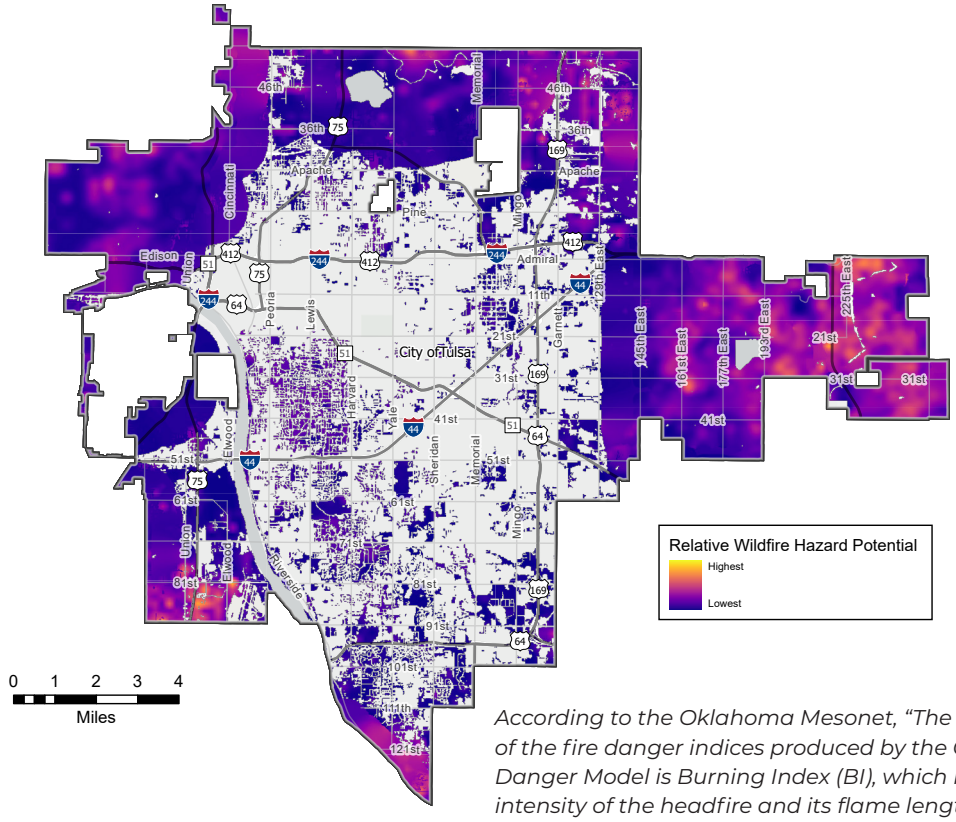


Figure 4-27: Wildfire Hazard Potential



According to the Oklahoma Mesonet, "The most important of the fire danger indices produced by the Oklahoma Fire Danger Model is Burning Index (BI), which relates to the intensity of the headfire and its flame length.

Figure 4-28: Oklahoma Fire Danger Model Burning Index
A general interpretation of fire danger based on Burning Index is as follows:

80-110 BURNING INDEX (>1BI)	FLAME LENGTH	FIRE DANGER
<20	<2 FEET	LOW
20-40	2-4 FEET	MODERATE
40-80	4-8 FEET	HIGH
80-110	8-11 FEET	SEVERE
>110	>11 FEET	EXTREME

Besides being a function of weather and dead fuel moisture, BI is also strongly influenced by the type, amount, and greenness levels of the native surface fuels being modeled."

Table 4-10: Fire Danger Rating System

FIRE DANGER RATING AND COLOR CODE	DESCRIPTION
LOW (L) (DARK GREEN)	Fuels do not ignite readily from small firebrands although a more intense heat source, such as lightning, may start fires in duff or punky wood. Fires in open cured grasslands may burn freely a few hours after rain, but woods fires spread slowly by creeping or smoldering, and burn in irregular fingers. There is little danger of spotting.
MODERATE (M) (LIGHT GREEN OR BLUE)	Fires can start from most accidental causes, but with the exception of lightning fires in some areas, the number of starts is generally low. Fires in open cured grasslands will burn briskly and spread rapidly on windy days. Timber fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel, especially draped fuel, may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
HIGH (H) (YELLOW)	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High-intensity burning may develop on slopes or in concentrations of fine fuels. Fires may become serious and their control difficult unless they are attacked successfully while small.
VERY HIGH (VH) (ORANGE)	Fires start easily from all causes and, immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high-intensity characteristics such as long-distance spotting and fire whirlwinds when they burn into heavier fuels.
EXTREME (E) (RED)	Fires start quickly, spread furiously, and burn intensely. All fires are potentially serious. Development into high-intensity burning will usually be faster and occur from smaller fires than in the very high fire danger class. Direct attack is rarely possible and may be dangerous except immediately after ignition. Fires that develop headway in heavy slash (trunks, branches, and tree tops) or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions, the only effective and safe control action is on the flanks until the weather changes or the fuel supply lessens.

Table 4-11: Wildfire Event Narratives

The most notable wildfire affecting the City of Tulsa in recent history remains the Turley fire of August 2011. Other fires have affected various areas of Tulsa County, but not within Tulsa city limits. Narratives for all notable wildfire events from 2000 to 2023 are included below.

DATE	EVENT NARRATIVE
Nov 2005-Apr 2006	Wildfires impacted areas in and around Tulsa County and the City of Tulsa. In neighboring Creek County, the Depew Fire Complex burned for than a thousand acres and threatened 1,450 homes in Bristow. The Wainwright Fire Complex in nearby Muskogee County burned more than 4,000 acres and threatened nearly 12,000 homes in the Town of Muskogee. The Shamrock Fire Complex in Creek County threatened more than 300 homes in Drumright and Shamrock, OK. More than 6,500 homes near Kellyville were threatened as a result of the Sapulpa Fire Complex in Creek County, which burned over 800 acres. The Prague Fire Complex in Lincoln and Okfuskee Counties burned more than 640 acres and threatened 2,650 homes in eight communities.
August 2011-Turley	On August 2, 2011, very dry, hot, and breezy conditions, along with extremely dry fuels as a result of long-term drought, promoted the rapid spread of wildfire just outside of Tulsa city limits near Turley, OK. The fire burned from 56th St. N. to 66th St. N., and from Lewis Ave. to Peoria Ave. Losses from the fire were assessed at $491,200. The total included five total loss homes, eight damaged homes, loss of three mobile homes, eleven storage sheds, two barns, one plane hangar, 10 vehicles, one dump truck and $37,000 in miscellaneous losses.
May 2017-Tulsa County	Two wildfires burned in Tulsa and Creek County coming dangerously close to several homes. Keystone firefighters responded to a Tulsa County grass fire near 225th West Avenue and Highway 51, between Mannford and Sand Springs. Crews were initially concerned because there were some structures nearby, but firefighters said they were able to contain the fire without any losses.

4.6.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Highly Likely, 90 to 100 percent probability of occurrence in the next year or a recurrence interval of less than 1 year.

The Tulsa Fire Department currently responds to over 57,000 incidents annually. (Approximately 33,000 are EMS related). While structural fires occur on an annual basis, wildfires are less frequent. It is not likely Tulsa will experience wildfires on an annual basis, but at least one wildfire event is expected during the 5-year plan maintenance period.

The U.S. Global Change Research Program predicts periods of abundant precipitation followed by drought and high temperatures will increase wildfire activity in the region. Their model simulations show that wildfire risk will increase throughout the region as temperatures rise, particularly in the summer, and the duration of the fire season will increase.

4.6.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Medium: The event's impacts on the planning area are noticeable but not devastating.

The area of Tulsa most at risk of wildfire damage is in the vicinity of S. Union Ave. and W. 81st St. S. This area is mostly rural with few vulnerable homes or businesses. Development is not active in this part of the city, vulnerability is not expected to increase.

People

From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67

percent, from, 401,190 to 411,894. People residing in structures located in areas of wildfire concern have the most exposure to loss of life and property as a result of a wildfire. Tulsa Fire Department (TFD) employs public education officers who present educational programs to citizens across the community in schools, churches, day cares, and other businesses about general safety and fire prevention. This service is a proactive program helping citizens of all ages learn how to keep themselves and their community safer. TFD public education officers also plan and direct smoke detector installation events, the juvenile fire-setter intervention program, and all-hazard community risk reduction programs.

Economy

Economic impacts of wildfires include the more obvious variables, such as acreage burned and number of lost personnel. The economic impact depends on the level of event. Tulsa has not, and likely will not, experience a catastrophic wildfire. Economic losses from wildfires are expected to remain low.

Built Environment

Existing Structures: Tulsa, unlike many newer and smaller cities surrounding it, has significant risk due to older buildings and densely concentrated businesses and residences that were built prior to modern life safety measures. Due to age and other factors, it's not safe to assume that every building in Tulsa meets modern fire codes and that every high-rise has automatic fire sprinklers.

Infrastructure: Fires have the potential to impact community infrastructure, including highways, communication facilities, power lines, and water delivery systems.

Critical Facilities: None of Tulsa's critical facilities are located in wildfire areas of concern.

Cultural Resources: None of Tulsa's cultural resources, such as historic neighborhoods or structures, are in wildfire areas of concern.

Future Development: The Tulsa Fire Depart-

4.6.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Tulsans rely on warning sirens as primary source of weather notifications.	Educate the public on purpose of outdoor warning sirens and promote NOAA weather radios.	30, 31
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8
Tulsa Fire Department identified Turkey Mountain, a heavily forested area, as a wildfire area of concern. There is limited access for emergency responders on Turkey Mountain.	Determine what actions can be taken, if any, to reduce the risk to wildland fires in this area. Implement actions requested by the Tulsa Fire Department to lessen response times.	39
East Tulsa has higher ISO ratings and an increased wildfire concern. Higher ISO ratings are because of longer response times in this area of Tulsa.	A new fire station is planned in this area of Tulsa.	42

ment provides fire code enforcement for the City of Tulsa. Code enforcement personnel ensure that public and private buildings meet or exceed current nationally recognized and legal fire codes. The department works with the City of Tulsa and community business owners to ensure proper fire safety is provided throughout Tulsa. The department's code enforcement efforts are a critical element in the success of fire prevention programs. Almost every aspect of a thorough fire prevention program is affected by code enforcement in some way. It plays a major role in fire and life safety inspections, plans review, hazardous materials, code adoption, environmental investigations, and the issuance of fire prevention code permits. Since the last plan update in 2019, no changes in development patterns have affected Tulsa's overall vulnerability.

Natural Environment: Fire is a vital ecological process. Wildfires revitalize watersheds and renew soil when allowed to burn in areas where development is not impacted.

4.7 Hailstorm

4.7.1 Hazard Description

A hailstorm is an outgrowth of a severe thunderstorm in which balls or irregularly shaped lumps of ice fall with rain. Hail is formed in thunderstorms when the updraft is strong enough to hold freezing masses of water above the freezing level. Extreme temperature changes from the ground upward into the jet stream produce strong updraft winds that cause hail formation. Strong winds aloft

Table 4-12: Combined NOAA/TORRO Hailstorm Intensity Scales

SIZE CODE	INTENSITY CATEGORY	TYPICAL DIAMETER (INCHES)	APPROXIMATE SIZE	TYPICAL DAMAGE IMPACTS
H0	Hard Hail	up to 0.33	Pea	No damage
H1	Potentially Damaging	0.33-0.60	Marble or Mothball	Slight damage to plants, crops
H2	Potentially Damaging	0.60-0.80	Dime or grape	Significant damage to fruit, crops, vegetation
H3	Severe	0.80-1.20	Nickel to Quarter	Severe damage to fruit & crops, damage to glass & plastic structures, paint & wood scored
H4	Severe	1.2-1.6	Half Dollar to Ping Pong Ball	Widespread glass damage, vehicle bodywork damage
H5	Destructive	1.6-2.0	Silver dollar to Golf Ball	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
H6	Destructive	2.0-2.4	Lime or Egg	Aircraft bodywork dented, brick walls pitted
H7	Very Destructive	2.4-3.0	Tennis ball	Severe roof damage, risk of serious injuries
H8	Very Destructive	3.0-3.5	Baseball to Orange	Severe damage to aircraft bodywork
H9	Super Hailstorms	3.5-4.0	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
H10	Super Hailstorms	4+	Softball & up	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open

promote the formation of larger stones, which increase in size until they are heavy enough to fall out of the updraft to the ground. Rotating thunderstorms, known as supercells, make the most significant hail. Hailstorms are usually considered "severe" when hail is larger than one inch in diameter or accompanied by winds greater than 58 miles per hour.

4.7.2 Location

The risk of this hazard is uniform over the planning area. Hailstorms are no more likely to occur in any specific area of the city versus another area.

4.7.3 Extent

As shown in the Combined NOAA/TORRO Hailstorm Intensity Scale, Table 4-12, hail is considered "destructive" when it reaches 1.6 inches in diameter, or golf ball size. Tulsa can experience the full range of this hazard and may experience hail exceeding 4 inches.

HISTORICAL HIGHLIGHTS

NOV 18, 2003

2.75 inches of hail fell in Tulsa. Baseball-sized hail was reported at 31st and Harvard and again at 21st and Harvard. The hail broke windows and damaged numerous roofs of buildings and cars. Damage was estimated at $20 million.

APR 5, 2005

Reports of golfball-sized or larger hail was common in a densely populated area of the county from Jenks to across the City of Tulsa. The largest hailstones reported were 3 inches in diameter. Many automobiles, homes, and businesses were damaged by the hailstorm. Damage was estimated at $65 million.

4.7.4 Previous Occurrences

According to the NCEI, the City of Tulsa reported 68 events with hail greater than 1.5 in diameter since 1998. Hailstones in Tulsa County ranged from 0.75 to 4.25 inches in diameter during this time, causing an estimated $91 million in damages. Two events since 1998 caused greater than $1 million in damages.

4.7.5 Probability of Future Events

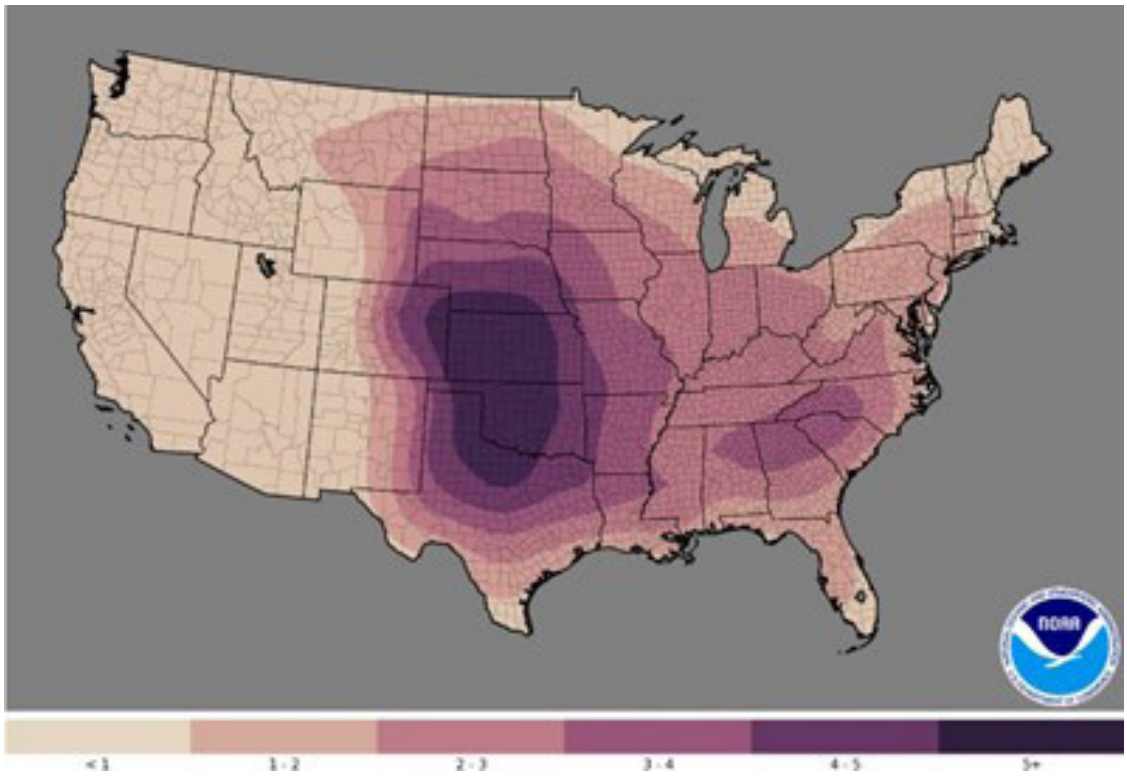
Overall Probability Rating based on Classifications in Chart 1: Highly Likely, 90 to 100 percent probability of occurrence in the next year or a recurrence interval of less than 1 year.

The map in Figure 4-30, provided by the NOAA/National Weather Service Storm Prediction Center, shows the average number of days per year in which severe hail reports were received in the Tulsa area during the period noted. Tulsa can expect to see severe hail, exceeding 1 inch in diameter, 4-5 times per year. According to the SCIPP Simple Planning Tool, "climate models project an increase in the frequency and intensity of severe thunderstorms, and events with large hail are projected to increase (Kossin et al. 2017). At the same time, models project an overall decrease in the number of days with hail per year (Brimelow et al. 2017). Confidence in the projections is currently low, however, due to the isolated and sporadic nature of hail events and limited comprehensive datasets which make it difficult to track long-term trends (Wuebbles et al. 2017a)."

4.7.6 Vulnerability and Risk Assessment

Overall significance based on classifications in Chart 1: Medium. The event's impacts on the planning area area noticeable but not devastating. The increasing unpredictability of weather patterns due to climate change could potentially alter this frequency and intensity in the future.

Figure 4-29: Mean Number of Hail > 1.00" Days per Year 1986-2015



Overall Significance based on Classifications in Chart 1: Medium: The event's impacts on the planning area are noticeable but not devastating.

People

All the population of Tulsa is exposed and at risk for experiencing this hazard. From the last plan update in 2019 to 2023, the City of Tulsa's population has grown 2.67 percent, from 401,190 to 411,894. Although not as common as structure and vehicle damage, personal injury can be caused by large hail driven by high winds. Baseball-sized hail falls at 100 mph. Those engaging in outdoor activities may find themselves in a situation where adequate shelter is unavailable and be seriously injured. All outdoor parks and recreation areas should be equipped with warning sirens to ensure sufficient time to seek refuge from hailstorms.

Low-income populations are less likely to be able to recover entirely from a destructive hailstorm. Resources, such as CDBG, should be available to help these populations recover as needed. Tulsa could also consider applying for a FEMA grant to mitigate residential properties from hail damages.

There has also been a noted shift towards infill development, where new growth occurs within existing urban areas (planitulsa, housing and neighborhoods). As a result, the population density in certain areas of Tulsa has increased, potentially heightening the impact of hailstorms on the community.

Economy

The economic impacts associated with this hazard are primarily agricultural-related and not applicable to Tulsa. Most losses to businesses are covered by insurance.

Built Environment

Existing Structures: All structures are exposed to this hazard. Hail damages occur on an

annual basis in Tulsa causing insured losses to residential and commercial properties and automobiles. Hail can cause bruises, punctures, and leaks on roofing systems. The amount of damage depends on the size of the hail and the age, material, and surface temperature at the time of the event. Substantial hail damage may result in the need for an entirely new roofing system. Large hail driven by high winds can break through windows, doors, and skylights that are not impact-resistant, allowing rainwater to enter buildings. When building a new home or replacing the roof, homeowners should consider using hail-resistive roofing products.

Infrastructure

Disruption of electric power, water treatment systems, gas service, or the local municipal authorities is not anticipated. Fire, Police and Medical Services would all be similarly at risk to the secondary effects of a hail event. Response vehicles in the open during a hail event would all face the same risk of damage, most likely to windows and windshields.

Critical Facilities: All critical facilities in Tulsa are exposed to this hazard. It is unlikely a hailstorm would render a building non-operational.

Cultural Resources

Large hail could cause significant impacts on properties listed on the National Register of Historic Places. The Tulsa Preservation Commission ensures proper design standards are met when required in the six historic overlay districts.

4.7.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Tulsans rely on warning sirens as primary source of weather notifications.	Educate the public on purpose of outdoor warning sirens and promote NOAA weather radios.	30
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8
Hail causes damage to all structure types on an annual basis.	Educate the public on the benefits of disaster-resistant construction.	1
The general public, and even insurance agents, are unaware of the benefits associated with disaster-resistant construction and discounts on insurance premiums.	Tulsa should work with the State Department of Insurance to educate the public on better building practices.	5
Though interest in building to IBHS Fortified Standards is increasing, there are few fortified inspectors in Oklahoma.	Tulsa should work with the State Department of Insurance, IBHA, and the HBA to train home builders on disaster-resistant construction techniques and encourage certification as fortified inspectors.	5
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Apply for HMGP funds and build to higher standards in future recovery efforts. CDBG can match HMGP.	2
Some areas of Tulsa appear to be out of range of an outdoor warning siren.	Install, update, and maintain warning sirens.	30

Future Development

The City of Tulsa adopted the ICC International Building Code, 2018, and the ICC International Residential Code for One- and Two-Family Dwellings, 2018 Edition. The City of Tulsa should incorporate disaster-resistant construction to increase the likelihood that homes, workplaces, and essential public buildings can survive a hailstorm. Tulsa should continue to work with the Oklahoma Insurance Department to educate both insurance agents and consumers of the discounts offered for building to higher standards.

Natural Environment

Large pieces of hail can damage branches and take down tree limbs. There are 40.7 trees per acre in Tulsa, a total tree population of 5.2 million[1]. A hailstorm could devastate the tree population.

4.8 Drought

4.8.1 Hazard Description

A drought is a period of unusually persistent dry weather that persists long enough to cause deficiencies in the water supply (surface or underground). Droughts are slow-onset hazards but, over time, they can severely affect crops, municipal water supplies, recreational resources, and wildlife. If drought conditions persist over many years, the direct and indirect economic impacts can be significant. High temperatures, high winds, and low humidity can worsen drought conditions and also make areas more susceptible to wildfire. In addition, human actions and demands for water resources can accelerate drought-related impacts. TMUA undertook a comprehensive analysis of their water system in 2011-2012 that includes CIP measures to expand the system to continue to meet projected demand through the life of this plan.

4.8.2 Location

Drought is a widespread hazard that affects the entire planning area. No areas of the city are more or less prone to drought than others. The risk of this hazard is uniform across the practice area.

4.8.3 Extent

The Palmer Drought Severity Index (PDSI) Figure 4-30, depicts prolonged periods of abnormal dryness or wetness. It is a standardized index that spans -10 (dry) to +10 (wet). Based on the Palmer Drought Index, Tulsa drought conditions can range from 4 to −4. This value is adjusted weekly through the Climate Prediction Center. As of May 2024, Tulsa was not experiencing a drought.

4.8.4 Previous Occurrences

The City of Tulsa experiences drought to some extent on an annual basis. Tulsa is fortunate to have a plentiful supply of good, reliable water that's available for ready use to residents and businesses. The last time Tulsa had mandatory water rationing from drought was in the 1980s. In more recent history, notable events include the following periods of drought in Table 4-13. Since 2000, Tulsa has experienced 64 total drought events.

4.8.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Highly Likely. Based on drought occurrences over the past 15 years, the City of Tulsa can expect to experience the effects of a severe drought cycle about every 5 to 10 years.

As global temperatures continue to rise, the region could experience more frequent and severe droughts. This assumption considers

1 The Complete Tulsa Urban Forest Master Plan, https://upwithtrees.org/Tulsa_UFMP_Final.pdf

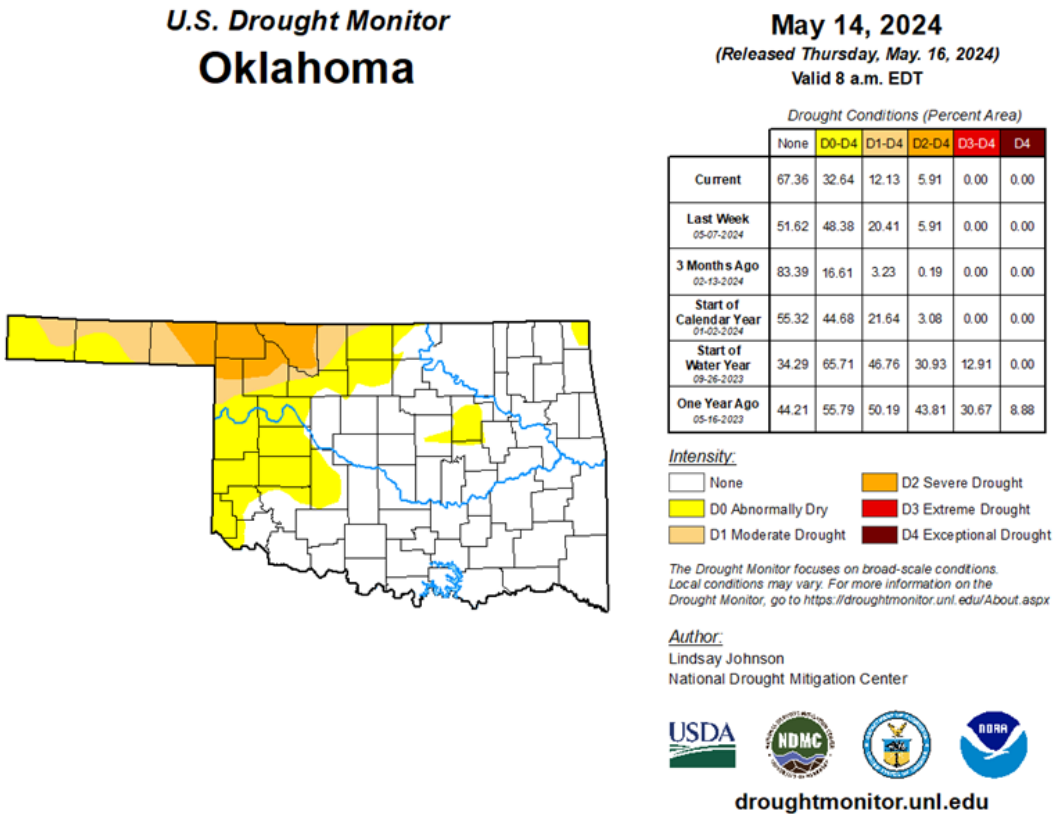
Figure 4-30: Palmer Drought Severity Index

-4.0 OR LESS	-3.0 TO -3.9	-2.0 TO -2.9	-1.9 TO +1.9	+2 TO +2.9	+3 TO +3.9
EXTREME DROUGHT	SEVERE DROUGHT	MODERATE DROUGHT	NEAR NORMAL	UNUSUAL MOIST SOIL	VERY MOIST SOIL

Table 4-13: Drought Event Narratives

DATE	EVENT NARRATIVE
Dec 2005-Apr 2006	In Tulsa, only 1.59 inches of precipitation fell during December, January, and February. The winter of 2005-2006 was the driest ever in Tulsa. On average, 5.36 inches of precipitation falls during the winter months in Tulsa County.
Jan 2011-Nov 2011	July 2011 was officially the hottest month on record locally and nationally. High temperatures were over 100° F for almost the entire month. The City of Tulsa restricted water use for the first time since the 1980s during this summer due to the high demand for water
Summer 2012	Scorching temperatures combined with a lack of measurable rainfall resulted in significantly worsening drought conditions across all of eastern Oklahoma during July. Much of northeastern Oklahoma received less than 25 percent of average precipitation. The USDA declared all counties in eastern Oklahoma disaster areas due to the drought. Monetary damage estimates resulting from the drought were not available. The City of Tulsa initiated voluntary water restrictions in the summer of 2012

Figure 4-31: Drought Monitor Conditions



several factors, including increased evaporation rates and changes in precipitation patterns (NIDIS). Droughts in Tulsa are likely to affect both urban and rural areas.

Additionally, changes in precipitation patterns, such as more intense but less frequent rainfall, can lead to prolonged dry periods. These shifts can result in more severe and frequent droughts, impacting agriculture, water supply, and overall ecosystem health (NIDIS).

4.8.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Low, the event has a minimal impact on the planning area.

People

All the population of Tulsa is exposed and at risk for experiencing this hazard. NOAA Weather Radios are one way to keep the general public informed of drought conditions.

Tulsa's drinking water comes from two sources: Lakes Spavinaw and Eucha on Spavinaw Creek and Lake Oologah on the Verdigris River. Lakes Spavinaw and Eucha are owned and operated by the City. Lake Oologah is operated by the U.S. Army Corps of Engineers. A third emergency source of water is available from Lake Hudson on Grand River. Water is treated at two treatment plants: Mohawk and A.B. Jewell.

At the time of this plan update, the water supply is adequate to meet the current needs in the City of Tulsa. There is no concern drought would cause lack of drinking water. One potential impact of drought in Tulsa, mentioned by Tulsa Ministerial Alliance, is the effect on rural communities surrounding Tulsa. During periods of drought, Tulsa sees an influx in the request for meals at shelters. Drought conditions can cause prices for food to increase because of a drop in supply. If people are not able to afford increasing prices during drought conditions, it is possible for them to suffer health problems because of the lack of healthy food. This is especially true in areas identified as having a high vulnerability in Tulsa based on their socio-economic status.

Urban expansion and higher population density put additional pressure on water supplies, making the city more vulnerable to drought. As more people move to urban areas, the demand for residential, industrial, and recreational water use rises, exacerbating the effects of drought. Moreover, population growth can lead to over-extraction of groundwater, further depleting water resources during dry periods (NIDIS).

Economy

According to the University of Nebraska's Drought Monitor, the primary impact currently to the Tulsa area is the effect on wheat production, although other factors listed above may come into play for individual homeowners and businesses.

Built Environment

Existing Structures: Drought's primary threat to structures within the City of Tulsa is from its contribution to the shrinkage of expansive soils. More information on this hazard is available in Section 4.10.

Agricultural lands, which are crucial for food production, may be converted to urban use, reducing the area's capacity to withstand drought impacts (Oklahoma State University)."

Infrastructure

During periods of drought the City of Tulsa experiences water line breaks.

Critical Facilities

Critical facilities in the City of Tulsa have no specific vulnerability to the Drought hazard other than from expansive soils.

4.8.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Though water supply is adequate, Tulsans should be prepared for future drought conditions.	WaterSense is a program sponsored by the U.S. Environmental Protection Agency (EPA), is both a label for water-efficient products and a resource for helping save water. Tulsa should implement aspects of the WaterSense program.	45
Tulsa has adequate water supply. Even in historic drought conditions, water restrictions remained voluntary. The population is projected to increase over the next 20 years.	Tulsa should continue to plan and implement plans for population growth and additional water supply needs.	45
Essential facilities in Tulsa need back-up generators. Nearly every hazard can cause power outages.	Tulsa should assess the need for generators at critical facilities and implement as funding becomes available.	6
Some areas of Tulsa are less equipped to prepare for or recover from hazard events.	Create community facilities (resilience hubs) that can serve as gathering places during emergencies and interruptions in services, and outfit such facilities with access to key services, including water, electricity for charging cell phones, etc. Such capabilities could be integrated into schools and other existing community facilities.	8

Cultural Resources

The primary threat to historic properties and cultural resources within the City of Tulsa lies in the effect of its contribution to the shrinkage of expansive soils.

Future Development

The 2012 TMUA comprehensive assessment recommends the following as Tulsa continues to develop:

Distribution Needs: The cumulative system upgrades relative to the current (2011) water distribution system required to meet the needs of the anticipated 2030 water system include: 10.9 miles of 72-inch waterline; 8.9 miles of 48-inch waterline; 13.3 miles of 24-inch waterline." Tulsa Utilities Comprehensive Assessment Executive Summary, August 2012.

Natural Environment

Drought has many negative effects on the natural environment. The effects of drought on the ecosystem are one Tulsa should be concerned with. Specifically, tree mortality, wind erosion, insect infestations, plant disease, and loss of migratory bird populations.

4.9 Expansive Soils, Subsidence and Erosion

4.9.1 Hazard Description

Soils and soft rock that tend to swell or shrink due to changes in moisture content are commonly known as expansive soils. Expansive soils are often referred to as swelling clays because clay materials attract and absorb water. Dry clays will increase in volume as water is absorbed and, conversely, decrease as they dry. Subsidence—sinking of the ground because of underground material movement—is most often caused by the removal of water, oil, natural gas, or mineral resources out of the ground by pumping, fracking, or mining activities. Soil erosion is the detachment and movement of soil particles by water wind, ice, or gravity. These movements lead to cracking and buck-

ling of the infrastructure built on such soils and result in billions of dollars of damage annually.

4.9.2 Location

Based on surveys of underlying soils, Figure 4-32 shows a generalized map of the areas of Tulsa where soils have low to very high expansive qualities. Generally, many Tulsa lowlands along the river and waterways have low shrink-swell soils. Many higher elevations have moderate to a high potential, including large areas of central and east Tulsa.

Subsidence: Not all parts of Tulsa would be equally susceptible; risk is higher in areas with significant groundwater extraction, such as those used for agricultural or industrial purposes (USGS). Additionally, regions with karst topography, where soluble rocks like limestone are present, can experience more sudden subsidence events (USGS).

Erosion: Erosion is a more widespread issue in Tulsa, particularly in areas where soil is exposed to water, wind, or ice (City of Tulsa, Public Works). Urban development can exacerbate erosion by increasing runoff and reducing vegetation cover. Construction sites, riverbanks, and areas with steep slopes are particularly vulnerable.

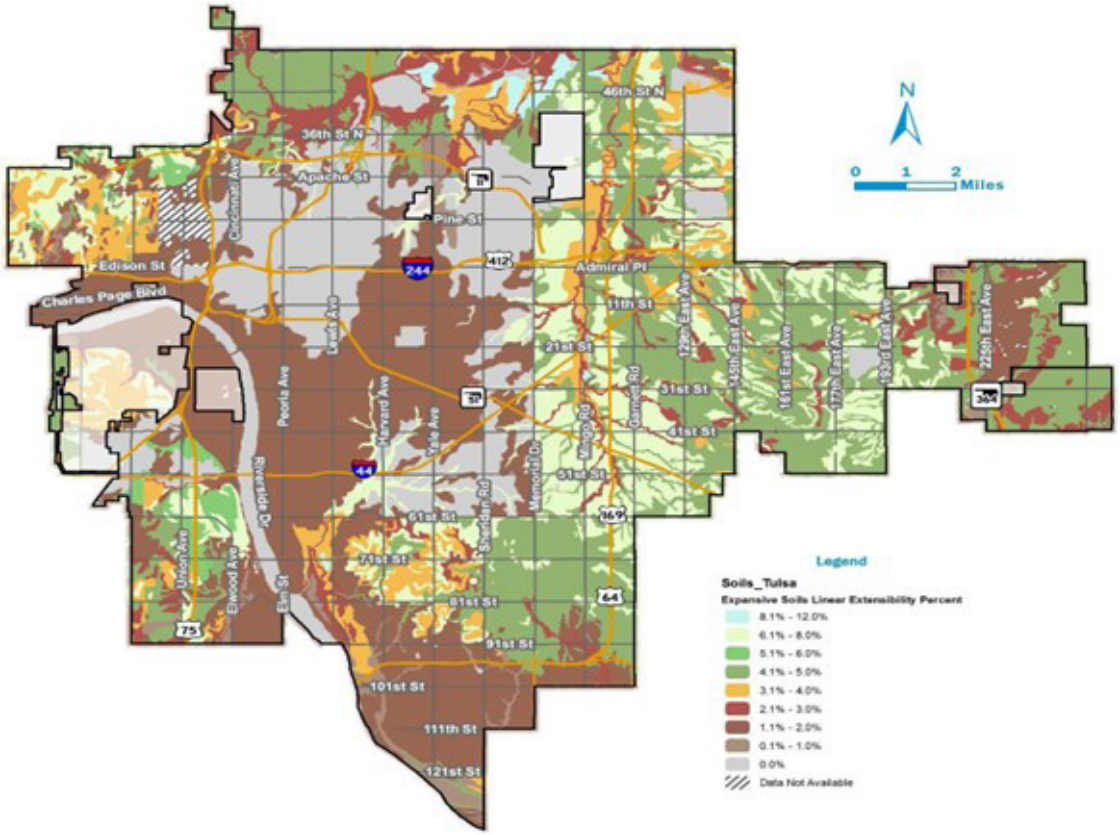
4.9.3 Extent

The extent to which soil expansion is present in an area or site can be measured using the Soil Expansion Potential standard (ASTM D-4829). An "Expansion Index" associated with the standard provides a range of scores that are used to test soil and determine the extent of expansion. Tulsa is underlain by soils with very high expansion potential as identified on the ASTM Expansion Index. Based on the expansion potential rating, mitigation may be required for building construction or repairs. As an example, the Uniform Building Code (UBC) mandates that "special [foundation] design consideration" be employed if the Expansion Index is 20 or higher with the associated expansion potential. If the linear extensibility is more than 3, as shown in Table 4-14, shrinking and swelling can cause damage to buildings, roads, and other structures and to plant roots. Special design commonly is needed.

Table 4-14: Soil Expansion Potential

LINEAR EXTENSIBILITY %	POTENTIAL EXPANSION
0%	Water
<3%	Low
3%-6%	Medium
6%-9%	High
>9%	Very High

Figure 4-32: Location of Expansive Soils, Tulsa



4.9.4 Previous Occurrences

There have been no federally declared disasters for expansive soils. Historical records including scientific study data for this hazard is either sparse, not readily available, or does not exist in summary form. There may have been instances of expansive soils causing damage but have not been reported. Damage of varying degrees of severity occurs on an ongoing and seasonal basis. The frequency of damage from expansive soils can be associated with the cycles of drought and heavy rainfall and also reflect changes in moisture content based on typical seasonal patterns. Published data summarizing damages specific to Tulsa is not available, but it is acknowledged that a certain degree of damage to property and infrastructure occurs annually.

4.9.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Low

Analyses of future probability have not been prepared because of the nature of this hazard, which is consistent with other geologic events that occur rarely or slowly over time. It could be assumed that shrink-swell soils in Tulsa will continue to cause localized problems in areas of high to very high expansive soils, similar to those experienced in the past. Tulsa is considered to have a high probability of experiencing losses associated with this hazard in the future.

4.9.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Low, the event has a minimal impact on the planning area.

People

Direct threats to life or personal injury have not generally been documented for expansive soils, due to the nature of the hazard. Indirect threats to populations in Tulsa include economic damages in residential structures. Public health concerns arise from this hazard when the shrinking and swelling of soils cause water or sewer lines to break, which often occur in critical times such as periods of extreme heat and drought.

Economy

Neither the City nor insurance companies monitor damage to structures from expansive soils as the impact of a specific natural hazard. The City treats all such damage as a maintenance issue. According to City Engineers, the expansive soil hazard is routinely taken into account in engineering studies and construction practices for infrastructure projects but not specifically documented.

Built Environment

Existing Structures: The increase in soil volume can cause damage to foundations. The most obvious manifestations of damage to buildings are sticking doors, uneven floors, and cracked foundations, floors, walls, ceilings, and windows. If damage is severe, the cost of repair may exceed the value of the building. It does not take much movement to damage buildings. As little as a differential movement of 0.25 inches between adjacent columns can cause cracking in load-bearing walls of a 2-foot-wide bay. A total of 373 structures in Tulsa are underlain by soils with Very High shrink-swell potential, with an estimated market value of $191 million.

Climate Change – specifically changes in rainfall intensity and frequency – can exacerbate soil erosion. More intense rainfall events increase runoff, which accelerates erosion, particularly in areas with exposed soil. Population growth can indirectly impact erosion. As Tulsa expands, more land is developed, leading to increased soil disturbance during construction, deforestation, or urbanization (National Science Foundation).

Infrastructure

Damage to the built environment results from differential vertical movement that occurs as clay moisture content adjusts to the changed environment. In a highway pavement, differential movement of 0.4 inches within a horizontal distance of 20 feet is enough to pose an engineering problem if high standards for fast travel are to be maintained.

There exists the potential for paradoxical climatic impacts on expansive soils in Tulsa. Higher temperatures and increased evaporation rates can lead to drier soils. Expansive soils, which swell when wet and shrink when dry, can become more prone to cracking and shifting during prolonged dry periods. Conversely, climate change is expected to also increase the frequency and intensity of heavy rainfall events. This can lead to rapid soil expansion, causing structural damage to buildings and infrastructure.

Critical Facilities

Of the facilities identified as critical by the city of Tulsa, 166 are built upon soils classified as having high or very high shrink-swell potential.

Cultural Resources

It is not anticipated this hazard would have great impacts on cultural resources.

Future Development

Because of the level of structural damage that is often incurred as a result of building on soils with high to very high shrink-swell potential, it is imperative for builders to identify soil types at proposed sites before they are developed.

Natural Resources

It is not anticipated this hazard would affect natural resources in the city of Tulsa.

4.9.7 Summary of Conclusions and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
During periods of extreme heat and drought, the City of Tulsa experiences water line breaks due to expansive soils.	Tulsa should replace broken pipes in areas of high soil expansion, with piping more resistant to breakage.	46
Many Tulsans are unaware of the impacts associated with high and very high expansive soils.	Tulsa should educate the public on the importance of identifying soils types when purchasing or building a new home.	1

4.10 Lightning

4.10.1 Hazard Description

Lightning is a discharge of electrical energy that results from the buildup of positive and negative charges in a thunderstorm, which creates a "bolt" when the buildup of charges becomes strong enough. Lightning can occur between a cloud and the ground (Cloud-to-Ground Lightning), between two clouds (Intercloud Lightning), or within the same cloud (Intracloud Lightning). Lightning can strike 10 miles out from the rain column.

4.10.2 Location

As lightning is a byproduct of thunderstorms, all areas of Tulsa are subject to the exposure and effects of lightning events. The risk of this hazard is uniform over the planning area.

4.10.3 Extent

The The Lightning Activity Level gauge, Table 4-16, indicates that the City of Tulsa may experience between 4 and 8 lightning flashes per sq km per year, or between 3,108 to 4,144 lightning flashes within the jurisdiction each year (4 to 8 flashes x 518 sq. km/yr). Tulsa can experience the full range of this hazard.

According to NOAA's Severe Weather Data Inventory, the highest number of lightning flashes on a single day in Tulsa occurred on July 15, 2017, with a total of 63 strikes. This number was pulled from five years of data 2013-2018.

4.10.4 Previous Occurrences

The NCEI Storm Events Database includes reports of seven damaging lightning events between 1998 and 2023. The low number of reported incidents does not mean lightning only occurred seven times in the city. Based on information provided by the Vaisala Flash Density Map, Tulsa likely experienced between 4 and 8 lightning flashes per sq km per year, or between 3,108 to 4,144 lightning flashes within the jurisdiction each year. Narratives of several damaging lightning events in Tulsa are in Table 4-15.

4.10.5 Probability of Future Events

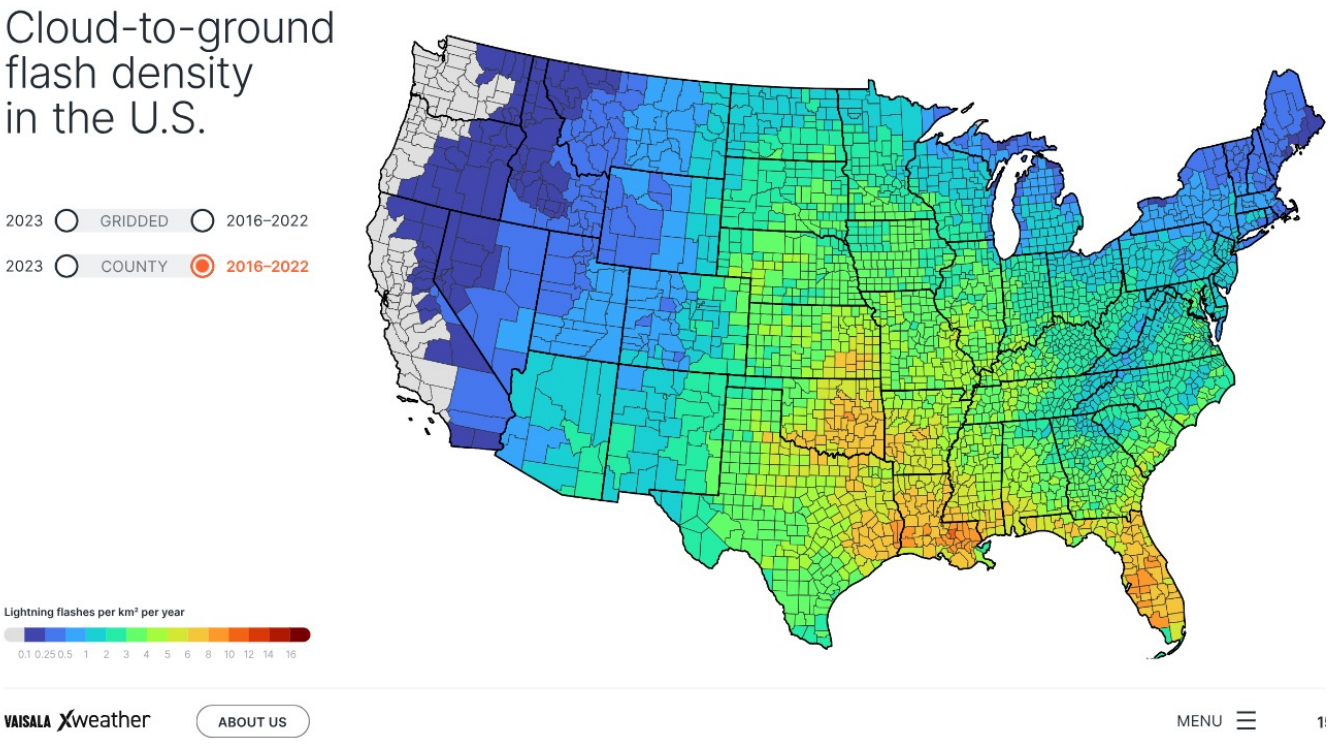
Overall Probability Rating based on Classifications in Chart 1: Highly Likely, 90 to 100 percent probability of occurrence in the next year or a recurrence interval of less than 1 year.

Tulsa should expect future lightning events to fall in line with the NLDN data from previous years, with a high probability of lightning occurring on an annual basis. Rising temperatures enhance atmospheric instability. Warmer air can hold more moisture, leading to more intense thunderstorms and, consequently, more frequent and severe lightning events (USGS).

4.10.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Low, the event has a minimal impact on the planning area.

Figure 4-33: Vaisala Flash Density



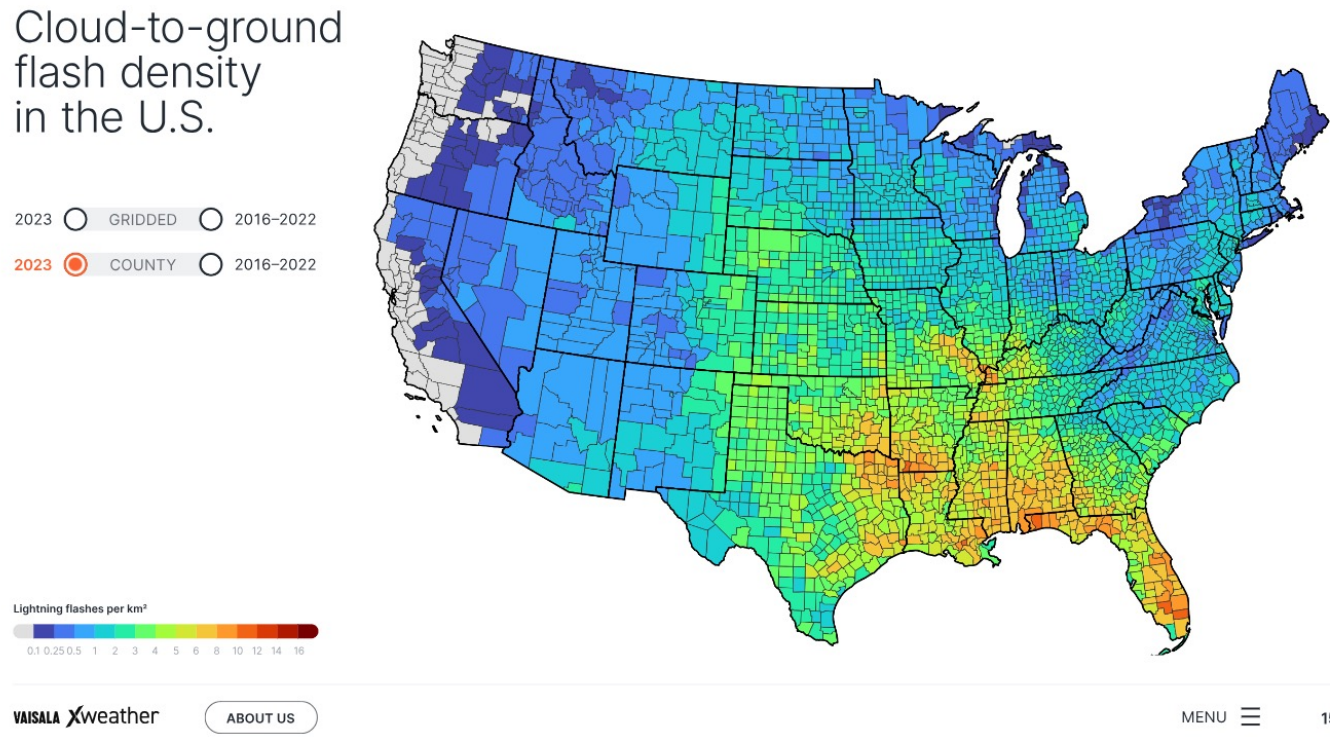


Table 4-15: Lightning Event Narratives

DATE	EVENT NARRATIVE
May 9, 2000	One mile to the east of Tulsa, lightning strikes burned out two power pole phases, causing power outages to approximately 550 residents.
Mar 20, 2012	March 20, 2012: Computer records indicate a single “super bolt” struck in the heart of South Tulsa just after 3:30 AM. It woke Tulsans and set off car alarms. Many thought it was an earthquake. A super bolt is a positively charged cloud-to- ground stroke of lightning. No damage from the super bolt was reported (source: KRMG Tulsa)
July 23, 2013	Lightning struck the Union 8th Grade Center, igniting a fire that severely damaged the roof of the building.
Aug 6, 2017	Lightning struck Holy Apostles Orthodox Christian Church at 15th and Peoria. The lightning strike hit the cross on top of the church and blew a hole in the cupola ceiling. A lightning rod was installed after the event to prevent future strike damage.
May 3, 2018	Lightning is believed to be the cause of a structure fire in a Midtown Tulsa home.

Table 4-16: Lightning Activity Level (LAL)

LAL is a scale which describes lightning activity. Values are labeled 1-6.

LEVEL	LIGHTNING ACTIVITY
LAL1	No thunderstorms.
LAL2	Isolated thunderstorms. Light rain will occasionally reach the ground. Lightning is very infrequent, 1 to 5 cloud to ground strikes in a five minute period.
LAL3	Widely scattered thunderstorms. Light to moderate rain will reach the ground. Lightning is infrequent, 6 to 10 cloud to ground strikes in a five minute period.
LAL4	Scattered thunderstorms. Moderate rain is commonly produced. Lightning is frequent, 11 to 15 cloud to ground strikes in a five minute period.
LAL5	Numerous thunderstorms. Rainfall is moderate to heavy. Lightning is frequent and intense, greater than 15 cloud to ground strikes in a five minute period.
LAL6	Dry lightning (same as LAL3 but without rain). This type of lightning has the potential for extreme fire activity and is normally highlighted in fire weather forecasts with a Red Flag Warning.

People

All the population of Tulsa is exposed and at risk for experiencing this hazard. The City of Tulsa includes over 9,000 acres of total park space and several golf courses. Lightning events could place park visitors in imminent danger, potentially causing park evacuation. Injuries and deaths associated with lightning are highly preventable. Areas of Tulsa of most concern are those with higher concentrations of people who do not have a way to receive severe weather alerts, especially low-income and non-English speaking populations. Mitigation of the action associated with this hazard includes public education and outreach. Additionally, Tulsa could install lightning detection systems to keep park visitors safe from lightning when storms approach.

Economy

Economic impacts of this hazard are primarily related to loss of power and business interruption. The amount of impact on the economy depends on the length of time until service restoration.

Built Environment

Existing Structures: All structures and buildings within the City of Tulsa are vulnerable to the impact of a lightning event. A bolt of lightning can explode walls of brick and concrete and cause fires to ignite within facilities.

Infrastructure

The most severe consequence of a lightning strike on Tulsa's infrastructure is from loss of electrical power and communications. Lightning has caused damage to transformers and downed lines in the past, resulting in outages in the service area.

Critical Facilities

All critical facilities in Tulsa are exposed to this hazard. Lightning can cause extensive damages to facilities. Tulsa should equip critical facilities with lightning solutions to lessen the impact of a direct strike.

Cultural Resources

All cultural institutions in Tulsa are exposed to lightning. Many of these institutions keep records or are considered to be historic. Loss of any historic resources because of fire as a result of lightning would be devastating.

Future Development

All future development is exposed to the lightning hazard. Tulsa should consider integrating lightning protection solutions in future growth.

Natural Environment

Lightning does not pose a significant threat to the natural environment. The main concern would be a grassland fire caused by lightning during dry conditions. Summary of Observations and Recommendations

4.10.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Populations involved in outdoor activities are at risk from severe weather events.	Notify the public of the risks associated with severe weather.	1
Tulsa benefits from having many outdoor recreation areas. Unless directly connected to a mobile device with severe weather alerts, patrons of these areas may be unaware of lightning risks.	Tulsa should consider installing lightning detection and warning systems at parks to keep guests safe from lightning when storms approach.	53
Lightning strikes have caused service disruption to businesses and critical facilities in Tulsa. Lightning can cause extensive damages to facilities.	Tulsa should equip critical facilities with lightning protection solutions to lessen the impact of a direct strike.	53

4.11 Earthquake

4.11.1 Hazard Description

An earthquake is a sudden release of energy that creates a movement in the Earth's crust. Most earthquake-related property damage and deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the extent and duration of the shaking. Most severe earthquakes take place where the vast tectonic plates that form the Earth's surface collide and slide slowly over, under, and past each other. They can also occur along any of the multitudes of fault and fracture lines within the plates themselves.

4.11.2 Location

All of Tulsa is equally susceptible to an earthquake as they are not limited to one specific geographic area. An earthquake occurring in an entirely different state could affect Tulsa County, and consequently the City of Tulsa. The risk of this hazard is uniform over the entire planning area.

4.11.3 Extent

Two standard measures are used to classify an earthquake's extent: magnitude and intensity. These measures are sometimes referred to as the Richter Scale (magnitude) and the Modified Mercalli (intensity). As more seismograph stations were installed around the world, it became apparent that the method developed by Richter was strictly valid only for certain frequency and distance ranges. Because of the limitations of all three magnitude scales (ML, Mb, and Ms), a new, more uniformly applicable extension of the magnitude scale, known as moment magnitude, or Mw, was developed. In particular, for very large earthquakes, moment magnitude gives the most reliable estimate of earthquake size. Earthquakes are classified in categories ranging from minor to great, depending on their magnitude. Table 4-17 shows the list the USGS uses to classify earthquakes:

Table 4-17:
USGS Earthquake Magnitude Scale

CLASS	MAGNITUDE
Great	8 or more
Major	7-7.9
Strong	6-6.9
Moderate	5-5.9
Light	4-4.9
Minor	3-3.9

4.11.4 Previous Occurrences

The USGS and Oklahoma Geological Survey report earthquakes with a magnitude of 3.0 or higher. Earthquakes are not felt until they reach a magnitude of 3.0 on the Richter Scale. No earthquakes with a magnitude of 3.0 or higher have occurred in Tulsa. The 5.6 magnitude earthquake on November 5, 2011 near Prague, OK was felt within Tulsa limits. Another 5.6 magnitude quake occurred near Pawnee, OK on September 3, 2016. Both events were felt in Tulsa; no injuries were reported, and damages were limited to unsecured items falling and cracks to drywall. Events near Tulsa are mapped in Figure 4-34.

4.11.5 Probability of Future Events

Overall Probability Rating based on Classifications in Chart 1: Unlikely

According to the 2017 Hazard Map published by the USGS22, Tulsa is located in an area with a 2%-5% chance of damaging shaking on an annual basis. It is unlikely that climate change will have a measurable impact on the frequency or intensity of earthquakes.

4.11.6 Vulnerability and Risk Assessment

Overall Significance based on Classifications in Chart 1: Low, the event has a minimal impact on the planning area.

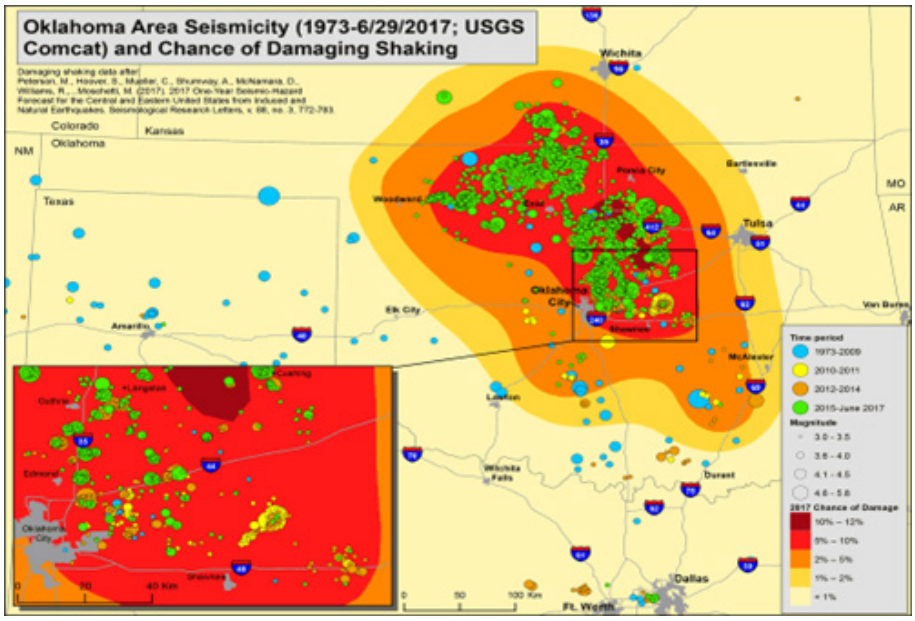
People

Most earthquake injuries and fatalities occur within buildings from collapsing walls and roofs, flying glass, and falling objects. As a result, the extent of a community's risk depends not just upon its location relative to a known fault, and its underlying geology and soils, but also on the design of its structures. Those populations who do not know how to respond when an earthquake occurs remain vulnerable to potential earthquakes. All people in the City of Tulsa should be made aware of what actions to take during an earthquake event. Contents in a home can be as or more dangerous and damage-prone than the structure itself. Any unsecured objects that can move, break, or fall as an earthquake shakes are potential safety hazards and potential property losses.

Economy

Earthquakes felt in Tulsa are not likely to

Figure 4-34: 2017 Oklahoma Area Seismicity



directly affect the economy. Even so, small business owners should make their businesses safer to be in during earthquakes and more resistant to earthquake damage by assessing its structure and contents and correcting any weaknesses.

Built Environment

Existing Structures: Depending on when and how it was designed and built, a structure may have weaknesses that make it more vulnerable to earthquakes. Common examples include structures not anchored to their foundations or having weak crawl space walls, unbraced pier-and-post foundations, or unreinforced masonry walls or foundations. It is not likely an earthquake would cause major structural damage to any City of Tulsa facilities. It is unlikely that climate change or changes in population will have a measurable impact on the frequency or intensity of earthquakes.

Infrastructure

It is not likely the City of Tulsa's infrastructure will be impacted by an earthquake, as the city is located in an area of low seismicity.

Critical Facilities

Critical facilities face the same potential impacts to earthquakes as other structures/buildings in the City of Tulsa. While unlikely, of particular concern are the design and construction of critical facilities, such as hospitals and transportation facilities, oil and gas pipelines, electrical power and communication facilities, and water supply and sewage treatment facilities and lines.

Cultural Resources

Earthquakes could cause minor structural damages to historic structures. A more significant concern is the contents of structures, such as museum collections. Tulsa could consider a program to stabilize irreplaceable pieces in museums, highly susceptible to damage from even minor earthquake events.

Future Development

The City of Tulsa adopted the ICC International Building Code, 2018, and the ICC International Residential Code for One- and Two-Family Dwellings, 2018 Edition. There is no reason to believe that any future development will be impacted to any degree greater than existing development.

Natural Environment

Earthquakes can cause land subsidence, either directly related to an earthquake or provoked by shaking.

4.11.7 Summary of Observations and Recommendations

OBSERVATION(S)	RECOMMENDATION	ACTION
Shaking from earthquakes outside the Tulsa metro may still affect structures within the City.	Tulsa should educate the public on ways to make their property safe from earthquakes and the proper response.	1
Damage associated with earthquakes in Tulsa is generally minor. Citizens notice smaller impact such as pictures falling off walls, or small cracking. Properties in Tulsa were not constructed with earthquakes in mind.	Critical facilities should be constructed or repaired to resist the effects of earthquakes.	
Earthquakes could cause minor structural damages to historic structures. A more significant concern is the contents of structures, such as museum collections.	Tulsa could consider a program to stabilize irreplaceable pieces in museums highly susceptible to damage from even minor earthquake events.	55

4.12 Ransomware

4.12.1 Hazard Description

Ransomware is an ever-evolving form of malware designed to encrypt files on a device, rendering any files and the systems that rely on them unusable. Malicious actors then demand ransom in exchange for decryption. Ransomware actors often target and threaten to sell or leak exfiltrated data or authentication information if the ransom is not paid. In recent years, ransomware incidents have become increasingly prevalent among the nation's state, local, tribal, and territorial government entities and critical infrastructure organizations, as attackers recognize they possess a trove of sensitive data about their residents[1].

Electronic data is essential to the operation of many public facilities and should be viewed as critical to the function of a facility as much as the power or water needed to keep the facility running. Continued access to this data and damaged physical systems and cyber data must be recovered quickly and efficiently to ensure minimal disruption.

4.12.2 Location

City-wide services could be compromised by ransomware attacks, including the City's ability to respond to natural hazards.

4.12.3 Extent

The magnitude of ransomware attacks can vary widely. Some may result in the temporary suspension of online services provided by the City, such as water utility billing and requests for new service. More severe attacks could compromise emergency responders and cost in excess of one million dollars should the City pay a requested ransom. Eighty percent of organizations who pay demanded ransoms are targeted again in the future[2].

4.12.4 Previous Occurrences

On May 6, 2021 the City's Information Technology Department received notice that some servers were actively communicating with a known threat site and a ransomware attack was initiated on several City systems. A cybersecurity incident response team was assembled to assess the threat and disconnected the affected servers. The team immediately began isolating the affected systems and the attack moved quickly through the network, prompting the team to shut down all services to halt the attack.

As such, the City engaged an outside incident response team to assist with threat assessment as the forensic investigation began. Forensic data was handed over to that team and to law enforcement for further investigation.

Most of the files contained in the data breach were online Tulsa Police report files that contained information ranging from name only to name, address, date of birth, and/or driver's license number. There were 27 instances where a social security number was shared. The attack also had a significant impact on certain city services and Tulsans wanting to get police reports, pay utility bills, or have utilities connected. As of 2021, the City spent just over $300,000 on its response[3]. The ransomware attack remains an ongoing investigation[4].

4.12.5 Probability of Future Events

Cities and towns have been facing an uptick in ransomware — where hackers encrypt an

1 cisa.gov

2 cbsnews.com/news/ransomware-victims-suffer-repeat-attacks-new-report

3 kjrh.com/news/local-news/story-behind-the-ransomware-attack-on-the-city-of-tulsa

4 cityoftulsa.org/cyber

organization's networks until a ransom is paid — since at least 2019.

4.12.6 Vulnerability and Risk Assessment

Following the attack, an Emergency Response Team assembled and initiated the City's IT Disaster Recovery and Business Continuity Plan and advised departments to implement manual business processes as defined in their Continuity of Operations Plans until online services could be restored.

Moving forward, the City's main priority is to restore critical resources and mission-essential functions, which include public-facing systems and internal communications and network access functions. Business recovery teams have categorized and prioritized system restoration efforts and are continuing their work to restore and validate business system functionality.

People

All citizens and businesses that rely upon City services could be affected by ransomware should an attack prompt system-wide shut downs.

Economy

Aside from government agencies, private businesses are also vulnerable to ransomware and hacking. Ransomware attacks are on the rise and are considered an escalating threat for the foreseeable future. As of 2021, between 50% and 75% of ransomware attack victims are small businesses. Small businesses are primary targets, as they typically spend less on security, making it easier to hack into the systems[1].

Large businesses are also targeted. The world's largest meat processing company, JBS, paid an $11 million ransom to cyber criminals in 2021[2].

Built Environment

Cyber attacks can jeopardize the City's ability to respond to natural disasters, thereby putting affected structures and utilities at risk of further damage.

Infrastructure

Providers of utilities and other public services are vulnerable to the effects of malicious hacking.

Cultural Resources

In the case of a simultaneous ransomware attack and other natural disaster, emergency responders' efforts to protect cultural resources such as historic structures and museums could be compromised.

Future Development

There is no reason to believe that any future development will be impacted to any degree greater than existing development.

Natural Environment

In the case of a simultaneous ransomware attack and other natural disaster, emergency responders' efforts to protect natural resources such as forests and grasslands could be compromised.

1 content.naic.org/cipr-topics/ransomware

2 cbsnews.com/news/jbs-ransom-11-million

4.12.7 Summary of Observations and Recommendations

The following is a non-exhaustive list of potential cybersecurity activities that may be eligible for FEMA's Building Resilient Infrastructure and Communities (BRIC) funding if incorporated into a hazard mitigation project[1]*:*

OBSERVATION(S)	RECOMMENDATION	ACTION
Cyber criminals can target facilities that house servers to physically intrude and hack systems.	Harden facilities (buildings, wiring, rooms, etc.) that house the cybersecurity system component such as computers, hardware, or the system's servers. This could also include elevation of server racks or physical components to mitigate damage in the event of a flood, similar to the elevation of power generation equipment.	56
Natural disasters could potentially damage IT systems.	Install backup equipment to provide redundancies in IT systems for critical infrastructure; this may include installing equipment elsewhere on the property that would be less likely to be damaged in the event of a disaster.	56
Substandard wiring could cause loss of function or data in the event of an emergency.	Update wiring and other electrical components to ensure that older or substandard wiring does not cause loss of function or data in the event of a disaster or emergency.	56
If a utility fails, there may not be a back-up.	Provide redundancy for necessary utilities (such as water for cooling) to ensure continuous operations.	56
Outdated computer equipment is vulnerable to hacking and external damage.	Update critical IT systems for enhanced cybersecurity, including replacing old/outdated computer equipment, the continued usage of which is susceptible to cyberattacks or external damage. Systems that use hard-to-obtain critical components may be converted, or modernized, to a standard as published by CISA (or another federal agency) that would prevent misuse or reduce the possibility of a cyberattack.	56
Outdated software could lead to system vulnerability.	Ensure that software required for City operations is up to date, prioritizing updates that address known exploited vulnerabilities. This could include software such as building management software that controls climate, power, or other critical building functions that, if damaged or compromised, would result in the loss of function of the facility or its services. If using this type of critical infrastructure control systems or operational technology, conduct a test of manual controls to ensure that critical functions remain operable if the City's network is unavailable or untrusted.	56
Software can be used to protect systems from attack.	Conduct a review to confirm that the City's entire network is protected by antivirus/antimalware software and that signatures in these tools are updated. Purchase and install software that validates that all remote access to the organization's network and privileged or administrative access requires multi-factor authentication to reduce the opportunity for system intrusions or cyberattacks.	56
If data is stolen, backup data may not be available or safe from hacking.	Test backup procedures to ensure that critical data can be rapidly restored if the organization is impacted by ransomware or a destructive cyberattack; ensure that backups are isolated from network connections.	56
A dedicated cybersecurity plan could address systemic weaknesses.	Development of an applicant-level cybersecurity plan, based on CISA's Cyber Guidance for Small Businesses, may be eligible under the Capability- and Capacity-Building category. However, to be eligible, the cybersecurity plan must be developed and incorporated into the actions of a hazard mitigation plan, so this activity would be funded as part of a future update to a hazard mitigation plan.	56

1 FEMA 2023 Joint Cybersecurity Program Support Manual

CHAPTER 5
MITIGATION STRATEGY

This chapter identifies the hazard mitigation strategy and goals set by the City of Tulsa and discusses the mitigation projects, or measures, to be taken to achieve those goals. The mitigation strategy describes how the community will accomplish the overall purpose, or mission, of the planning process. The mitigation strategy is made up of three main required components: mitigation goals, mitigation actions, and a plan for implementation. These provide the framework to identify, prioritize, and implement actions to reduce risk to hazards.

5.1 Mitigation Goals

Goals from the 2019 City of Tulsa All Hazard Mitigation Plan were reviewed and evaluated by the Planning Team based on both progress and actions taken in the plan maintenance period and on development or review of other pertinent City of Tulsa plans. Goals that were deemed to be effective and pertinent to the current plan were retained and incorporated into the 2024 update.

Significant development activities in the past several years include the 2018 opening of The Gathering Place, a world-class riverfront park which will be expanded in 2024 to include Zink Lake, a new pedestrian bridge over the Arkansas River additional river access and a whitewater flume. These features will draw more people to the riverfront on a regular basis. Additional social service facilities, a new food bank (Iron Gate), a family safety center, the Tulsa County Family Center for Juvenile Justice have opened in downtown locations and new public safety center which will house Tulsa Police Department headquarters, Tulsa Fire Department headquarters, and the Tulsa Area Emergency Management (TAEMA) with plans to include City Medical and the Mingo Valley Police Division. Additional industrial properties near the Tulsa International Airport have been developed.

Development has not led to annexation of additional land area into the City. Notable regulatory updates include a river corridor development overlay and increased utilization of mixed use zoning provisions have been added to the City's zoning code which offers greater flexibilty for infill development focused on the efficient utilization of existing infrastructure.

Some of these changes, such as improved social and public service facitlies, have aided the City's ability to respond to hazards by creating more outreach opportunities and places to provide resources to vulnerable populations. Increased development activities within the river corridor should be monitored to understand how they impact various hazards, particularly flooding. Industrial development should comply with state and local regulations to ensure proper protections for stormwater runoff and other possible adverse impacts on adjacent properties.

The City of Tulsa was elevated to a CRS Class 1 community in April 2022. This rating is a high priority for the City that is supported by this plan update. In addition to providing a road map for sustained and improved hazard mitigation policies, projects and programs, the plan is designed to better integrate the City's long-range planning objectives and offer a guide for allocation of public resources to address the community's shared vision for the future.

5.1.1 Mission Statement

To create a disaster-resistant community and to improve the safety and well-being of Tulsa by reducing deaths, injuries, property damage, environmental and other losses from natural and technological hazards in a manner that advances community goals, quality of life, and results in more livable, viable, and sustainable community.

5.2 Goals for All Hazards

1. Minimize loss of life and property while safeguarding public health and safety during natural hazards;
2. Increase public awareness of risk from natural hazards;
3. Determine local hazards, evaluate risk factors, and analyze historical occurrence and frequency;
4. Restrict development in high-risk zones and enhance building standards to mitigate the risks posed by natural disasters.

Table 5-1 Evaluation Criteria

AREA	CRITERIA
Life and Safety	• What impact will the project have on businesses, residences, and properties in the planning area? • Will the project proactively reduce natural hazard risk?
Administrative/Technical Assistance	• Is there sufficient staff to implement the project? • Is training required for the staff to implement the project? • Is there political support for the project? • Does the community have the legal authority to do the project?
Project Costs and Economic Factors	• What is the cost of the project? • Does the community have the funds for the project on the whole or the local match?
Support for Community Objectives	• Does the action advance other objectives or plans, like capital improvement, economic development, environmental quality, or open space preservation?
Equity	• Will the action adversely affect underserved and socially vulnerable populations? • Does the action build resilience for underserved and socially vulnerable populations?

5.3 Recommended Mitigation Actions

A mitigation action is a specific action, project, activity, or process taken to reduce or eliminate long-term risk to people and property from hazards and their impacts. A review of the 2019 mitigation actions identified in the previous plan was completed by the planning team. Actions were evaluated with the intent of carrying over any not started, or continuous actions for the next five years. Actions with the same intent were combined into a general action item to allow more opportunity for FEMA funding. Specific observations and problem statements, resulting in the actions listed below, are included at the end of each hazard section in the Risk Assessment, Chapter 4.

In addition to the previous mitigation actions, stakeholders considered a broad array of different actions to mitigate against the observations identified in the risk assessment at a meeting on January 25, 2024. Potential mitigation actions were evaluated using the criteria recommended on Worksheet 7 in the FEMA Local Mitigation Planning Handbook and developed an Action Plan for the actions determined to be highly effective and feasible. Certain mitigation measures are recommended for multiple hazards.

The types of mitigation actions reviewed to reduce long-term vulnerability include:

- Preventative Activities
- Floodplain Management Regulatory/Current and Future Conditions
- Property Protection Activities
- Natural Resource Protection Activities
- Emergency Services Activities
- Structural Projects
- Public Information Activity

5.3.1 Evaluation Criteria

Several criteria were used to determine the recommended mitigation actions. Equity was included as a new criteria to ensure the plan's focus on supporting vulnerable populations more effectively moving forward.

5.3.2 Lifelines

Lifelines are included in Table 5-1 to identify the services in the community that are needed to allow critical government and business functions to continue in the face of a hazard. Action Strategies may address multiple lifelines. Lifelines should be coordinated and strengthened to build resilience and help the community stabilize quickly following a disaster.

5.3.3 Prioritization

To prioritize the hazard mitigation action items, a benefit/cost exercise was employed. This informal analysis reflects a planning-level assessment based on FEMA's BCA module and prioritizes projects on how they will accomplish the plan's mission.

The Benefits of each measure are scored as High (H), Medium (M), or Low (L) based on how well the measure moves the City towards this plan's stated mission statement "To create a disaster-resistant community and improve the safety and wellbeing of Tulsa by reducing deaths, injuries, property damage, environmental and other losses from natural and technological hazards in a manner that advances community goals, quality of life, and results in a more livable, viable, and sustainable community."

The Costs are also measured as H, M, or L. Costs estimate the resources needed to implement the measure. While monetary cost is the primary resource, staffing and other resources should also be considered. The ratio of Benefits/Costs then determines whether an action item is considered H, M, or L.

Table 5-2 Prioritization

TOPIC	REVIEW CONSIDERATION	
Benefits	High	The project will effectively and immediately accomplish the mission statement.
	Medium	The project may protect lives in the long term or wouldn have an immediate impact on protecting property.
	Low	It is difficult to quantify if the project will protect lives and/or property.
Costs	Low	Funds, staffing, or resources exist to implement the project.
	Medium	Existing funds or resources would have to be reallocated to implement.
	High	Additonal funds, staffing, or other resources would have to be secured.

Table 5-3 Benefit Cost Analysis

		BENEFITS		
		Low	Medium	High
COSTS	High	Low/High	Med/High	High/High
	Medium	Low/Med	Med/Med	High/Med
	Low	Low/Low	Med/Low	High/Low

Measures that are High/Med or High/Low or Med/Low are high priority.

Measures that ae Low/Low or Med/Med or High/High are medium priority.

Measures that are Low/Med or Low/High or Med/High are low priority.

Table 5-4 Recommended Mitigation Actions

#	Action	Priority	Timeline	Cost
1	Develop and fund hazard preparedness, education, information, and awareness programs	High	0-60 months	$50,000 - Annual funding for the PPI program
2	Update the city-wide disaster recovery and reconstruction plan	High	12-24 months	$350,000
3	Inventory and maintain an active list of disaster resources available in Tulsa	High	Ongoing	$125,000 annual expense
4	Develop and emergency preparedness and mitigation website	Medium	Ongoing	Costs related to staff time to maintain the site
5	Educate the general public and local builders, and other stakeholders on the benefits of disaster resistant construction	Medium	Ongoing	Grant funding request $ in addition to costs related to staff time and resources to support the program
	Provide training/education on disaster resistant techniques to local builders.			
6	Install generators at critical facilities	Medium	0-60 months	$50,000 to $100,000 per facility. (Purchase cost of 150 KW Kohler Stand-bu Generator is $42K)
7	Develop and implement an on-going air conditioner program as part of the City's extreme temperature plan.	High	0-60 months	$10,000 per unit plus installation costs depending on individual structural requirements
8	Develop Resilience Hubs in neighborhoods within each council district to ensure proper hazard preparation, response, and recovery information is disseminated to the public	High	12-36 months	$250,000 in addition to staff time and resources
9	Update and Implement Tulsa Urban Forest Master Plan	Medium	36-48 months	$350,000
10	Develop and maintain a list of critical facilities outlining appropriate protections and resources related to natural hazards.	High	0-12 months	Staff time and resources

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
1	Public awareness, education and information campaigns are ongoing via various avenues.	All Hazards	Safety and Security, Communication	TAEMA, Public Works, CoT Communications	Local/General, FEMA HMA	1
2	Reworded/updated Action Item to reflect shifting initiative from development of a plan, to updating the plan.	All Hazards	Safety and Security, Communication	TAEMA	Local/General, FEMA HMA	2
3	TAEMA maintains a list in VEOCI which is updated continuously.	All Hazards	Communication	TAEMA, CoT Asset Mgmt.	Local/General, FEMA HMA	3
4	City has configured the website and has been provided the necessary datasets to maintain it.	All Hazards	Communication	Public Works, CoT Information Tech.	Local/General, FEMA HMA	4
5	Reworded/updated Action Item; Action Item is carried out in practice to continually educate builders and developers.	All Hazards	Communication	CoT Development Services; City Communications	Local/General, FEMA HMA	11
	Removed - Combined with Action Item 5	All Hazards	Communication	CoT Development Services; City Communications	Local/General, FEMA HMA	12
6	Generator needs at critical facilities have been identified. Awaiting funding.	All Hazards	Energy, Communication, Water Systems	CoT Asset Mgmt.	Local/General, FEMA HMA	14
7	Reworded/updated Action Item. Community Service Council ceased operations in 2023 and have since re-established as Oklahoma Veteran's United.	All Hazards	Food, Hydration, Shelter	TAEMA, OK Veterans United	Local/General, FEMA HMA	15
8	Reworded/updated Action Item: Resilient Tulsa program managed by the Mayor's Office of Resilience and Equity will implement when funding is identified; program is scalable	All Hazards	Food, Hydration, Shelter	Resilient Tulsa	Local/General, FEMA HMA	29
9	Current plan was completed in 2015 and needs to be updated	All Hazards	Health and Medical	Parks and Recreation, Up With Trees, Inc.	Local/General	
10		All Hazards	Communications, Safety and Security, Food, Hydration and Shelter	All Partners, led by TAEMA	Local/General, FEMA HMA	

#	Action	Priority	Timeline	Cost
11	Every 5 years perform or compile an overall infrastructure assessment to address deficiencies and necessary improvements and make the report available to the public.	High	0-60 months	Staff time and resources
12	Develop a generator rebate program for small businesses.	Medium	On-going	$10,000 to $25,000 per generator depending on size and type of business; staff time to administer the program
13	Educate the public on the importance of flood insurance.	High	On-going	$50,000 - Annual funding for the PPI program
14	Update Master Drainage Plans when conditions warrant.	High	On-going	$500,000
15	Acquire properties in the FEMA floodplains, Tulsa regulatory floodplain and repetitive loss/ severe repetitive loss properties; develop a Substantial Damage Management Plan.	High	On-going	$200,000 annually
	Enhance emergency plan for the Arkansas River Corridor.			
16	Implement recommendations of the COT Master Drainage Plans	Medium	On-going	$15M annual (includes Stormwater capital projects); $447,555,087 identified in Annual Budget and Capital Plan for FY2024-2026 includes a backlog and entire inventory of unfunded projects
17	Repair levees and berms that fall within the City of Tulsa's area of responsibilities.	Medium	On-going	The District was awarded a $150,000,000 project to repair the levees.

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
11		All Hazards		Public Works, Water/Sewer	Local/General FEMA HMA	
12		All Hazards	Energy, Communication, Water Systems	CoT Asset Mgmt.	Local/General, FEMA HMA	
13	Development of Flood Insurance Brochure currently underway in lieu of Flood Expo, which will be held every 3 years (as outlined in 2024 PPI Report). Multiple items are distributed through public outreach initiatives.	Flood, Dam/Levee Failure	Communication	Public Works, PPI Committee	Local/General, FEMA HMA	17
14	City of Tulsa maintains a GIS Viewer, which is used to track and schedule updates as required.	Flood, Dam/Levee Failure	Water Systems	Public Works	Flood, Dam/Levee Failure	18
15	Added "Develop a Substantial Damage Management Plan" to Item description. The City is in the process of building an historic acquisition database for tracking of all previously and future acquired properties. Identification of RL/SRL properties for possible acquisition are gathered from MDP updates and added to a database for considerations when funding becomes available.	Flood, Dam/Levee Failure	Safety and Security, Water Systems	TAEMA, Public Works, Development Services	Local/General, FEMA HMA	19
	Removed - Action complete	Flood				20
16	"Tupelo Creek MDP improvements will be complete in December 2025. Fulton Creek (43rd & Sheridan) BRIC application has been approved for Phase 1 activities and work is ongoing."	Flood, Dam/Levee Failure	Water Systems	Public Works	Local/General FEMA HMA	21
17	Reworded/updated Action Item; Project has begun and is in preliminary development.	Flood, Dam/Levee Failure	Water Systems	USACE, Levee District 12	Local/General, FEMA HMA	22

#	Action	Priority	Timeline	Cost
18	Notify the general public of the risk of living within the floodplain, levee or dam inundation area	High	On-going	$10,000 annually
19	Seek funding to design and implement storm drainage improvements to prevent repetitive flooding.	Medium	On-going	$6,670,000
20	Partner with neighboring jurisdictions and stakeholders, including state, Tribal, and Federal partners to develop a comprehensive response and recovery plan for the Arkansas River.	Medium	24-48 months	$250,000
21	Provide incentives for developers to incorporate green stormwater infrastructure into overall site design, such as density bonuses, expedited permitting, or fee reductions.	Medium	12-24 months	$250,000 in addition to staff time and resources
22	Continue to right-size parking and density requirements outside of CBD, CH, or MX zoning districts to support the reduction of impervious surfaces throughout the City.	Medium	0-12 months	Staff time and resources
23	Implement a riparian buffer restoration and erosion control project along creeks, streams and waterways, focusing on areas prone to flooding and lacking vegetation. This project may include planting native vegetation along the creek banks to stabilize soil, reduce erosion, and improve water quality.	Medium	24-48 months	Staff time and resources for program development and administration; funding for planting programs will vary
24	Support ongoing City efforts to develop and implement LID/Green Infrastructure education and construction guidance for both public and private development activities.	Medium	On-going	Staff time and resources
	Maintain debris management plan and update as required/needed.			

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#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
18	Annual messaging campaign is conducted by the City. Approximately 15,000 notifications are sent out each year.	Flood, Dam/Levee Failure	Communication, Water Systems	Public Works?, Development Services, CoT Communications, PPI Committee	Local/General, FEMA HMA	23
19	Stormwater projects funded in the City's FY2024-2025 capital budget	Flood, Dam/Levee Failure	Water Systems	Public Works	Local/General FEMA HMA	
20		Flooding	Water Systems, Safety and Security	Development Services	Local/General, FEMA HMA, USFWS, EPA	
21		Flooding, Erosion	Safety and Security	Development Services, Tulsa Planning Office, Public Works	Local/General, FEMA HMA, EPA	
22		Flooding, Erosion	Water Systems, Safety and Security	Development Services, Tulsa Planning Office	Local/General, FEMA HMA	
23	Implemented as part of the City's annual stormwater operations and maintenance program and supported by the Stormwater CIP	Flooding, Erosion	Water Systems	Parks and Recreation	Local/General, FEMA HMA, USFWS, EPA	
24		Flooding, Drought, Expansive Soils, Subsidence, Erosion	Communication, Water Systems	Water/Sewer, Development Services, Tulsa Planning Office	Local/General, FEMA HMA	
	Remove; Action is complete	Severe Winter Storm, High Wind/Tornado, Floods, Dam/Levee Failure, Earthquake, Wildfire				7

#	Action	Priority	Timeline	Cost
25	Temperature controlled space to house emergency materials related to water resources	Low	0-12 months	Staff time and resources
26	Identify, pre-screen and vet locations for post-disaster shelters	High	0-12 months	Staff time and resources
27	Convert generators at critical facilities to solar panels and battery backups.	Low	On-going	$20k for a power wall system, plus $500/Kw
28	Implement policy change to replace emergency response equipment used in weather event situations on a more frequent basis.	High	0-12 months	Staff time and resources
29	Protection and maintenance of stockpile facilities, identify locations for future placement.	High	0-12 months	Staff time and resources
30	Evaluate, upgrade and maintain outdoor warning systems	High	On-going	$56,000 per siren to replace; $15,000-20,000 annual maintenance; 17 needing repairs/updates current RFP $1.1M system upgrade over 5 years; $1.5M to encrypt and modernize the system ($3M over 5 years)
31	Purchase and distribure NOAA weather radios.	Medium	0-60 months	Approx. $30 per household with funds when available; additional costs related to staff time to administer the program
32	Initiate an individual safe room program including a rebate program to reimburse for installation of qualified safe rooms and site surveys.	Medium	12-24 months	Sooner Safer Room program provide a $3,000 rebate; $100,000 would fund 33 rebates; Estimate administrative cost of a program (1 person/25%)
33	Maintain safe room inventory and GIS database	High	On-going	Costs related to staff time to maintain the database
	Provide safe rooms at critical facilities.	High	0-60 months	$1M-$2M per safe room depending on the design needs, square footage, and type of facility being served; additional staffing to administer will require $100k per year
	Retrofit critical facilities to withstand hazard events	Medium	0-60 months	Variable

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
25		Severe Winter Storm	Water Systems	TAEMA	Local/General, FEMA HMA, OWRB, EPA	
26		Severe Winter Storm	Food, Hydration, Shelter	TAEMA, American Red Cross	Local/General, FEMA HMA	
27		Severe Winter Storm	Energy	Asset Mgmt.	Local/General, FEMA HMA, EPA	
28		Severe Winter Storm	Safety and Security	TAEMA, All City Departments	Local/General	
29		Severe Winter Storm	Safety and Security	Asset Mgmt., Public Works	Local/General, FEMA HMA	
30	TAEMA has replaced and repaired sirens damaged because of the June 2023 storms, bringing the City's total to 110 sirens. There are 18 sirens approaching obsolescence that will need to be replaced soon.	High Wind/ Tornado, Flood, Dam/Levee Failure	Communication	TAEMA, CoT Information Tech.	Local/General, FEMA HMA	5
31	Funding is needed to implement	High Wind/ Tornado, Flood, Severe Winter Storm	Communication	TAEMA	Local/General, FEMA HMA	6
32	Reworded/updated Action Item; No change, still awaiting funding availability.	High Winds/ Tornado	Food, Hydration, Shelter	TAEMA	Local/General, FEMA HMA	8
33	Database is complete and will be maintained/updated as needed. Database is tracked through Tulsa Fire Department (TFD).	High Winds/ Tornado, Floods	Food, Hydration, Shelter	Development Services	Local/General, FEMA HMA	9
	Action Item was removed and replaced with Action Item #34	High Winds/ Tornado	Food, Hydration, Shelter	CoT Asset Mgmt.	Local/General, FEMA HMA	10
	Removed; 406 Mitigation has been acquired to repair damage to critical facilities.	High Winds, Tornados, Hail, Earthquakes	Energy, Communication, Transportation, Water Systems	CoT Asset Mgmt.	Local/General, FEMA HMA	13

#	Action	Priority	Timeline	Cost
34	Initiate a safe room program for multifamily and group living facilities including a rebate program to reimburse for installation of qualified safe rooms and site surveys.	High	0-60 months	$1M-$2M per safe room depending on the design needs, square footage, and type of facility being served; additional staffing to administer will require $100k per year
35	Partner with schools and university to budget for increased use of cooled facilities for athletic events during peak summer temperatures.	Medium	On-going	$15,000 in addition to staff time and resources
36	Partner with non-government organizations to provide bottled water and cooling devices (e.g., fans) to vulnerable populations during peak summer temperatures.	Medium	On-going	$15,000 in addition to staff time and resources
	Construct additional fire stations in outlying areas.			
37	Continue replacing inadequately sized water lines with lines of sufficient size as an element of both utility replacement and roadway projects whenever inadequate waterlines are identified	Medium	On-going	$12M/yr is invested in water main replacement citywide
38	Implement mitigation actions to reduce fire access issues.	High	On-going	Variable depending on scope and scale of individual projects ($30,000 - $3M)
39	Create a Community Wildfire Protection Plan (CWPP) in cooperation with Oklahoma Forestry Service (OFS) and United States Department of Agriculture (USDA) Forest service; adopt as an addendum to the Multi-Hazard Mitigation Plan	Medium	12-24 months	$25,000
40	Identify areas of urban interface; create and implement a prescribed burn plan. Include in CWPP.	Medium	12-24 months	$10,000
41	Review and update building codes to ensure compliance with National Fire Protection Association (NFPA) recommendations	Medium	0-12 months	Staff time and resources
42	Reduce fire response times to eastside wildfires by building a new fire station in this area of Tulsa.	Medium	0-60 months	Average cost is $750/sqft. Assume $6.0M for a small fire station and equipment.

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
34		High Winds/ Tornado	Food, Hydration, Shelter	CoT Asset Mgmt.	Local/General, FEMA HMA	
35		Extreme Heat	Food, Hydration, Shelter; Health and Medical	TPS, UT, TAEMA	Local/General, FEMA HMA	
36		Extreme Heat	Food, Hydration, Shelter; Health and Medical	Resilient Tulsa, Nongovernment organizations/ local non-profits	Donations, Private Funding	
	Removed	Fire				24
37	Water & Sewer Dept. maintains a Water Main Rehabilitation Risk Map that identifies high-risk/ high-priority water lines in need of replacement, which is updated quarterly.	Fire	Water Systems	Public Works, Water/Sewer	Local	25
38	Reworded/updated Action Item; TAEMA is working with the State and Gilcrease Park to do a control for fire access roads in the park area since they are in the WUI.	Fire	Transportation	Tulsa Fire Department	Local/General, FEMA HMA	26
39		Fire	Safety and Security	TAEMA, TFD	OFS, USDA, HMGP Post-Fire	
40		Fire	Safety and Security	TAEMA	Local/General, OFS, HMGP Post-Fire	
41		Fire	Food, Hydration, Shelter	Fire Marshal (TFD), Development Services, Asset Mgmt.	Local/General, FEMA HMA	
42		Fire	Safety and Security	TFD	Local/General, FEMA HMA, USFWS, EPA	

#	Action	Priority	Timeline	Cost
43	Implement vegetation management programs to reduce the risk of wildfires during drought periods and to prevent fallen trees and branches from occurring during severe winter storms.	Medium	24-36 months	$50,000 - Annual funding for the PPI program
44	Install hail guards for Heating, Ventilation, and Air-Conditioning (HVAC) systems on critical facilities (as appropriate) to protect against severe hail that is greater than ½ inch diameter.	Medium	24-36 months	$25-$50 per square foot plus installation
45	Implement Water Sense Program	Medium	On-going	Staff time and resources for newsletter content/distribution; additional funding needed for administration of the program.
46	Continue replacing broken pipes in areas of high soil expansion with piping more resistant to breakage	Medium	On-going	$12M/yr is invested in water main replacement citywide
47	Maintain and update the City's water and wastewater system master plans as needed	High	On-going	$3M for both water and wastewater plans
48	Require proper foundation design and construction practices to mitigate local conditions such as expansive soils and neighborhood run off.	High	0-12 months	Staff time and resources
49	Introduce a "Healthy Lawns for Stable Soils Program" promoting the selection of turfgrass species and cultivars adapted to Tulsa's environmental conditions.	Med.	12-24 mo.	Staff time and resources
50	Incorporate strategic native trees, shrubs, and other plant materials into plans and regulations for public and private development	Med.	0-12 mo.	Staff time and resources

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
43		Fire, Severe Winter Storm	Safety and Security	TFD	Local/General, FEMA HMA	
44		Hailstorm	Safety and Security	Asset Mgmt.	Local/General, FEMA HMA	
45	TRO Title 11C, Chapter 13 contains the City of Tulsa water use restrictions in time of shortage. Ongoing water conservation is implemented on a voluntary basis. Public outreach program coordinated through CityLife newsletter.	Drought	Water Systems	Water/Sewer	Local/General, FEMA HMA	27
46	The City of Tulsa maintains a Water Distribution System risk map that identifies water mains that are at a higher risk of failure.	Drought, Extreme Heat, Expansive Soils	Water Systems, Energy	Water/Sewer	Local/General, FEMA HMA	28
47	The City of Tulsa and TMUA are currently updating the Water and Wastewater Comprehensive Plan. Plans are reviewed and revised every 10 years.	Drought	Water Systems	Public Works, Water/Sewer	Local/General, FEMA HMA, EPA	
48		Expansive Soils	Safety and Security	Code Enforcement/ Development Services	Local/General, FEMA BRIC, HMGP, and HMGP Post- Fire	
49		Expansive Soils	Water Systems, Food, Hydration, Shelter	Parks and Recreation, Development Services, OSU Cooperative Extension	Local/General, FEMA HMA, OSU Extension	
50		Expansive Soils, Subsidence, Erosion	Health and Medical	Parks and Recreation, Development Services, Tulsa Planning Office, OSU Ag Extension	Local/General, FEMA HMA, NRCS	

#	Action	Priority	Timeline	Cost
51	Maintain a list of species that homeowners/ property landscapers can reference when developing landscape plans	Low	0-12 mo.	Staff time and resources
52	Implement an educational campaign with a mixture of media to share small tasks that the everyday person can take to mitigate expansive soils, subsidence	Med.	0-12 mo.	$50,000 - Annual funding for the PPI program
53	Construct lightning rods or air terminals for protection of critical facilities.	High	24-36 mo.	$5000 per air terminal plus installation costs
54	Increase public awareness about seismicity. This may involve public information campaigns and outreach efforts to educate residents about the risks and how to stay safe during seismic events.	Low	0-36 months	$25k and Staff time and resources
55	Consider a program to stabilize irreplaceable art pieces in museums, highly susceptible to damage from even minor earthquake events.	Low	36-60 months	Variable depending on scale and type of artwork and location ($30,000 - $3M)
56	Take measures to protect against cyber criminals; backup and update IT systems.	Medium	On-going	Staff time and resources
57	Follow the Recommendations of the Eucha Dam Anchoring and Concrete Repairs, TMUA-W 190-01, Preliminary Engineering Report, first major component, to provide stability improvement to the three sections consisting of post-tensioned anchors.	High	0-60 months	The City of Tulsa just opened bid for a major construction project to install anchors at the Eucha Dam to increase its resilience. This is a $25M investment with a 2-year construction schedule.
58	Provide an assessment and repairs of the downstream concrete surfaces of the Eucha Dam.	Medium	48-60 months	Project will not commence before 2029; cost estimate TBD

Additional columns continued on next page →

#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
51		Expansive Soils, Subsidence, Erosion	Health and Medical	Parks and Recreation, Development Services, OSU Ag Extension	Local/General, FEMA HMA	
52		Expansive Soils, Subsidence, Erosion	Communication	Development Services; CoT Communications, PPI Committee	Local/General, FEMA HMA	
53	No significant changes or progress to report.	Lightning	Energy, Communication, Water Systems	CoT Asset Mgmt.	Local/General, FEMA HMA	16
54		Earthquake	Communication	Public Works, PPI, CoT Communication, LEPC (local emergency planning committee)	Local/General, FEMA HMA,	
55	Coordinate with the Gilcrease Museum; where possible incorporate appropriate elements of the facility's risk management or disaster preparedness plans into the city-wide disaster recovery and reconstruction plan.	Earthquake	Safety and Security	Tulsa Historical Society and Museum	Local/General, FEMA HMA	
56		Ransomware	Safety and Security, Communication	Tulsa IT	Local/General, FEMA BRIC	
57	Adopted with 2023 HHPD Amendment addressing Spavinaw Lake Dam and Eucha Dam	Dam/Levee Failure	Safety and Security, Water Systems	City of Tulsa/ Tulsa Municipal Utility Authority	Local/General, FEMA HHPD	30
58	Adopted with 2023 HHPD Amendment addressing Spavinaw Lake Dam and Eucha Dam; description updated to reflect planned project	Dam/Levee Failure	Safety and Security, Water Systems	City of Tulsa/ Tulsa Municipal Utility Authority	Local/General, FEMA HHPD	31

#	Action	Priority	Timeline	Cost
59	Develop a contingency plan for a scenario where the Spavinaw and Lake Eucha water sources are lost due to catastrophic failure for the City of Tulsa, including alternative water sources, costs of development, and implementation processes.	Medium	0-60 months	
	Update the EAPs for Eucha and Spavinaw to include impacts on the specific size and nature of populations affected by a closure of Mohawk Water Treatment Plant due to loss of water delivery to this facility from Spavinaw and Eucha reservoirs because of catastrophic failure of the dams.	Medium	0-60 months	
	Provide a study with recommendations to repair Spavinaw Dam based on deficiencies identified in the annual dam inspection reports, to include other potential catastrophic failure scenarios.	Medium	0-60 months	

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#	Status (if applicable)	Hazard Addressed	Lifeline	Responsible Agency	Potential Resources	2019 Action Item
59	"Tulsa is currently completing the Comprehensive Plan for the Water System. The plan will review future water demand, source water supplies, and recommend improvements. Tulsa has two primary water sources, one emergency water source, and one future water source. In addition, there are two flow lines from each water source, and water can be moved from Lake Oologah to the Mohawk WTP. Both plants have terminal storage for up to 30 days of water supply. Spavinaw Dam has already been anchored to resist the current probable maximum flood, and the overall system capacity is two times the average day base demand."	Dam/Levee Failure	Safety and Security, Water Systems	City of Tulsa/ Tulsa Municipal Utility Authority	Local/General, FEMA HHPD	32
	Remove; EAPs are current for both dams. The Emergency Operation Plans for Eucha and Spavinaw are reviewed annually and updated as needed. The current plan was last updated in November 2023.	Dam/Levee Failure	Safety and Security, Water Systems	City of Tulsa/ Tulsa Municipal Utility Authority	Local/General, FEMA HHPD	33
	Remove; A professional engineer inspects the Eucha and Spavinaw dams annually following the OWRB rules. Annual dam inspections cover the current condition and maintenance requirements to maintain the dams in safe condition. Maintenance tasks identified are completed within 12 months. If capital improvements are identified, they are incorporated into a business case and funded as part of the water capital improvement program. The City has also incorporated satellite monitoring into our annual dam safety program. Monthly reports are provided on dam movement and vegetation.	Dam/Levee Failure	Safety and Security, Water Systems	City of Tulsa/ Tulsa Municipal Utility Authority	Local/General, FEMA HHPD	34

5.4 Financial Assistance for Hazard Mitigation Actions

The Federal Emergency Management Agency (FEMA) administers the Hazard Mitigation Assistance (HMA) program, which includes several grant funding opportunities for eligible natural hazard mitigation measures, projects, plans, and activities. Eligibility can be found in the Hazard Mitigation Assistance Program and Policy Guide (HMAPPG), March 23, 2023.

The funding opportunities include the following:

- Hazard Mitigation Grant Program (HMGP)
- Hazard Mitigation Grant Program (HMGP) Post-Fire
- Building Resilient Infrastructure and Communities (BRIC)
- Flood Mitigation Assistance (FMA)
- Flood Mitigation Assistance (FMA) Swift Current

Hazard Mitigation Grant Program (HMGP)

HMGP funding is authorized with a Presidential Major Disaster Declaration. The amount of funding made available to the applicant (state or tribe) is based on the estimated total federal assistance, generally 15%. This program is authorized under Section 404 of the Stafford Act.

Hazard Mitigation Grant Program (HMGP) Post-Fire

HMGP Post Fire funding is authorized under Sections 404 and 420 of the Stafford Act and provides hazard mitigation grant funding to State, Local, Tribal, and Territorial (SLTT) governments in areas receiving a Fire Management Assistance Grant (FMAG) declaration.

Building Resilient Infrastructure and Communities (BRIC)

FEMA funds BRIC with a 6% set-aside from federal post-disaster grant funds, such as Public Assistance and Individual Assistance grants. As a competitive grant program, SLTT applicants can apply annually. BRIC is authorized under Section 203 of the Stafford Act.

Flood Mitigation Assistance (FMA)

Flood Mitigation Assistance (FMA) grants provide funding to SLTT governments to reduce or eliminate the risk of repetitive flood damage to buildings insured under the National Flood Insurance Program (NFIP). The program is authorized by Section 1366 of the National Flood Insurance Act.

BRIC and FMA funding depend on the amount Congress appropriates annually for those programs. Individual homeowners and business owners may not apply directly to FEMA. Eligible local governments may apply on their behalf.

Flood Mitigation Assistance (FMA) Swift Current

The Flood Mitigation Assistance Swift Current (Swift Current) effort provides funding to mitigate repetitively and substantially flood-damaged buildings insured through the National Flood Insurance Program after a presidentially declared flood-related disaster to reduce risk against future flood damage. Funds will be made available to states, territories, and federally recognized tribal governments that receive a major disaster declaration following a flood-related disaster event and meet all other eligibility criteria. Swift Current was made possible through the Bipartisan Infrastructure Law (BIL).

The intent of this section is to identify projects contained in the City of Tulsa Capital Improvements Program or Master Drainage Program and eligible for FEMA Hazard Mitigation Assistance. The list may be expanded as additional projects are identified. Implementation will be based on the availability of funds.

Sub-applications submitted for federal grant funding must meet the minimum eligibility criteria for all submittals as outlined in 2 CFR Part 200. All sub-applications submitted must include, but are not limited to, a scoping narrative (scope of work, work schedule, and detailed cost estimate) and forms. All mitigation project sub-applications must also include proof of cost-effectiveness, feasibility and effectiveness, and documentation of compliance with Environmental and Historic Preservation (EHP) laws and forms. If there is insufficient information to submit a sub-application, Tulsa should consider applying for Project Scoping/Advance Assistance through BRIC, FMA, or HMGP/HMGP Post-Fire. Eligible activities for Project Scoping/Advance Assistance include the following:

- Scoping and developing hazard mitigation projects, including engineering design and feasibility studies. Physical work (e.g., soil tests) associated with these studies is generally eligible.
- Conducting meetings, outreach, and coordination with potential sub-applicants and community residents to identify potential future mitigation projects.
- Evaluating facilities or areas to determine appropriate mitigation actions.
- Incorporating environmental planning and historic preservation considerations into project planning activities.
- Collecting data for Benefit-Cost Analyses, environmental compliance, and other program requirements.
- Conducting hydrologic and hydraulic studies for unmapped flood zones or other areas where communities propose to submit hazard mitigation projects.
- Coordinating, scoping, and developing regional or multi-community hazard mitigation projects that require coordination to cohesively address resilience and sustainability goals.
- Using third-party cost estimation services for project budgeting across sub-applications.
- Contracting services to address data consistency needs for other project application categories, such as EHP, cost-sharing mechanisms, and work schedules.
- Coordinating with property owners of substantially damaged structures to review project alternatives and provide engineering and design support to bring structures into compliance with appropriate building code standards.

CHAPTER 6
PLAN ADOPTION & MAINTENANCE

6.1 Introduction

This chapter includes a discussion of the plan maintenance process and documentation of the adoption of the plan by the Tulsa City Council. The City of Tulsa will ensure that a regular review and update of the Multi-Hazard Mitigation Plan occurs. The Stormwater Drainage and Hazard Mitigation Advisory Board (SDHMAB) will continue to meet monthly to oversee and review updates and revisions to the plan. The City of Tulsa Lead Engineer and Stormwater Projects Coordinator will continue to head the Program for Public Information and oversee the day-to-day implementation of the plan. The plan will be updated and resubmitted to the state and FEMA for approval prior to the 5-year approval period expiration, as per FEMA requirements.

6.1.1 Monitoring the Plan

Monitoring of the plan, the action plan, and mitigation measures is the responsibility of the Emergency Manager, Special Projects Engineer, and Floodplain Administrator. Departments responsible for implementation of the action plan and the mitigation measures will update their progress reports on an annual basis, and report to the SDHMAB on progress and/or impediments to the mitigation measures.

6.1.2 Evaluating the Plan

The City of Tulsa will use a continuous improvement approach to continually monitor and evaluate the Multi-Hazard Mitigation Plan. The City of Tulsa Special Projects Engineer will lead the evaluation process and provide monthly updates to the SDHMAB. Evaluation will include both routine maintenance and incident response tasks as outlined below.

Routine Maintenance

Annually, a comprehensive review of the plan will be conducted to determine the following:

1. Are adopted goals and objectives still adequate to address current and future expected conditions?
2. Has the nature or magnitude of risks changed?
3. Are adequate resources allocated for implementation of the plan?
4. Have outcomes of mitigation strategies occurred as expected? Have risks been reduced?
5. Are agencies, departments and community partners participating as anticipated?
6. What progress has been made towards implementation?
7. Are all recommended mitigation actions still relevant and necessary?

Incident Response

Review mitigation actions related to specific hazards when they occur to assess the effectiveness of implementation measures and improve future responses. The Special Projects

Engineer, in coordination with the Emergency Management Director will develop a post-incident report to be provided to the SDHMAB following incidents documenting the occurrence, its impact on the community and any recommendations regarding the adopted Multi-Hazard Mitigation Plan. Others may be selected to participate in the development of this report based on subject matter expertise and knowledge of the incident. Consideration should be given to the list of questions below to inform the SDHMAB discussion and any recommended actions to improve future outcomes.

1. Will implementation of the Plan's mitigation action(s) improve outcomes from future occurrences of this hazard?
2. Should any action items be elevated in priority?
3. Should the City update responsible parties, estimated cost and timeline, related to any of the mitigation actions?
4. Are additional or modified mitigation actions needed to prevent or mitigate future occurrence of this hazard?
5. Should different notification or follow-up actions be taken to address future incidents? If so, what are they?

6.1.3 Updating the Plan

The Special Projects Engineer will initiate the plan update in coordination with the Emergency Management Director, the SDHMAB and other City departments and partners. The City of Tulsa Multi-Hazard Mitigation Plan will be updated according to the following schedule:

- Revise and Update - the City will incor¬porate revisions to the plan document identified during the monitoring and evaluation period (annually and following each declared emergency event), as well as items identi¬fied in the previous Planning Tool.
- Submit for Review - the revised plan will be submitted to OEM and FEMA through the State Hazard Mitigation Officer for review and approval, and to FEMA no later than six (6) months prior to the plan expiration date.
- Final Revision and Adoption - if neces¬sary, the plan will be revised per OEM and FEMA remarks, adopted by the Tulsa City Council, and the updated plan sent to FEMA prior to the expiration of the 5-year approval period.

6.1.4 Public Involvement

The City of Tulsa is committed to involving the public directly in updating and maintaining the Multi-Hazard Mitigation Plan. Copies of the plan will be maintained at the public library, and the plan will be placed on the website of the City of Tulsa.

Small area-specific meetings will be held on no less than a semi-annual basis at public libraries or other public venues. A public meeting will be held prior to submission of the update of the City of Tulsa Multi-Hazard Mitigation Plan. This meeting will be advertised to the general citizenry. This meeting will be held to update citizens on the progress that has been made in implementing the plan and related capital projects. The meetings will also be used to distribute literature and inform and educate citizens as to actions they can take to mitigate natural hazards, save lives, and prevent property damage. Input from the citizens will be solicited as to how the mitigation process can be more effective.

The City of Tulsa established the Program for Public Information (PPI) for CRS credit. The program focuses on outreach projects and other types of information delivery under the following activities:

- Activity 330 (Outreach Projects),
- Activity 340 (Hazard Disclosure),
- Activity 350 (Flood Protection Information),

- Activity 360 (Flood Protection Assistance),
- Activity 420 (Open Space Preservation), educational materials in natural areas, and
- Activity 540 (Drainage System Maintenance), publicizing dumping regulations.

Target areas are focus areas or priority areas in Tulsa with concerns related to floods, floodplains, and other hazards. The areas include parts of the community with similar flooding, building, and population characteristics. The PPI committee works closely with the Department of City Experience to ensure the public is educated about the various hazards that may impact them. These outreach efforts allow for the general public to be involved with the hazard mitigation efforts in Tulsa on an ongoing basis.

6.1.5 Incorporating the Multi-Hazard Mitigation Plan

The Hazard Mitigation Planning Committee recognizes the importance of fully integrating hazard mitigation planning and implementation into existing local plans, regulatory tools, and related programs; this process was used for the integration of the 2019 City of Tulsa All Hazard Mitigation Plan.

The City of Tulsa's local planning mechanisms available for incorporating the recommendations and requirements of the Hazard Mitigation Measures are listed below. The Project Manager and PPI Committee will ensure annual review of specific plans, ordinances, and codes identified in Chapter 3, to incorporate the requirements of this plan and hazard mitigation practices into those documents whenever feasible.

The City of Tulsa Multi-Hazard Mitigation Plan will be adopted by the Tulsa Metropolitan Area Planning Commission and the Tulsa City Council as an amendment to the City's Comprehensive Plan. The Tulsa City Council will adopt the plan as a guide to City mitigation activities. Appropriate action items and mitigation measures from the plan will be incorporated into the following plans and codes:

- Capital Improvements Plan
- City of Tulsa Building Code
- Tulsa Emergency Operations Plan
- City of Tulsa Water and Sewer Plan
- City of Tulsa Comprehensive Plan
- City of Tulsa Zoning Code
- City of Tulsa Subdivision and Development Regulations

The Stormwater Drainage and Hazard Mitigation Advisory Board, in conjunction with the PPI Committee, will oversee the implementation of this plan once adopted. The process to include the adopted mitigation measures in other local planning mechanisms includes the following:

- Mitigation measures will be assigned to the appropriate departments for planning and implementation.
- The responsible departments will report the progress made on each measure, identifying successes and impediments to their implementation to the PPI Committee.

APPENDIX A: Planning Team

The team assembled to direct the City of Tulsa 2024 Multi-Hazard Mitigation Plan Update included a Planning Team from the City of Tulsa, shown in Table A-1, formed to coordinate planning efforts and request input and participation in the planning process. Table A-2 includes the current members of the City of Tulsa appointed Storm Drainage Hazard Mitigation Advisory Board (SDHMAB). Resolution #20258 designated the SDHMAB to serve as the Citizen's Advisory Committee for this plan update. Public outreach efforts, a list of participating stakeholders, and meeting documentation is provided in Appendix E.

Table A-1: City of Tulsa Planning Team

Joan Gausvik	Planning and Asset Manager
Gary McCormick	Senior Special Projects Engineer
Joe Kralicek	Tulsa City/County Director of Emergency Management
Lara Weber	Communications Team
Eric Lee	Director, Water and Sewer
Terry Ball	Director, Public Works
Michael Skates	Director, Development Services
Michael Ling	Floodplain Administrator
Kian Kamas	Executive Director, Partner Tulsa
James Wagner	Director, City Experience
Krystal Reyes	Mayor's Office of Resilience and Equity

Table A-2: SDHMAB Committee Members

Dr. Anna Childers, PhD.	Benham Design
Dr. David Williams, PE	USACE
Kyle Brierly, Owner	Roto-Rooter
Steve Walman, Owner/Broker	Walman Commercial
Michael Grogan, Meteorologist	Fox 23 Tulsa

Table A-3: Consultants

Dawn Warrick, AICP	Freese and Nichols
Dave Van De Weghe, AICP	Freese and Nichols
Shobha Pathmanathan	Freese and Nichols
Jake Lange	Freese and Nichols
Barrett Waller	Propeller Consulting
Jesse Boudiette	Propeller Consulting

APPENDIX B: Critical Facilities

Table B-1: Critical Facilities

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
1	AB Jewell Water Treatment Plant	18707 E 21st St	Lynn Lane Dam Inundation Area		
2	Bird Creek #2 Pump Station	17111 E 46th St N			
3	Bird Creek 5mg Storage Tank	17111 E 46th St N			
4	Bishop Tract Detention Basin	3600 S 103rd E Ave		AE	Y
5	Mohawk Water Treatment Plant	3800 E Mohawk Blvd	Skiatook Dam Breach Inundation Area		
6	Permit Office	West of Hwy 10-59 - 5 Mi. S of			
7	Permit Office/water Plant/Lab/Shop	401 E Lake Ave			
8	Reservoir Manager Residence	402 E Lake Ave			
9	Sampling Station Ind. Pre-treatment	E 54th Stat Mingo Creek			
10	Sampling Station Ind. Pre-treatment	58th St & Mingo Creek			
11	Sewage Pump Station	16th Pl. & West Bank River --			
12	Shop Area	East of Hwy 10-59 - 5 Mi. S of			
13	Storm Water Pump Station	5665 N 105th E Ave	Skiatook Dam Breach Inundation Area		
14	Storm Water Storage	5665 N 105th E Ave	Skiatook Dam Breach Inundation Area		
15	Tower Site	Top of FNB			
16	Tower Site	Top of FNB - Fire, Police, Comm			
17	Tower Site	11707 East 31st St			
18	Tower Site	7310 East 71st St			
19	Tower Site	21st & Louisville Water Tank An			
20	Tower Site	7429 S Lewis Ave	Keystone Dam Breach Inundation Area		
21	Tower Site	14333 East 11th St			
22	Tower Site	2404 West 51st St N			
23	Tower Site - Communications	6650 E 61st St			
24	Tower Site/Building - Pryor	2080 S New Haven Ave			
25	Jennifer Massey	7915 E. 17th St.			
26	Kelly Caldwell	5434 E. 91st Street			
27	Carol McClure	6161 S. Yale			
28	Sandy Randolph	6730 S. Sheridan Rd.			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
29	Patty Banes	1301 S. Boston Ave			
30	Ramona Rogers	2131 E. 31 Pl. N.			
31	Laurie Pearn	3515 S. Harvard Ave.			
32	RoseMarie Was	3434 S. Garnett Road			
33	Debbie Guilfoyle	2501 East Archer			
34	Lisa Carter	5085 S. 76th East Ave.			
35	Karen Howard	2437 S. Sheridan			
36	Sue Wooldridge	2327 S. Darlington			
37	Melissa Robins	11610 East 25th St.			
38	Judy Landers	1115 S. Boulder			
39	Debra Axton	14002 E. 21st St., Ste. 300			
40	Mindy Burkhardt	913 S. Boulder			
41	Marcus Paul	203 West 28th Street North			
42	Shannon/Robyn	12000 E. 31st St.			
43	Clara Gray	1121 S. Victor			
44		8304 S. 107th East Ave.			
45	Maria Alcaraz	2510 E Admiral Blvd			
46	Nia Stokes	8925 S. Harvard			
47	Stephanie Taylor	2929 E. 31st St.			
48	Christie Gilbert	3515 S. Harvard			
49	Kim Baker	5110 East 71st St. S.			
50	Kim Hopkins	11633 E. 31st St. South			
51	Carolyn Monroe	12928 E. 43 Pl. S.			
52	Ronda Osborn	9625 S. Mingo Rd.			
53	Mary Pettine	4102 E. 61st St.			
54	Donna Terry	2906 E. Third			
55	Lisa Ctr	1950 S. 131st East Ave.			
56	Jerome Smith	1231 N. Harvard			Y
57	Lisa Forbes	6150 S. Yorktown	Keystone Dam Breach Inundation Area		
58	Gregoria Garcia	8119 East 12th Street			
59	Jayme Wingo-Martin	4849 S. Mingo			
60	Jeanette Tankersley	1470 W. 41st St.	Keystone Dam Breach Inundation Area	X	
61	Pam Summers	10940 E. 5th Ave.			
62	Jeanette Easterling	2433 W. 61st St.			
63	Brandy Gage	6605 E. 93rd Street			
64	Carolyn Gates	10310 S. Sheridan			
65	Judy Priebe	1710 E. 17th St.			Y
66	Sasha Reedy	2004 E. 22nd Pl.			Y

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
67	Pamela Goodwin	501 S. Cincinnati Ave.			
68	Amy Fain	2511 E. 5th Pl. S			
69		7700 S. Lewis	Keystone Dam Breach Inundation Area	X	
70	Cara Thomas	7700 S. Lewis Ave.	Keystone Dam Breach Inundation Area	X	
71		7700 S Lewis	Keystone Dam Breach Inundation Area	X	
72	Collette Sawyer	5511 S. Harvard			
73	Joyce Cooper	PO BOX 481018			
74	Beth Jennings	455 S. Memorial			
75	LaDawna Knighten	5424 N. Madison Ave.			
76	N Gordon	1910 S. Lewis			Y
77	City Garage	1720 W Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
78	River Parks Authority	707 S Houston Ave, S 510			
79	Tulsa Convention Center	100 Civic Center			
80	City Garage	1720 W Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
81	City Of Tulsa (City Hall)	200 Civic Center Plaza			
82	River Parks Authority	707 S Houston Ave, S 510			
83	Tulsa Convention Center	100 Civic Center			
84	Tulsa Performing Arts Center	110 E 2nd St			
85	Community Service Council - Tulsa	16 E 16th St			
86	Tulsa Transit	510 S Rockford Ave			
87	Juvenile Delinquency Project	315 S Gilcrease Museum Rd	Keystone Dam Breach Inundation Area	X	Y
88	PSRC Tower	911 Bldg - 600 Civic Center			
89	Communication Area For Fire Dept	1712 S Phoenix Ave	Keystone Dam Breach Inundation Area	X	
90	Fire Dept Dog Kennel	1760 Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
91	Fire Station #9	1420 Charles Page Blvd	Keystone Dam Breach Inundation Area	X	
92	Garage & Fuel Facility	1720 Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
93	Tulsa Fire Department #10	508 E Pine St			
94	Tulsa Fire Department #11	5009 E 15th St			
95	Tulsa Fire Department #12	3123 W 40th St			
96	Tulsa Fire Department #13	345 S 41st W Ave	Keystone Dam Breach Inundation Area	X	Y

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
97	Tulsa Fire Department #14	3602 S Lewis Ave			
98	Tulsa Fire Department #15	4168 E Admiral Pl			
99	Tulsa Fire Department #16	1401 N Lewis Ave			
100	Tulsa Fire Department #17	1351 N Sheridan Rd			
101	Tulsa Fire Department #18	4802 S Peoria Ave	Keystone Dam Breach Inundation Area	X	
102	Tulsa Fire Department #19	509 E 56th St N			
103	Tulsa Fire Department #2	524 W Edison St			
104	Tulsa Fire Department #21	4606 E 31st St			
105	Tulsa Fire Department #22	616 S 73rd E Ave		AE	Y
106	Tulsa Fire Department #23	4348 E 51st St			
107	Tulsa Fire Department #24	3520 N Peoria Ave			
108	Tulsa Fire Department #25	7419 E 42nd Pl			
109	Tulsa Fire Department #26	2404 W 51st St			
110	Tulsa Fire Department #27	11707 E 31st St			
111	Tulsa Fire Department #28	7310 E 71st Street			
112	Tulsa Fire Department #29	7429 S Lewis Ave	Keystone Dam Breach Inundation Area		
113	Tulsa Fire Department #3	62 N Utica Ave			
114	Tulsa Fire Department #30	14333 E 11th St			
115	Tulsa Fire Department #31	3002 N Mingo Rd			
116	Tulsa Fire Department #32	6010 E 91st St			
117	Tulsa Fire Department #4	524 W 12th St			
118	Tulsa Fire Department #5	102 E 18th St			
119	Tulsa Fire Department #51 (Airport)	Taxiway Echo & Bravo			
120	Tulsa Fire Department #6	7212 S Union Ave			
121	Tulsa Fire Department #7	601 S Lewis Ave			
122	Tulsa Fire Department Hazardous Mtls	1420 W Charles Page Blvd	Keystone Dam Breach Inundation Area	X	Y
123	Tulsa Fire Department Hdqtrs	411 S Frankfort Ave			
124	Tulsa Fire Department Supply	1790 Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
125	Tulsa Fire Department Training	1760 Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
126	Tulsa Fire Dept (Alarm Office/tower)	1010 E 8th St			
127	Fuel Island - UDN	3411 N Columbia Ave			
128	Fuel Island - UDSW	7515 S Riverside Dr	Keystone Dam Breach Inundation Area	X	
129	Tulsa Police Department (Courts Bldg)	600 Civic Center			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
130	Tulsa Police Department Support Division	5963 E 13th St			
131	Tulsa Police Department Training Facility	6066 E 66th St N			
132	Tulsa Police Dept (North Div)	3411 N Columbia			
133	Tulsa Police Dept (East Div)	10122 E 11th St			
134	Tulsa Police Dept (Southwest Div)	7515 Riverside Dr	Keystone Dam Breach Inundation Area	X	
135	Tulsa Police Dept Seized Vehicle Facility	1326 E Mohawk Blvd			
136	Tulsa Police Offices Street Level	600 Civic Center			
137	Chemical Storage Building	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
138	Equipment Maintenance	5625 S Garnett Rd			
139	Equipment Management	1720 Newblock Park Dr	Keystone Dam Breach Inundation Area	X	Y
140	Field Customer Services	2445 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
141	Fuel Facility	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
142	Portable Building	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
143	Satellite Fuel Station	1747 S 101st E Ave			
144	Storage Shed	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
145	Street Dept Garage/Offices	5675 S Garnett Rd			
146	Structural Maintenance	1712 Charles Page Blvd	Keystone Dam Breach Inundation Area	X	Y
147	Surplus Facility	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
148	Tire Shop	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
149	W&M South Yard Storage Building	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
150	W&M South Yard Office/stock Building	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
151	Warehouse/Materials Stockroom	2317 S Jackson Ave	Keystone Dam Breach Inundation Area	X	
152	Water District Office/Warehouse	5605 S Garnett Rd			
153	USPS - Downtown Post Office	333 W 4th St Fl 1			
154	USPS - Northside Post Office	626 E Apache St			
155	USPS - Tulsa AMF Retail	2161 N Cargo Rd, Ste A			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
156	USPS - Northeast Post Office	5313 E Independence St			
157	USPS - Univ. of Tulsa Post Office	University of Tulsa			
158	USPS - Westside Post Office	3408 W 42nd Pl			
159	USPS - Donaldson Post Office	1423 Terrace Dr			
160	Post Office - CPU American Heritage Bank	7042 S Union Ave			
161	USPS - Robert Jenkins Post Office	6910 S Yorktown Ave	Keystone Dam Breach Inundation Area		
162	USPS - Sheridan Tulsa Post Office	6110 E 51st Pl			
163	USPS - Southeast Tulsa Post Office	9023 E 4th St			
164	USPS - Eastside Tulsa	2920 S 129th East Ave			
165	FBI - Tulsa	8023 E 63rd Pl			
166	NOAA - NWS	10159 E 11th St			
167	USACE	2488 E 81st St			
168	Internal Revenue Service	8023 E 63rd Pl #400			
169	USPS - Postage Handling Facility	2132 S 91st E Ave			
170	ATF	125 W 15th St #600			
171	Secret Service	125 W 15th St #400			
172	US Attorney	110 W 7th St			
173	Oklahoma State Univeristy - Tulsa	700 N Greenwood Ave			
174	Tulsa Community College - Metro Campus	909 S Boston Ave			
175	OSU College of Osteopathic Medicine	1111 W 17th St	Keystone Dam Breach Inundation Area	X	
176	University of Tulsa	800 S Tucker Dr			
177	Tulsa Community College - Northeast Campus	3727 E Apache St			
178	Tulsa Technology Center - Peoria	3850 N Peoria Ave			
179	Tulsa Technology Center - Lemley Campus	3420 S Memorial Dr			
180	Oral Roberts University	7777 S Lewis Ave			
181	Tulsa Community College - Southeastern Campus	10300 E 81st St			
182	Tulsa Community College - Conference Center	6111 E Skelly Dr			
183	Tulsa Technology Center - Skyline	6111 E Skelly Dr			
184	Tulsa Community College - Riverside	801 E 91st St	Heyburn & Keystone Dam Breach Inundation Area	X	
185	(Jenks) East Elementary School	8925 S Harvard Ave			
186	(Jenks) Southeast Elementary School	10222 S Yale Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
187	Jenks Middle School (Ind. Dist. No.5)	3019 E 101st St	Keystone Dam Breach Inundation Area	X	
188	(Jenks) East Intermediate School	3933 E 91st St			
189	American Bank & Trust Corp	6100 S Yale Ave			
190	American TrustCorp	5727 S Lewis Ave	Keystone Dam Breach Inundation Area		
191	Bank of Oklahoma Tech. Center	6424 E 41st St			
192	Bank South of Tulsa	6130 E 81st St			
193	Oklahoma Central Credit Union	11335 E 41st St			
194	ONB Bank & Trust Co.	8908 S Yale Ave			
195	Triad Bank NA	7666 E 61st St			
196	Tulsa Valley Bancshares	8080 S Yale Ave			
197	Tulsa National Bancshares	7120 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
198	Trust Co of Oklahoma	7120 S Lewis Ave			
199	National Bank of Commerce	7127 Riverside	Keystone Dam Breach Inundation Area	X	
200	Sooner Southwest Bankshares	1751 E 71st St	Keystone Dam Breach Inundation Area	X	
201	Tulsa Teachers Credit Union	3720 E 31st St			
202	F & M Bank Trust Co	1330 S Harvard Ave			
203	Bank of Oklahoma	1 Wiliams Ctr			
204	BOK Financial Corp	Bank of Oklahoma Tower			
205	Energy One Federal Credit Union	220 W 7th			
206	Peoples State Bank Inc	445 S Lewis Ave			
207	Red Crown Federal Credit Union	509 S Boston			
208	Tulsa Federal Employees Credit Union	401 E 4th			
209	Bishop Kelly High School	3905 S Hudson Ave			
210	Cascia Hall Prepatory School	2520 S Yorktown Ave			
211	Evangelistic Temple School	1339 E. 55th St	Keystone Dam Breach Inundation Area	X	
212	Happy Hands Educational Center	5717 E 32nd St			
213	Holland Hall	5666 E 81st St			
214	Holy Family Cathedral School (Diocese of Tulsa)	820 S. Boulder Ave			
215	Lincoln Christian School	1003 N 129th E Ave			
216	Little Light House	5120 E 36th St			
217	Marquette Catholic School	1519 S Quincy Ave			
218	Metro Christian Academy	6363 S Trenton Ave	Keystone Dam Breach Inundation Area		
219	Mingo Valley Christian School	8720 E 61st St.			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
220	Monte Cassino School	2206 S Lewis Ave			
221	ORU eAcademy	7777 S Lewis Ave			
222	Oklahoma Job Corps Academy	1133 N Lewis Ave			
223	Peace Academy	4620 S Irvington Ave			
224	Riverfield Country Day School	2433 W 61st St		AE	
225	School of Saint Mary	1365 E 49th Pl	Keystone Dam Breach Inundation Area	X	
226	Southpark Christian School	10811 E 41st St			
227	Saint Catherine Catholic School	2515 W 46th St			
228	St. Pius X Catholic School	1717 S 75th E Ave			
229	Sts. Peter & Paul School	1428 N 67th E Ave			
230	Town & Country School	8906 E 34th St			
231	Tulsa Adventist Jr. Academy	900 S New Haven Ave			Y
232	Victory Christian School	7700 S Lewis Ave	Keystone Dam Breach Inundation Area	AE	
233	Wright Christian Academy	11391 E Admiral Pl			
234	Aldersgate Learning Center (Christian Montessori Academy)	3702 S 90th E Ave			
235	Asbury United Methodist Weekday Preschool	6767 S Mingo Rd			
236	Bethany Christian School	6730 S Sheridan Rd			
237	Boston Avenue Weekday School	1301 S Boston Ave			
238	Christ the Redeemer Lutheran Church	2550 E 71st St			
239	Christview Christian Church	2525 S Garnett Rd			
240	Early Learning Center - Christ UMC	3515 S Harvard Ave			
241	Oklahoma Air National Guard - 138th Fighter Wing	9100 E 46th St N			
242	Oklahoma Highway Patrol - Troop B HQ	9191 E Skelly Dr			
243	Medical Examiner	1627 Southwest Blvd	Keystone Dam Breach Inundation Area	X	
244	Dept. of Human Services	4848 S 129th E Ave			
245	Ok. State Office Building				
246	Addams Elementary School	5323 S 65th West Ave			
247	Alcott Elementary School	525 E 46th St North			
248	Anderson Elementary School	1921 E 29th St North			
249	Zarrow International School	2714 S 90th East Ave			
250	Barnard Elementary School	2324 E 17th St			
251	Bell Elementary School	6304 E Admiral			
252	Bryant Elementary School	6201 E Virgin St			
253	Bunche Early Childhood Development	2703 N Yorktown Pl			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
254	Burroughs Elementary School	1924 N Cincinnati Ave			
255	Carnegie Elementary School	4309 E 56th St			
256	Cherokee Elementary School	6001 N Peoria Ave			
257	Chouteau Elementary School	575 N 39th West Ave			
258	Celia Clinton Elementary School	1740 N Harvard Ave			
259	Columbus Elementary School	10620 E 27th St			
260	Cooper Elementary School	1808 S 123rd East Ave			
261	Disney Elementary School	11702 E 25th St			
262	Eisenhower International School	2819 S New Haven Ave			
263	Eliot Elementary School	1442 E 36th St	Keystone Dam Breach Inundation Area		
264	Emerson Elementary School	909 N Boston Ave			
265	Eugene Field Elementary School	2249 S Phoenix Ave	Keystone Dam Breach Inundation Area	X	
266	Greeley Elementary School	105 E 63rd St North			
267	Grimes Elementary School	3213 E 56th St			
268	Hawthorne Elementary School	1105 E 33rd St North			
269	Hoover Elementary School	2327 S Darlington Ave			
270	Houston Elementary School	5402 N Cincinnati Ave			
271	Jackson Elementary School	2137 N Pittsburg Ave			
272	Kendall-Whittier Elementary School	2601 E 5th Pl			
273	Kerr Elementary School	202 S 117th East Ave			
274	Key Elementary School	5702 S Irvington Ave			
275	Lanier Elementary School	1727 S Harvard Ave			
276	Lee Elementary School	1920 S Cincinnati Ave			
277	Lindbergh Elementary School	931 S 89th East Ave			
278	Mark Twain Elementary School	541 S 43rd West Ave	Keystone Dam Breach Inundation Area	AE	
279	Marshall Elementary School	1142 E 56th St	Keystone Dam Breach Inundation Area	X	
280	MacArthur Elementary School	2182 S 73rd East Ave			
281	McClure Elementary School	1770 E 61st St	Keystone Dam Breach Inundation Area		
282	McKinley Elementary School	6703 E King Ave			
283	Mitchell Elementary School	733 N 73rd East Ave			Y
284	Owen Elementary School	1132 N Vandalia Ave			
285	Park Elementary School	3205 W 39th St			
286	Patrick Henry Elementary School	3820 E 41st St			
287	Peary Elementary School	10818 E 17th St			
288	Penn Elementary School	2138 E 48th St North			
289	Phillips Elementary School	3613 S Hudson Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
290	Newcomer International School	10908 E 5th St			
291	Remington Elementary School	2524 W 53rd St			
292	Robertson Elementary School	2721 W 50th St			
293	Roosevelt Elementary School	1202 W Easton St			
294	Salk Elementary School	7625 E 58th Ave			
295	Sandburg Elementary School	18580 E 3rd St			
296	Sequoyah Elementary School	3441 E Archer			
297	Skelly Elementary School	2940 S 90th East Ave			
298	Springdale Elementary School	2510 E Pine St			
299	Whitman Elementary School	3924 N Lansing Ave			
300	Wright Elementary School	1110 E 45th Pl	Keystone Dam Breach Inundation Area	X	
301	Academy Central Elementary School	1789 W Seminole St			
302	Grissom Elementary School	6646 S 73rd East Ave			
303	Mayo Demonstration Academy	2525 S 101st East Ave			
304	Booker T Washington High School	1514 N Zion St			
305	Central High School	3101 W Edison St			
306	East Central High School	12150 E 11th St		AE	Y
307	Edison High School	2906 E 41st St			
308	Hale High School	6960 E 21st St			
309	McLain High School	4929 N Peoria Ave			
310	Memorial High School	5840 S Hudson			
311	Rogers High School	3909 E 5th Pl			
312	Webster High School	1919 W 40th St			
313	Project ""12""	1205 W Newton St			
314	Byrd Middle School	7502 E 57th St			
315	Carver Middle School	624 E Oklahoma Pl			
316	Cleveland Middle School	724 N Birmingham Ave			
317	Clinton Middle School	2224 W 41st St			
318	Edison Middle School	2800 E 41st St			
319	Foster Middle School	12121 E 21st St			
320	Franklin Youth Academy	1136 S. Alleghany			
321	Fulton Teaching & Learning Academy	8906 E 34th St		AE	
322	Gilcrease Middle School	5550 N Cincinnati Ave			
323	Hamilton Middle School	2316 N Norwood Pl			
324	Lewis and Clark Middle School	737 S Garnett Rd		X	
325	Madison Middle School	4132 W Cameron St	Keystone Dam Breach Inundation Area	X	
326	Nimitz Middle School	3111 E 56th St			
327	Whitney Middle School	2177 S 67th East Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
328	Wilson Middle School	1127 S Columbia Ave			
329	KIPP Tulsa Academy	1661 E Virgin St			
330	Thoreau Demonstration Academy	7370 E 71st St			
331	Margaret Hudson	209 S Lakewood Ave			
332	Tulsa Academic Center	2740 E 41st St N			
333	Margaret Hudson	2010 E 48th St N			
334	Tulsa Learning Academy (North Star Academy)	526 E 46th St N			
335	Charles Mason Education Service Center	3027 S New Haven Ave			
336	Transportation Admin. Bldg/ Warehouse	1815 N 77th E Ave			
337	Maintenance	1555 N 77th E Ave			
338	TAEMA Emergency Operations Center	600 Civic Center			
339	Tulsa City-County Health Dept, Main	5051 S. 129th East Ave.			
340	Tulsa City-County Health Department	4616 E. 15th St.			
341	Tulsa City-County Health Department	315 S. Utica			
342	Tulsa County Correctional Facility	300 N. Denver			
343	Tulsa County Deputy Sheriff	3240 Charles Page Blvd	Keystone Dam Breach Inundation Area	X	Y
344	Tulsa County Sheriff	500 S. Denver Ave			
345	Tulsa County Offices	500 S. Denver Ave.			
346	Tulsa County Sheriff Office	303 W. 1st St.	Skiatook Dam Breach Inundation Area		
347	OK Highway Dept Construction Division	4002 N. Mingo Expressway			
348	Tulsa Co Fairgrounds	4145 E 21st St			
349	Tulsa County Juvenile Detention Center	315 S Gilcrease	Keystone Dam Breach Inundation Area	X	Y
350	Brookhaven Hospital	201 S Garnett Rd			
351	Hillcrest Medical Center	1120 S Utica Ave			
352	Hillcrest Speciality Hospital	1125 S Trenton Ave			
353	Laureate Psychiatric Clinic & Hospital	6655 S Yale Ave			
354	Saint Francis Hospital	6161 S Yale Ave			
355	Select Speciality Hospital - Tulsa	6161 S Yale Ave, 5 South			
356	Oklahoma Surgical Hospital	2408 E 81st St Ste 300	Keystone Dam Breach Inundation Area	X	
357	Tulsa Spine & Speciality Hospital	6901 S Olympia			
358	Shadow Mountain Behavioral Health System	6262 S Sheridan Rd			
359	SouthCrest Hospital	8801 S 101st East Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
360	Saint Francis Heart Hospital	10501 E 91st St			
361	Southwestern Regional Medical Center	10109 E 79th St			
362	Parkside Community Psychiatric Services & Hospital	1620 E 12th St			
363	Saint John Medical Center	1923 S Utica Ave			
364	Oklahoma State University Medical Center	744 W 9th St			
365	Meadowbrook Specialty Hospital of Tulsa	3219 S 79th East Ave			
366	Aberdeen Heights	7220 S Yale			
367	Ambassador's Courtyards	1380 E 61st St	Keystone Dam Breach Inundation Area	X	
368	The Arbors	10201 S Yale Ave			
369	Brighton Gardens	5211 S Lewis Ave			
370	The Health Centers @ Montereau - The Villa	6800 S Granite Ave			
371	Heatheridge Assisted Living Community	2130 S 85th East Ave			
372	Inverness Village - Alzheimers & Memory Support	3800 W 71st St			
373	Inverness Village - Redbud Court	3800 W 71st St			
374	Oklahoma Methodist Manor	4134 E 31st St			
375	The Parke Senior Living	7821 E 76th St			
376	Sterling House of Tulsa	6022 E 71st St			
377	Sterling House of Tulsa South	8231 S Mingo			
378	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Keystone Dam Breach Inundation Area	X	
379	University Village Retirement Community	8555 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
380	Saint Simeons Episcopal Home	3701 N Cincinnati Ave			
381	Vintage Heights	1 W 36th St North			
382	Heatheridge Residential Care	2130 S 85th East Ave			
383	Country Club of Woodland Hills Residential Care	6333 S 91st East Ave			
384	Colonial Manor Nursing & Rehab Center	1815 E Skelly Dr	Keystone Dam Breach Inundation Area	X	
385	The Cottage Extended Care	2552 E 21st St			
386	Green Country Care Center	3601 N Columbia Ave			
387	Rest Haven	1944 N Iroquois Ave			
388	Saint Simeons Home Memory Center	3701 N Cincinnati Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
389	Saint Simeons Episcopal Home	3701 Cincinnati Ave			
390	Saint Simeons Health Care Center	3701 N Cincinnati Ave			
391	The Montereau in Warren Woods	6800 S Granite			
392	The Health Care Centers @ Montereau - Memory Support	6800 S Granite			
393	The Health Care Centers @ Montereau - Skilled Nursing	6800 S Granite			
394	Maplewood Care Center	6202 E 61st St			
395	The Mayfair Nursing Center	7707 S Memorial Dr			
396	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Keystone Dam Breach Inundation Area	X	
397	Inverness Village	3800 W 71st St			
398	Inverness Village - Heather Hall	3800 W 71st St			
399	Lakewood Care Center	6201 E 36th St			
400	Oklahoma Methodist Manor	4134 E 31st St			
401	Oklahoma Methodist Manor	4134 E 31st St			
402	Parks Edge Nursing & Rehab Center	5115 E 51st St			
403	Ambassador Manor Nursing & Rehab Center	1340 E 61st St	Keystone Dam Breach Inundation Area	X	
404	Ambassador Manor Nursing & Rehab Center	1340 E 61st St	Keystone Dam Breach Inundation Area	X	
405	Leisure Village	2154 S 85th East Ave			
406	ManorCare Health Services	2425 S Memorial Dr			
407	Southern Hills Rehab Center	5170 S Vandalia			
408	Southern Hills Retirement Community	5170 S Vandalia			
409	Tulsa Nursing Center	10912 E 14th St			
410	Wildwood Care Center	3333 E 28th St			
411	University Village Retirement Community	8555 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
412	University Village Retirement Community	8555 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
413	Sherwood Manor	2416 W 51st St			
414	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Keystone Dam Breach Inundation Area	X	
415	Burgundy Place	8887 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
416	Colonial Manor	5015 S Victor Ave	Keystone Dam Breach Inundation Area	X	Y
417	Country Club of Woodland Hills	6333 S 91st East Ave			
418	Woodland Terrace	9524 E 71st St			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
419	4100 Apartments	3933 S Norfolk Ave	Keystone Dam Breach Inundation Area	X	
420	5400 South Apartments	4700 E 54th St		X	
421	Boulder Plaza	1840 S Boulder			
422	Cornerstone Village	1045 N Yale Ave			
423	Country Club Gardens	959 Country Club Dr			
424	Crestview Senior Duplexes	3535 N Cincinnati Ave			
425	Gilcrease Estates	1143 N 24th West Ave			
426	Pioneer Plaza	901 N Elgin Ave			
427	West Edison Plaza	570 N 39th West Ave			
428	Jordan Plaza I & II	630 E Oklahoma St			
429	Jordan Plaza III	775 E Pine St			
430	The Broadmoor Retirement Community	8205 E 22nd St			
431	Disciples Village	9014 E 31st st			
432	Garnett Village	3524 S 120th East Pl			
433	Glenwood Apartments	10221 E 34th St			
434	Shadybrook Apartments	4203 S 109th East Ave			
435	Sheridan Terrace	1937 S 68th East Ave			
436	Tulsa Pythian Manor	6568 E 21st Pl			
437	Park Village	650 S Memorial Dr			
438	Murdock Villa	828 S Wheeling			
439	Luther Place on Troost	1304 S Troost			
440	Hewgley Terrace	420 S Lawton Ave			
441	LaFortune Tower	1725 S Southwest Blvd	Keystone Dam Breach Inundation Area	X	
442	Mansion House	1638 S Carson			
443	Tulsa Pythian Manor West	1700 Riverside Dr	Keystone Dam Breach Inundation Area		
444	Oklahoma Methodist Manor	4134 E 31st St			
445	The Scandia	3510 E 32nd St			
446	Southern Elms	4519 E 31st St			
447	French Villa	4752 S Harvard Ave			
448	Colonial Manor	5015 S Victor Ave	Keystone Dam Breach Inundation Area	X	
449	Heatherwood Apartments	3006 E 51st St		X	
450	Southern Hills Retirement Community - The Villa	4515 E 53rd St			
451	Versailles Apartments	4816 S Sheridan			
452	Woodland Manor	8641 E 61st St			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
453	Woodland Terrace	9524 E 71st St			
454	Quail Creek Villa	7334 S Memorial Dr			
455	Country Club of Woodland Hills	6333 S 91st East Ave			
456	Montereau in Warren Woods	6800 S Granite			
457	Town Village	8222 S Yale Ave			
458	Tulsa Jewish Retirement & Health Care Center	2025 E 71st St	Keystone Dam Breach Inundation Area	X	
459	University Village Retirement Community	8555 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
460	Burgundy Place	8887 S Lewis Ave	Keystone Dam Breach Inundation Area	X	
461	Prairie Rose	7401 Riverside Parkway	Keystone Dam Breach Inundation Area	X	
462	Inhofe Plaza	6565 S Newport	Keystone Dam Breach Inundation Area	X	
463	Inverness Village	3800 W 71st St			
464	Edgewood at Gable Hills	7702 W Parkway Blvd			
465	Country Oaks	5648 S 33rd West Ave			
466	Union George F Boevers Elementary	3433 S 133rd E Ave			
467	Union Briarglen Elementary CAP Tulsa Briarglen Early Childhood Education Center)	3303 S 121st E Ave			
468	Union Cedar Ridge Elementary	9817 S Mingo Rd			
469	Union Roy Clark Elementary	3656 S 103rd E Ave			
470	Union James Darnaby Elementary	7625 E 87th St S			
471	Union Robert Grove Elementary	10202 E 62nd St			
472	Union Wesley Jarman Elementary	9015 E 79th St			
473	Union Rosa Parks Elementary	13702 E 46th Pl S			
474	Union Thomas Jefferson Elementary	8418 S 107th E Ave			
475	Tulsa Union High School	6636 S Mingo Rd			
476	Union Intermediate High School (Union HS Freshman Academy)	7616 S Garnett, Broken Arrow, OK 74012			
477	Union Alternative School	5656 S 129th E Ave			
478	Union 6th - 7th Grade Center	10100 E 61st St			
479	Union 8th Grade Center	6501 S Garnett, Broken Arrow, OK 74012			
480	Sewage Lift Station (Central)	5111 N 220th E Ave			
481	Sewage Lift Station (North)	6420 N 213th E Ave			
482	Sewage Lift Station (South)	4821 N 211th E Ave			
483	Sewer Lift Station	4203 1/2 N Evanston Ave	Skiatook Dam Breach Inundation Area	AE	Y

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
484	Sewer Lift Station	21st & Riverside Dr	Heyburn & Keystone Dam Breach Inundation Area	X	
485	Sewer Lift Station	67th St & S Gary Ave			
486	Sewer Pump Station	34 S 119th E Ave			
487	Southside Lift Station (Raw Sewage Pump House)	5300 S Elwood Ave	Keystone Dam Breach Inundation Area	X	
488	Southside Waste Water Treatment Plant	5300 S Elwood Ave	Keystone Dam Breach Inundation Area	X	
489	Undercroft Montessori School	3745 S Hudson Ave			
490	Temple Christian School	6308 E Apache St			
491	Winnetka Heights Baptist School	1020 W 49th St			
492	Calvary Temple Learning Center	4701 W Edison St			
493	Helmzar Challenge Course	1006 N Quaker Ave			
494	Tulsa School of Arts & Sciences	5155 E 51st St #200			
495	Before & After Program (Grant Bldg)	7635 E 42nd Pl			
496	Before & After Program (Transportation)	7623 E 42nd Pl			
497	Transportation-McBirney	1012 W 36th Pl	Keystone Dam Breach Inundation Area	X	
498	North Bus Lot	5720 N Cincinnati Ave			
499	Suburban Acres Library	4606 N Garrison Ave			
500	Tulsa Zoo & Living Museum	6421 E 36th St N	Oologah & Skiatook Dam Breach Inundation Area	X	
501	Tulsa Air & Space Museum	36240 N 74th E Ave			
502	Tulsa International Airport	7777 E Apache St			
503	Gilcrease Museum	1400 N Gilcrease Museum Rd			
504	Rudisill Regional Library	1520 N Hartford Ave			
505	Maxwell Park Library	1313 N Canton Ave			
506	Greenwood Cultural Center	322 N Greenwood Ave			
507	Cain's Ballroom	423 N Main St			
508	Brady Theatre	105 W Brady St			
509	Tulsa Performing Arts Center	110 E 2nd St			
510	Oklahoma Jazz Hall of Fame	111 E 1st St			
511	Tulsa Foundation for Architecture	321 S Boston Ave			
512	Tulsa Central Library	400 Civic Ctr			
513	Kendall Whittier Library	21 S Lewis Ave			
514	Nathan Hale Library	6038 E 23rd St S			
515	Martin Regional Library	2601 S Garnett Rd			
516	AIA of Eastern Oklahoma (Harwelden Mansion)	2210 S Main St			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
517	Tulsa Historical Society	2445 S Peoria Ave			
518	Philbrook Museum of Art	2727 S Rockford Rd			
519	Tulsa Geneology Center	2901 S Harvard Ave			Y
520	Zarrow Regional Library	2224 W 51st St			
521	Brookside Library	1207 E 45th Pl	Keystone Dam Breach Inundation Area	X	
522	University of Oklahoma - Tulsa	4502 E 41st St			
523	Herman & Kate Kaiser Library	5202 S Hudson Ave			
524	Sherwin Miller Museum of Jewish Art	2021 E 71st St	Keystone Dam Breach Inundation Area	X	
525	Peggy V. Helmerich Library	5131 E 91st St			
526	Hardesty Tegional Library	8316 E 93rd St			
527	Sylvester Morris Home	560 N Maybelle Ave			
528	B'nai Enumah Congregation	1719 S Owasso Ave			
529	Langston University, Tulsa	700 N Greenwood Ave			
530	11th St. Arkansas River Bridge	W 71st St S	Heyburn & Keystone Dam Breach Inundation Area	AE	Y
531	Ambassador Hotel	1324 S Main St			
532	Boulder Park (Dreamkeepers Park)	1875 S Boulder Park Dr	Keystone Dam Breach Inundation Area	X	Y
533	Blue Dome Gas Station	318 E 2nd St			
534	Cark K Dresser House	235 W 18th St			
535	City Veterinary Hospital	3550 S Peoria Ave	Keystone Dam Breach Inundation Area		
536	Circle Theatre	10 S Lewis Ave			
537	Mid-Continent Building (Cosden Building)	401 S Boston Ave			
538	Creek Council Tree Site	18th & Cheyenne Ave			
539	Dawson School	E Ute Pl & N Kingston Pl			
540	Gillette-Tyrell Building	423 S Boulder Ave			
541	Holy Family Cathedral	122 W 8th St			
542	Hooper Bros. Coffee Co. Building	731 E Admiral Blvd			
543	International Plaza	1350 S Boulder Ave			
544	James Alexander Veasey House	1802 S Cheyenne Ave			
545	James McBirney House	1414 S Galveston Ave			
546	Mayo Hotel & Residences	115 W 5th St			
547	McFarlin Building	11 E 5th St			
548	Mincks-Adams Hotel	403 S Cheyenne Ave			
549	Moore Manor	228 W 17th Pl			
550	Oklahoma Natural Gas Co Building	624 S Boston Ave			
551	Mt. Zion Baptist Church	419 N Elgin Ave			

	NAME	ADDRESS	INUNDATION AREA	FLOOD ZONE	FLOODPLAIN
552	Parriott House	2216 E 30th St			
553	Petroleum Building	420 S Boulder Ave			
554	Philcade Building	509 S Boston Ave			
555	Philtower Building	427 S Boston Ave			
556	Phillips 66 Station #473	2224 E Admiral Blvd			
557	Pierce Block Building	301 E 3rd St			
558	Public Service Oklahoma Building	600 S Main St			
559	Riverside Studio	1381 Riverside Dr	Keystone Dam Breach Inundation Area		
560	Robert Lawton Jones House	1916 E 47th St	Keystone Dam Breach Inundation Area	X	
561	ARCO Building (Service Pipeline Building)	520 S Cincinnati Ave			
562	Robert M McFarlin House	1610 S Carson Ave			
563	Sinclair Station	3501 E 11th St			
564	Sophian Plaza	1500 S Frisco Ave			
565	Southwestern Bell Main Dial Building	424 S Detroit Ave			
566	St. John Vianney Training School for Girls	4001 E 101st St			
567	Sue Bland Oil Well Site & Red Fork	4101 S 38th Pl	Keystone Dam Breach Inundation Area	X	
568	Tribune Building	20 E Archer St			
569	Tulsa Club Building	115 E 5th St			
570	Tulsa Monument Company Building	1735 E 11th St			
571	Tulsa Municipal Building	124 E 4th St			
572	Vickery Phillips 66 Station	602 S Elgin Ave			
573	Warehouse Market (Original building)	10th & Eligin			
574	Westhope	3704 S Birmingham Ave			
575	William G Skelly House	2103 S Madison Ave			
576	R.L. Jones, Jr. Airport (Tulsa Riverside Airport)	8605 S Elwood Ave	Heyburn & Keystone Dam Breach Inundation Area	X	
577	AEP Tulsa Power Station	3600 S Elwood Ave	Keystone Dam Breach Inundation Area	X	

APPENDIX C: Strategies

C.1 FEMA Hazard Mitigation Strategies

The following items illustrate many of the broad mitigation strategies that communities, tribes, counties, and other entities can implement to help protect lives, property, and the environment in their jurisdictions. The following grid lists the six basic mitigation categories outlined by FEMA (introduced in Chapter 2), the strategies that fall in those categories, and the hazards those strategies may be effective for. Many of the strategies, while listed under one category, may have elements that include other categories as well. For example, almost all strategies have a Public Information & Education component, where homeowners and business owners are educated about possible measures they may take on their own.

Table C-1: Mitigation Strategies

CATEGORY	MITIGATION STRATEGY		HAZARDS IMPACTED
Public Information & Education	C.1.1	Public Information Program Strategy	All Hazards
	C.1.2	Educational Programs	All Hazards
	C.1.3	Outreach Projects	All Hazards
	C.1.4	Technical Assistance	All Hazards
	C.1.5	Map Information	All Hazards
	C.1.6	Library	All Hazards
	C.1.7	Web Sites	All Hazards
	C.1.8	Real Estate Disclosure	Flood, Expansive Soils
	C.1.9	Firewise Communities	Wildfire
	C.1.10	Business Continuity Planning & Mitigation	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Wildfire, Earthquake, Dam Break
Preventive Measures	C.2.1	Planning	All Hazards
	C.2.2	Zoning	All Hazards
	C.2.3	Floodplain Development Regulations	Flood, Dam Break
	C.2.4	Stormwater Management	Flood, Dam Break
	C.2.5	Building Codes	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Expansive Soil, Wildfire, Earthquake
	C.2.6	IBHS Fortified Home Program	Flood, Tornado, High Wind, Lightning, Hail, Wildfire, Earthquake
	C.2.7	Smoke Detectors	Fires
	C.2.8	Hurricane Fasteners	Tornado, High Wind, Earthquake
	C.2.9	Mobile Home Tie-downs	Tornado, High Wind
	C.2.10	Lightning Warning Systems	Lightning
	C.2.11	Power Outages From Winter Storms	Winter Storm, Lightning
	C.2.12	Standby Electric Generators	Tornado, High Wind, Lightning, Winter Storm
	C.2.13	Critical Facility Protection	All Hazards
	C.2.14	Extreme Heat Protection	Extreme Heat

CATEGORY	MITIGATION STRATEGY		HAZARDS IMPACTED
Preventive Measures (continued)	C.2.15	Proper Storage and Disposal of Hazardous Materials	Floods
	C.2.16	Water Conservation	Drought
	C.2.17	Open Space Preservation	Flood, Drought, Dam Break
Structural Projects	C.3.1	Safe Rooms	Tornado, High Wind
	C.3.2	School Safe Rooms	Tornado, High Wind
	C.3.3	Reservoirs & Detention	Flood
	C.3.4	Levees & Floodwalls	Flood, Dam Break
	C.3.5	Channel Improvements	Flood, Dam Break
	C.3.6	Crossings & Roadways	Flood, Dam Break
	C.3.7	Drainage & Storm Sewer Improvements	Flood, Dam Break
	C.3.8	Drainage System Maintenance	Flood, Dam Break
Property Protection	C.4.1	The City's Role	All Hazards
	C.4.2	Insurance	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Wildfire, Earthquake, Dam Break
	C.4.3	Acquisition & Relocation	Flood
	C.4.4	Building Elevation	Flood, Dam Break
	C.4.5	Barriers	Flood, Dam Break
	C.4.6	Retrofitting	Flood, Tornado, High Wind, Lightning, Hail, Expansive Soil, Wildfire, Earthquake
	C.4.7	Impact-Resistant Windows & Doors	Tornado, High Wind, Hail
	C.4.8	Lightning Protection Systems	Lightning
	C.4.9	Surge and Spike Protection	Lightning
	C.4.10	Landscaping for Wildfire Prevention	Wildfire
Emergency Services	C.5.1	Threat Recognition	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.2	Warning	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.3	9-1-1 & 2-1-1	All Hazards
	C.5.4	Emergency Telephone Notification Systems (ETNS)	Flood, Winter Storm, Heat, Wildfire
	C.5.5	Response	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.6	Emergency Operations Plan (EOP)	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.7	Incident Command System (ICS)	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break

CATEGORY	MITIGATION STRATEGY		HAZARDS IMPACTED
Emergency Services (continued)	C.5.8	Mutual Aid / Interagency Agreements	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.9	CERT (Community Emergency Response Teams)	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.10	Debris Management	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.11	Critical Facilities Protection	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.12	Site Emergency Plans	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.13	Post-Disaster Recovery & Mitigation	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
	C.5.14	StormReady Communities	Flood, Tornado, High Wind, Lightning, Hail, Winter Storm, Heat, Drought, Wildfire, Earthquake, Dam Break
Natural Resource Protection	C.6.1	Wetland Protection	Flood, Wildfire
	C.6.2	Erosion and Sedimentation Control	Flood, Wildfire
	C.6.3	River Restoration	Flood, Wildfire
	C.6.4	Best Management Practices	Flood
	C.6.5	Dumping Regulations	Flood, Tornado, High Wind, Winter Storm

C.2 Public Information and Education

A successful public information and education program involves both the public and private sectors. Public information and education activities advise and educate citizens, property owners, renters, businesses, and local officials about hazards and ways to protect people and property from them. Public information activities are among the least expensive mitigation measures, and at the same time are often the most effective. All mitigation activities – preventive, structural, property protection, emergency services, and natural resource protection – begin with public information and education.

C.2.1 Public Information Program Strategy

Getting Your Message Out

Professional advertising agencies may be willing to help get the message out regarding disaster preparedness and mitigation at little or no cost. They have a vested interest in their community and want to keep it safe. The same holds true for the media. The local newspaper, radio, or television will contribute to keeping a safe and prepared community. Invite them to, and let them participate in special events, meetings, practice exercises, etc.

Education alliance partners, such as a restaurant, convenience stores, or the library, can put preparedness tips on tray liners or sacks, distribute brochures or allow you to erect a display with disaster information of local interest. Many other options are available, such as including brochures with utility bills, presentations at local gatherings, billboards, direct mailing, and websites.

General

Numerous publications on tornados, thunderstorms, lightning, winter storms, and flooding are available through NOAA. Up to 300 copies of most publications can be ordered from your local National Weather Service, NOAA Outreach Unit or American Red Cross. Many of the brochures can be downloaded from www.nws.noaa.gov/om/brochures.shtml.

For a nominal fee, the American Red Cross offers videos on general preparedness, winter storms, chemical emergencies, hurricanes, and earthquakes.

The Storm Prediction Center issues watches, and the National Weather Service issues warnings for severe weather that may include "call to action" statements. The messages appear on the NWS telephone line, the local weather service office website, and on television stations carrying Emergency Alert System messages.

Communities can encourage residents to prepare themselves by stocking up with necessary items and planning for how family members should respond if any of a number of possible emergency or disaster events strike.

Hazard Brochures

FEMA, area agencies, and nonprofits have free brochures and other material related to hazards, mitigation, response, and recovery. Example fliers have included: "Are You Ready For a Heat Wave?", "Are You Ready For a Winter Storm?", and "Are You Ready For a Thunderstorm?" And past brochures have included "Taking Shelter from the Storm: Building a Safe Room Inside Your Home."

C.2.2 Educational Programs

Environmental education programs can teach children about natural hazards, the forces that cause them, and the importance of protecting people, property and nature, such as watersheds and floodplains. Educational programs can be undertaken by schools, park and recreation departments, conservation associa-

tions, and youth organizations, such as the Boy Scouts, Campfire Girls, and summer camps. An activity can be complex enough as to require course curriculum development or as simple as an explanatory sign near a river.

Educational programs designed for children often reach adults as well. Parents often learn innovative concepts or new ideas from their children. If a child comes home from school with an assignment in water quality monitoring, the parents will normally become interested in finding out about it as well.

Youth programs and activities often include posters, coloring books, games, and references. Hands-on models that allow students to see the effects of different land use practices are also available through local natural resources conservation districts.

There are many programs that provide information and curriculum materials on nature and natural hazards. Agencies such as FEMA or the Red Cross have provided free access to materials in the past.

C.2.3 Outreach Projects

Mapping and library activities are not of much use if no one knows they exist. An outreach project can remedy this. Sending notices to property owners can help introduce the idea of property protection and identify sources of assistance.

Outreach projects are the first step in the process of orienting property owners to property protection and assisting them in designing and implementing a project. They are designed to encourage people to seek out more information in order to take steps to protect themselves and their properties.

The most effective types of outreach projects are mailed or otherwise distributed to flood-prone property owners or to everyone in the community. Other approaches include the following:

- Articles and special sections in newspapers
- Radio and TV news releases and interview shows
- Hazard protection video for cable TV programs or to loan to organizations
- Presentations at meetings of neighborhood, civic or business groups
- Displays in public buildings or shopping malls
- Floodproofing open houses
- Social media campaigns

Research has proven that outreach projects work. However, awareness of the hazard is not enough. People need to be told what they can do about the hazard, so projects should include information on safety, health, and property protection measures. Research has also shown that a properly run local information program is more effective than national advertising or publicity campaigns.

C.2.4 Technical Assistance

While general information helps, most property owners do not feel ready to take major steps, like retrofitting their buildings, without help or guidance. Local building department staff members are experts in construction. They can provide free advice, not necessarily to design a protection measure but to steer the owner onto the right track.

Building, public works, and engineering staff members visit properties and offer suggestions. Most can recommend or identify qualified or licensed companies, an activity that is especially appreciated by owners who are unsure of the project or the contractor.

Technical assistance can be provided in one-on-one sessions with property owners or can be provided through seminars. For instance, seminars or “open houses” can be provided on retrofitting structures, selecting qualified

contractors, and carrying out preparedness activities.

C.2.5 Map Information

Many benefits stem from providing map information to inquirers. Residents and businesses that are aware of the potential hazards can take steps to avoid problems and reduce their exposure to flooding, dam failure or releases, expansive soils, and other hazards that have a geographical distribution. Real estate agents and house hunters can find out if a property is flood-prone and whether flood insurance may be required.

Maps provide a wealth of information about past and potential hazards. Geographic Information Systems (GIS) can provide efficiency and add to capabilities of many government services. County assessors, public works, parks and recreation, and 911 services are all typical departments capable of applying GIS applications to improve their services. GIS allows trained users to complete comprehensive queries, extract statistical information, and completely manage all relevant spatial information and the associated attribute information that pertain to those departments.

Flood maps

Several legal requirements are tied to FEMA's Flood Insurance Rate Maps (FIRMs) and Flood Insurance Study Maps. These include building regulations and the mandatory purchase of flood insurance. FEMA provides floodplain and FIRM information as a mitigation service. The City can help residents submit requests for map amendments and revisions when these are needed to show that a building is outside the mapped floodplain.

Although FEMA maps are accurate, users and inquirers must remember that maps are not perfect. They display only the larger flood-prone areas that have been studied. In some areas, watershed developments make even recent maps outdated. Those inquiring about flood maps must be reminded that being outside the mapped floodplain is no guarantee that a property will never flood. In fact, many properties that flood are not located in a designated floodplain.

By taking the initiative locally to accurately map problem areas with information not already on FEMA maps, a community can warn residents about potential risks that may not have been anticipated. Upgrading maps provides a truer measure of risks to a community.

Other Hazard Data

Other data that can be shown on maps include those hazards that are distributed geographically. These include:

- Dam breach inundation areas
- Levee failure inundation areas
- Expansive soils
- Wildfire risk zones
- Earthquake risk zones
- Hazardous materials sites
- Wetlands

General location maps for many of these natural and man-made hazards have been developed by U. S. Army Corps of Engineers, Association of South Central Governments (ASCOG), Oklahoma Geological Survey, and R. D. Flanagan & Associates, several of which are included in this City of Tulsa Hazard Mitigation Plan study.

C.2.6 Library

The City of Tulsa public libraries are places for residents to seek information on hazards, hazard protection, and protecting natural resources. Historically, libraries have been the first place people turn to when they want to research a topic. Interested property owners can read or check out handbooks or other publications that cover their situation. The li-

braries also have their own public information campaigns with displays, lectures, and other projects which can augment the activities of the local government.

The local public library System maintains flood related documents required under the NFIP and CRS. The documents are available to the public in the library.

C.2.7 Web Sites

Today, the internet is the primary research tool that provides quick access to a wealth of public and private sites and sources of information. Through links to other web sites, there is almost no limit to the amount of up to date information that can be accessed by the user.

C.2.8 Real Estate Disclosure

After a flood or other natural disaster, people often say they would have taken steps to protect themselves if they had known their property was exposed to a hazard.

Flood insurance is required for buildings located within the base floodplain if the mortgage or loan is federally insured. However, because this requirement has to be met only ten days before closing, applicants are often already committed to purchasing a property when they first learn of the flood hazard.

The "Residential Property Condition Disclosure Act" requires sellers to provide potential buyers with a completed, signed, and dated "Residential Property Condition Disclosure Statement." Included in the statement are disclosures regarding flooding and flood insurance.

C.2.9 Firewise Communities

While incorporating components from several of the different mitigation strategies, Firewise primarily depends on homeowners taking actions to protect their own property, so Public Education and Information is key to the success of the Firewise program. While it is not possible, or in many cases even desirable, to prevent wildfires, it is certainly possible, by interrupting the natural flow of the fire, to assure that wildfires will not produce catastrophic home or crop losses. In the words of Judith Cook, Project Manager for Firewise Communities/USA, "We can modify our home ignition zones. We're basically saying to the fire, 'there's nothing for you here!'"

Firewise Community USA is a project of the National Wildfire Coordinating Group. It recognizes communities that have gone through a process to reduce the dangers of wildfires along what is referred to as the Wildland-Urban Interface (WUI). Additional information on the Firewise Community program can be found at www.firewise.org/usa.

In order to become a Firewise Community, a community will:

1. Contact a Firewise Specialist. In Oklahoma, the Firewise specialist may be reached through the Oklahoma Department of Agriculture, Forestry Services. The specialist will coordinate with local fire officials to schedule a site visit and assess the community.
2. The community will create a Firewise Board that includes homeowners, fire professionals, and other stakeholders.
3. The Firewise specialist will schedule a meeting with the board to present the assessment report for review and acceptance.
4. The board will use the report to create agreed-upon, area-specific solutions to the fire issues, which the specialist will review and, if acceptable, will work with the community to seek project implementation funds, if necessary.
5. Local solutions will be implemented following a schedule designed by the local board and the specialist. A permanent Firewise task force or committee is created that will maintain the program into the future.
6. A completed plan and registration form

will be submitted to Firewise Communities/USA for formal recognition of the community.

C.2.10 Business Continuity Planning and Mitigation

While Business Continuity Planning (BCP) can include portions from many of the categories listed in this chapter, an integrated program for businesses is a frequently neglected component in a community's mitigation strategy. It has been demonstrated repeatedly that many businesses that close their doors following a disaster either fail to re-open or struggle to remain open following the event. This is especially true of small- to medium-sized businesses that may rely on a limited number of locations and a narrow customer base or may not have the economic reserves to recover from financial losses. The lack of ability to recover may be for several reasons:

- Absenteeism from employees who are affected or who have affected family members;
- Psychological trauma from losing co-workers;
- Loss of an irreplaceable executive or manager;
- Economic stress on the business from having to make repairs and replenish stock over and above what may be covered by insurance;
- Loss of revenue from having the doors closed for even a short period of time;
- Loss of the customer base, either from people who are forced to evacuate the area or who may not have immediate disposable income for the company's products;
- Loss of a critical customer or the vendor of a critical inventory item ("upstream" and "downstream" issues);
- Loss of critical data, either paper or electronic records;
- An interruption in community infrastructure (utilities, road access, media losses, etc.).

In addition, the loss of a business, even for a short period of time, may adversely affect the community in many ways, some of which may include:

- Loss of tax revenue for city services;
- Loss of jobs for community residents;
- Loss of access to the company's products (especially significant if the company supplies an essential service or product, such as construction equipment, medications, transportation, or groceries).

Effective Business Continuity Planning (BCP) may include such activities as:

- Making regular back-ups of critical data and keeping it in an off-site location;
- Maintaining accurate contact information (phone, e-mail, pager, etc.) on critical employees;
- Identifying potential off-site locations that can be used in case the primary location of the company is damaged or inaccessible;
- Reviewing all activities of a company and identifying which activities are critical and must resume right away, which are less critical and may not need to resume for a short period of time, and which activities can be put on hold for a longer period of time;
- Developing "canned" PR pieces that can be quickly disseminated in the event of an incident at the company;
- Having an honest conversation with insurers to determine that policies are sufficiently inclusive and appropriate for the business;
- Communicating with suppliers and critical customers on what their emergency response and business resumption plans include.

Business continuity planning can be facilitated by the community in a number of ways, primarily in the area of Public Information.

- The Chamber of Commerce may sponsor programs such as the Institute for Business & Home Safety's (IBHS) Open For Business presentation.
- The American Red Cross has also teamed

with the Federal Emergency Management Agency to produce the Emergency Management Guide for Business and Industry. More information is available at www.redcross.org/services/disaster/0,1082,0_606_,00.html.

Several professional groups such as the Association of Contingency Planners or the Records & Information Management professionals (ARMA) may be available in your area to assist with developing disaster preparedness and mitigation plans or exploring ways to safeguard critical records and information.

In addition, if a community is promoting Community Emergency Response Teams (CERT), business CERTs can be developed to respond to a disaster, not only within a neighborhood but also within a business establishment. CERTs are trained in disaster organization, immediate disaster evaluation, immediate disaster first aid, light search and rescue, and light fire suppression.

C.2.11 Conclusions

1. There are many ways public information programs can be used so people and businesses will be more aware of hazards they face and how they can protect themselves.
2. Most public information activities can be used to advise people about all hazards, not just floods.
3. Other public information activities require coordination with other organizations, such as schools and real estate agents.
4. There are several area organizations that can provide support for public information and educational programs.

C.2.12 Recommendations

The areas of greatest likelihood to strengthen the community in this area would include identifying and developing a Public Education and Outreach manager at the city offices and coordinating with other agencies engaged in these kinds of activities. In addition, the recent ice storms have indicated a strong need for developing business continuity support for the small business community.

Refer to Chapter 5: Mitigation Strategy for a complete listing of all recommended mitigation measures by hazard and priority.

C.3 Preventive Measures

Preventive activities are designed to keep matters from occurring or getting worse. Their objective is to ensure that future development does not increase damage or loss of life, and that new construction is protected from those hazards. Preventive measures are usually administered by building, zoning, planning, and code enforcement offices. They typically include planning, zoning, open space preservation, building codes, drainage criteria, master drainage plans and floodplain development regulations, and stormwater management.

The first three measures (planning, zoning, and open space preservation) work to keep damage-prone development out of hazardous or sensitive areas.

The next two measures (building codes and floodplain development regulations) impose standards on what is allowed to be built in the floodplain. These protect buildings, roads, and other facilities from flood damage and prevent the new development from making any existing flood problem worse. Building codes are also critical to mitigating the impact of non-flood hazards on new buildings.

Stormwater management addresses the runoff of stormwater from new developments onto other properties and into floodplains.

C.3.1 Planning

While plans generally have limited authority, they reflect what the community would like to see happen in the future. Plans guide other local measures such as zoning, capital improvements, and the development of ordinances.

C.3.2 Zoning

Tulsa's zoning ordinances regulate development by dividing the community into zones or districts and setting development criteria for each zone or district. Zoning ordinances are considered the primary tool to implement a comprehensive plan's guidelines for how land should be developed.

C.3.3 Floodplain Development Regulations

Most communities with a flood problem participate in the National Flood Insurance Program (NFIP). The NFIP sets minimum requirements for subdivision regulations and building codes. These are usually spelled out in a separate ordinance.

Experience showed that the National Flood Insurance Program's minimum standard is insufficient for developing urban communities such as Tulsa. The city's regulations exceed the NFIP's minimum national standards in several significant ways.

The Community Rating System (CRS) is a companion program to the NFIP. It rewards a community for taking actions over and above minimum NFIP requirements, with the goal of further reducing flood damages in the community. The more actions a community takes, the lower the premiums for flood insurance within that community.

Subdivision regulations govern how land will be subdivided into individual lots and set the construction and location standards for the infrastructure the developer builds to serve those lots, including roads, sidewalks, utility lines, storm sewers, and drainageways. They provide an additional vehicle for floodplain development rules. For example, some communities require that every subdivision in a floodplain provide a building site above the flood level for every lot and/or require streets to be at or no more than one foot below the base flood elevation.

Floodplains are only part of flood-management considerations. Water gathers and drains throughout entire watersheds, from uplands to lowlands. Each watershed is an interactive element of the whole. A change at one place can cause changes elsewhere, whether planned or inadvertent. Tulsa is continuing the process of the development or updating of comprehensive, basin-wide Master Drainage Plans that identify existing and potential future drainage and flooding problems to public facilities and private property.

C.3.4 Stormwater Management

Development outside a floodplain can contribute significantly to flooding problems. Runoff is increased when natural ground cover is replaced by urban development. To prevent stormwater from flooding roads and buildings, developers construct storm sewers and improve ditches to carry the water away more efficiently.

As watersheds develop, runoff usually becomes deeper and faster and floods become more frequent. Water that once lingered in hollows, meandered around oxbows, and soaked into the ground now speeds downhill, shoots through pipes, and sheets off rooftops and paving.

Insurance purposes require that NFIP floodplain maps must be based on existing watershed development, but unless plans and

regulations are based on future watershed urbanization, the development permitted today may flood tomorrow as uphill urbanization increases runoff.

This combination of increased runoff and more efficient stormwater channels leads to increases in downstream storm peaks and changes in the timing when storm peaks move downstream. Unconstrained watershed development often will overload a community's drainage system and aggravate downstream flooding.

A second problem with stormwater is its impact on water quality. Runoff from developed areas picks up pollutants on the ground, such as road oil and lawn chemicals, and carries them to the receiving streams.

Tulsa enforces the NFIP minimum regulations and maps in order to maintain eligibility for federal flood insurance.

Retention / Detention

Some communities with stormwater management regulations require developers to build retention or detention basins to minimize the increases in the runoff rate caused by impervious surfaces and new drainage systems. Generally, each development must not let stormwater leave at a higher rate than under pre-development conditions. Tulsa does require a drainage plan from new developments.

The Community Rating System (CRS) uses three factors to measure the impact of stormwater management regulations on downstream flooding:

1. What developments have to account for their runoff? If only larger subdivisions have to detain the increased runoff, the cumulative effect of many small projects can still produce greater flows to downstream properties.

2. How much water is managed? Historically, local stormwater management programs address smaller storms, such as the 2- or 10-year storms. The CRS reflects the growing realization nationally that the runoff from larger storms must be managed. It provides full credit only for programs that address all storms up to the 100-year storm.

3. Who is responsible to ensure that the facility works over time? Roads and sewers are located on dedicated public rights-of-way and the community assumes the job of maintaining them in the future. Stormwater management detention basins have traditionally stayed on private property and maintenance has been left up to the owner. Often, homeowners associations do not know how and do not have the capability to properly maintain these facilities. Half the CRS credit is based on whether the community assumes responsibility to ensure that the facilities are maintained.

Watershed Approaches

The standard regulatory approach of requiring each development to manage stormwater to the same criteria has several shortcomings:

1. It does not account for differences in stream and watershed conditions (although the standards can be revised to reflect findings from watershed studies).
2. Municipalities within the same watershed may require different levels of control of stormwater.
3. There is no review of the downstream impacts from runoff or any determination of whether the usual standards compound existing flooding problems.
4. It results in many small basins on private property that may or may not be properly maintained.

The way to correct these deficiencies is to conduct a master study of the watershed to determine the appropriate standards for different areas and, sometimes, to identify where a larger central basin would be more effective and efficient than many smaller ones. The CRS provides up to double the stormwater management regulations credit if communities adopt

such master plans.

C.3.5 Building Codes

Hazard protection standards for all new and improved or repaired buildings can be incorporated into the local building code. These standards should include criteria to ensure that the foundation will withstand flood forces and that all portions of the building subject to damage are above, or otherwise protected from, flooding.

Building codes are also a prime mitigation measure for other natural hazards, especially earthquakes, tornados, windstorms, and heat and cold. When properly designed and constructed according to code, the average building can withstand the impacts of most of these forces. The code could include provisions such as:

- Requiring sprinkler systems for fire protection in larger or public buildings;
- Regulating overhanging masonry elements that can fall during an earthquake;
- Ensuring that foundations are strong enough for earth movement and that all structural elements are properly connected to the foundation, and;
- Making sure roofing systems will handle high winds and expected snow loads.

C.3.6 IBHS Fortified Home Program

The Fortified...for Safer Living home program gives builders and homeowners a set of criteria for upgrades that help reduce the risk of damage from natural disasters. The program raises a home's overall safety above building code minimum requirements. During construction and upon completion, a home is inspected and certified as a "Fortified...for Safer Living" home.

The combination of materials and techniques produces residences equipped to better resist hurricanes, tornados, fire, and floods. The fortified home construction method produces homes that are comfortable while being resistant to natural disasters.

The following are features of a "Fortified...for Safer Living" home:

• The home and critical utilities are elevated by reinforced continuous piles a minimum of two feet above ground-level walls, stairs and Base Flood Elevation (BFE).

• The home is connected from the peak of the roof to the foot of the reinforced piles to form a continuous load path capable of withstanding 130 mph winds.

• Windows, doors, and other openings are properly flashed and protected to withstand the impact of windborne debris without penetration of wind and water.

• The roof truss system has a 110 mph wind-rated covering, a secondary moisture barrier, twice the required underlayment, thicker plywood deck sheathing, and a stronger holding nail and nailing pattern.

• Other features include non-combustible roof materials, reinforced entry garage doors, and landscaping techniques reducing wildfire and flooding vulnerability.

• A certified inspector verifies all required Fortified home products and materials are installed correctly in accordance with manufacturer's specifications for "Fortified...for Safer Living" program specifications.

• The home and property are also verified to be a low-risk hazard for exposure to wildfire.

Depending on the quality of the material the buyer chooses, the cost to add fortified features could be as low as five percent of the total cost of a new home.

Cost (existing home)

Many of the fortification techniques used to

build new homes are too expensive as retrofits. Fortifying is much more expensive when a home is already built. However, there are creative ways to reduce costs and still fortify an existing home. Improving roof decking on an existing structure would cost about $5,000. For $50, a certain type of glue gun available in most hardware stores can retrofit a roof as effectively as if a new roof had been put on with wood screws.

Savings

In Florida, a fortified home can save homeowners over 20% in insurance premiums. A standard brick, stone, or masonry house in a coastal area, with a deductible of $500 and a 2% hurricane deductible, would generate an annual premium of $2,240. In contrast, the same home with the additional fortified construction features would pay an annual premium of $1,746, a savings of $504, or 22.5%. Also, underwriting guidelines may be relaxed for fortified homes. Insurers may make exceptions for fortified homes in areas where they wouldn't normally write policies.

Lower deductibles may be available. In Florida, policies covering wind damage typically have a deductible of 2% of the covered amount. On a $150,000, home the deductible would be $3,000. Fortified homeowners may be eligible for a flat deductible of $500.

As for intangible savings, personal photographs, important family documents, and computer data are just a few of the items a fortified home may protect. Additionally, there is the inconvenience and cost of other living arrangements while a home is being rebuilt.

C.3.7 Smoke Detectors

Smoke detectors save lives. Approximately two-thirds of fatal fires occur in the 10% of homes not protected with smoke detectors. You are twice as likely to die in a fire if you do not have a properly operating smoke detector.

There are two basic types of smoke detectors - photoelectric and ionization. Photoelectric smoke alarms generally are more effective at detecting slow-smoldering fires, fires that might smolder for hours before bursting into flames. Ionization smoke alarms are more effective at detecting fast-flaming fires, fires that consume materials rapidly and spread quickly.

Test smoke detectors every month, change the batteries twice per year, clean detectors at least once per year and replace smoke detectors every 10 years.

C.3.8 Hurricane Fasteners

A home's roof system is its most vulnerable and expensive component. Hurricane roof-to-wall and additional straps are metal connectors designed to hold a roof to its walls in high winds. They make a home's roof-to-wall connection five to 15 times stronger than traditional construction and can prevent damage in winds of at least 75 mph. In many coastal communities, reinforcing connections are enforced as a code restriction for new homes. Although designed to protect roofs during the extended and violent winds of hurricanes, these fasteners have proven effective in preventing roof removal in tornado events.

C.3.9 Mobile Home Tie-Downs

Tie-downs are devices that anchor or otherwise secure a mobile home to the ground in order to protect the mobile home and its surroundings from damage caused by wind and/or other natural forces. All tie-downs must comply with the specifications of the home manufacturer or, in the absence of such specifications, with standards set by the City Building Inspector.

Anchors are available for different types of

soil conditions, including concrete slab. Auger anchors have been designed for both hard soil and soft soil. Rock anchors or drive anchors allow attachment to a rock or coral base. This type of anchor is also pinned to the ground with crossing steel stakes.

C.3.10 Lightning Warning Systems

There are two basic types of warning systems:

Strike Location and Identification Systems sense the electromagnetic pulse or the electrostatic pulse that accompanies a lightning discharge. Sensors and processing equipment work from those pulses or transients. These systems are most useful for tracking storms, locating a lightning strike, and producing density plots of lightning activity by geographical area. They do not provide early warning of an impending storm.

Pre-storm Warning Systems sense the conditions that precede a storm. All severe storms create a related electrostatic field. This field provides a reliable storm signature that is peculiar to severe storms and can be related to the severity of the storm. That signature is present prior to lightning activity and provides a measurable parameter for pre-storm warning. The electrostatic field strength is directly related to the state of the storm and/or its proximity to the site. Therefore, an increase in the electrostatic field is an indicator of a storm moving into or building up over the area. The warning time is determined by the rate of buildup or the rate of movement of the storm.

Essential companions to any type of lightning warning system include:

- A written Lightning Safety Policy;
- Designation of Primary Safety Person;
- Determination of when to suspend activities;
- Determination of Safe/Not Safe Shelters;
- Notification to Persons at Risk;
- Education: at a minimum consider posting information about lightning and the organization's safety program;
- Determination of when to resume activities.

The above options can be developed with many variations, up to and including all-in-one units that include a lightning threat detector, strobe light and 360-degree warning horn, and fully automated programmable computer to pre-set various options for different types of facilities, such as times of operation, degrees of sensitivity, and appropriate sounding of an "all clear" signal.

C.3.11 Power Outages from Winter Storms

Power outages from winter storms can lead to an abundance of problems. Traffic can be disrupted with the loss of traffic signals. Homeowners without power will resort to candles or open flames for heat and light. Generators are noisy, produce potentially deadly exhaust and can cause power spikes damaging equipment. Kerosene heaters burn oxygen and increase the potential of asphyxiation and production of carbon monoxide. With fuel burning equipment there is a constant danger of fire or explosion, burns, and breathing poisonous exhaust. In addition, the inability to heat a home increases the risk of pipes freezing.

Power lines can be protected and power outages prevented by:

- Replacing existing power lines with heavier T-2 line, shorter spans, and heavier poles and crossbars. It is estimated this will increase the overall strength of power distribution lines by 66%.
- Burying utility lines. This removes the risk of power outages due to ice accumulation or tree limbs bringing down power lines.
- Pruning trees away from power lines and

enforcing policies regarding tree limb clearances.
- Designed-failure allowing for lines to fall or fail in small sections rather than as a complete system.

When power outages occur, the first imperative in emergency power planning is to equip essential facilities with permanent backup power and to make sure existing backup sources are properly sized and maintained.

Essential post-disaster services include:

- Medical care
- Drinking water supply
- Police and fire protection
- Refrigeration
- Communications
- Pollution control (especially wastewater treatment)
- Transportation (especially airports and seaports)
- Weather forecasting
- Temporary relief shelter
- Emergency response command and control

Backup systems should be sized to meet the requirements of a facility's necessary public services. Some facilities, such as wastewater treatment plants and hospitals, are so important that backup systems should be sized to carry full loads. All backup power systems should be covered by a complete and consistent planned maintenance program that includes regular inspection and operational testing.

C.3.12 Standby Electric Generators

Standby electric generators can provide an extra sense of security during unpredictable weather and resulting power outages. But even small, portable electric generators – if used improperly – can threaten resident safety and the safety of power company linemen working on the electrical system. For information on safely purchasing and using a residential generator, see http://www.redcross.org/prepare/disaster/power-outage/safe-generator use.

Before purchasing a generator, consider how it will be used. That will help ensure buying a generator that is correctly sized for the application in mind. Portable, gasoline-driven generators are designed to be used for appliances with cords connected to them. Typically, they are not designed to be connected to a home or building wiring. Citizens should not attempt to install these devices to an electrical panel.

Fixed Generators

Large, fixed generators generally are directly connected to building wiring to provide standby power during emergencies or power outages. However, the wiring needs to be properly installed by a qualified electrical contractor. Properly installing a "permanent" generator is extremely dangerous and usually requires an electrical permit from the local electrical or building inspector's office. Picking an appropriate fixed-site emergency generator involves a number of issues including:

- Type of fuel – Usually a choice between natural gas or diesel, depending on the availability of either fuel in an emergency and any possible regulations concerning on-site storage. Natural gas emits far fewer exhaust emissions, which may also be a factor.
- Proper voltage – It's usually best for an emergency generator to match your standard incoming voltage, whether it's single-phase 120/240 or three-phase 277/480, which is the more common commercial application.
- Power requirements – this will entail (a) identifying your critical functions, and (b) having an electrical professional rate the running/start-up kilowatt (kW) requirements for those functions. (See Table B-4 for some basic power ratings for typical applications.)
- Cost – even a small (30-45 kW, 277/480 volt) natural gas standby generator can cost $10,000, plus expenses for instal-

lation and automatic transfer switches. Most emergency operations centers, 911 dispatch centers, and other critical facilities will need a generator with higher requirements.

"Back feeding" - a dangerous condition

Improperly connecting a portable generator to electric wiring can produce "back feed" – a dangerous current that can electrocute or critically injure residents or others. Back feed into power lines from a generator could create "hot" power lines during an outage. Linemen who expect the line to be de-energized could be injured.

One good way to avoid back feeding is to install a double-pole, double throw transfer-switch gear. A qualified electrical contractor can install this transfer switch so that dangerous back feed can be prevented. "In accordance with the National Electrical Code, paragraph 700-6: Transfer equipment shall be designed and installed to prevent the inadvertent interconnection of normal and emergency sources of supply in any operation of the transfer equipment. Automatic transfer switches shall be electrically operated and mechanically held." The transfer switch must be a break-before-make switch, which will "break" the electrical connection with commercial power lines before it "makes" the connection between the generator and wiring. The switch also will prevent utility power from damaging the generator when regular service is restored. An electrical diagram of an installation using a transfer switch appears in Figure B-2.

Since transfer switches can be expensive, another way to install a generator is to have a sub-panel with main breakers and power from the main panel or generator. Main panel breaker and generator breaker in sub-panel would have handles interlocked to prevent both from being opened and closed at the same time. This prevents back feed to commercial power when the generator is in use.

For commercial emergency installations, it is also critical that an electrical professional review what the standard and max loads will be on the system. An evaluation needs to be made as to what critical functions need to be operational – HVAC, communications, lighting, security, cooking capabilities, and so on. In health care facilities, assistive devices and water supply equipment can pull large quantities of power, which will need to be taken into account.

C.3.13 Critical Facility Protection

Critical facilities require a higher level of protection because they are vital public facilities, reduce pollution of floodwaters by hazardous materials, and ensure that the facilities will be operable during emergencies. The Community Rating System (CRS) provides credit for regulations protecting critical facilities from the 500-year flood.

Critical facilities should be constructed on properly compacted fill and have the lowest floor (including basement) elevated at least one foot above the elevation of the 500-year flood. A critical facility should have at least one access road connected to land outside the 500-year floodplain capable of supporting a 4,000-pound vehicle. The top of the road must be no lower than six inches (6") below the elevation of the 500-year flood.

C.3.14 Extreme Heat Protection

Elderly, children, low-income individuals and people with compromised immune systems are more vulnerable to health risks due to intense climate changes, especially extreme heat.

Aging is often accompanied by chronic illness-

es that may increase susceptibility to extreme environmental conditions. Poverty among elderly increases the risk.

Children are vulnerable due to their size, behavior and fact that they are growing and developing. Children living in poverty or without access to proper medical care are especially vulnerable.

Low-income individuals are less likely to be able to afford air-conditioning and have less access to health care.

Cancer, AIDS and diabetes compromise individual's immune systems. Afflicted individuals are more susceptible to physical stresses such as those during extreme heat.

Steps to protect individuals from the heat include:

- Install window air-conditioners snugly and insulate spaces for a tighter fit.
- Hang shades, draperies, awnings, or louvers on windows receiving morning or afternoon sun. Awnings or louvers can reduce heat entering the house by as much as 80%.
- Stay indoors as much as possible. If air conditioning is not available, stay on the lowest floor out of the sunshine.
- Drink plenty of water and limit alcoholic beverages.
- Dress in light-colored, loose-fitting clothes that cover as much skin as possible.
- Take a cool bath.
- Slow down.

Suggestions for a community heat emergency intervention plan include:

- Standardizing guidelines for providing warnings to the public, including not only the National Weather Service but also Emergency Medical Services, the Health Department, Emergency Management, and other recognized community agencies.
- The public must have access to the steps to take to lessen the likelihood of heat problems, such as staying in air-conditioning, if possible, and drinking plenty of fluids.
- A room air conditioner loan program for bed ridden/chair-ridden individuals can assist those individuals who cannot physically leave their homes to visit an air-conditioned location each day.
- "Buddy systems" can be established where an individual is assigned to check on people at risk. The "buddy" should be trained to deal with heat-related emergencies.
- Utility companies should not be allowed to terminate service during a heat emergency, even if individuals have not paid their bill.

C.3.15 Proper Storage and Disposal of Hazardous Materials

Household chemicals and motor oil dumped down drains or directly onto the ground can work their way into the waterways and ground waters. Oil from a single oil change can ruin one million gallons of fresh water. Used crankcase oil has been reported to account for more than 40% of the oil pollution in waterways.

Most public and private vehicle maintenance facilities have well-developed systems to store their waste oil for recycling. However, "do-it-yourselfers" account for a large percentage of the oil changes in any community. Therefore, it is important for community recycling and solid waste management programs to include a system for waste oil collection and provide ways to collect and dispose of household chemicals.

Many counties and communities offer household pollutant collection events. Among the pollutants collected are oil-based paints, paint thinners, pesticides, fertilizers, cleansers, acids, ammunition, batteries, motor oil, and antifreeze. Residents are not charged for items collected. Events are typically funded by participating communities.

Containers of hazardous materials should not be located in a flood hazard area. If such

a location is necessary, hazardous material containers need to be anchored. Contents can contaminate water and multiply the damaging effects of flooding by causing fires or explosions or by otherwise making structures unusable. Buoyant materials should be anchored. If they float downstream, they may cause additional damage to buildings or bridges or may plug a stream resulting in higher flood heights. Websites, such as earth911.com, provide lists of hazardous waste recycling centers and used oil collection facilities based on zip code and materials.

C.3.16 Water Conservation

97% of the earth's water is in the oceans and 2% is trapped in icecaps and glaciers, leaving only about 1% of the earth's water available for human consumption. The water supply is taxed to supply all the competing interests: residential - including drinking and sanitation, manufacturing, environmental, agricultural, and recreational.

Conserving water conserves energy (gas, electric or both), reduces monthly water and sewer bills, and postpones the construction of or eliminates the need to build expensive capital projects such as wastewater or water treatment plants that will need future maintenance.

Plumbing codes implemented in Phoenix, Arizona in 1990 required low-flow faucets, shower heads, and toilets. Since then, water consumption per capita has decreased 27 percent. Other cities, such as Wilsonville, Oregon, have implemented an inverted block water rate structure, charging customers higher rates as water consumption increases.

Public education can have the most significant impact. Household water conservation tips include:

- Updating plumbing fixtures with low-flow devices.
- Keeping a pitcher of water in the refrigerator instead of running the tap.
- Watering the yard and gardens in the morning or evening when temperatures are cooler to minimize evaporation.
- Collecting water used for rinsing and reusing it to water plants.
- Turning off the water while brushing teeth and shaving.
- Landscaping with drought-resistant, low water use plants.
- Using a hose nozzle and turning off the water while washing cars.

C.3.17 Open Space Preservation

Keeping the floodplain open and free from development is the best approach to preventing flood damage. Preserving open space is beneficial to the public in several ways. Preserving floodplains, wetlands, and natural water storage areas maintains the existing stormwater storage capacities of an area. These sites can also serve as recreational areas, greenway corridors and provide habitat for local flora and fauna. In addition to being preserved in its natural landscape, open space may also be maintained as a park, golf course, or in agricultural use.

C.3.18 Conclusions

1. Planning and zoning will help Tulsa develop the community proactively so that the resulting infrastructure is laid out in a coherent and safe manner.
2. Building codes for foundations, sprinkler systems, masonry, and structural elements such as roofs are prime mitigation measures for occurrences of floods, tornados, high winds, extreme heat and cold, lightning strikes, and earthquakes.
3. Public education (see Section 0.1) can demonstrate preventive measures individuals and businesses can use to protect their own lives and facilities.
4. Tulsa participates in the NFIP and uses

subdivision regulations to control the direction of floodplain development.
5. Deficiencies in stormwater management can be corrected by conducting a master study of watersheds to determine appropriate standards for different areas.

C.3.19 Recommendations

Refer to Chapter 5: Mitigation Strategy for a complete listing of all recommended mitigation measures by hazard and priority.

C.4. Structural Projects

Structural projects are usually designed by engineers or architects, constructed by the public sector, and maintained and managed by governmental entities. Structural projects traditionally include stormwater detention reservoirs, levees and floodwalls, channel modifications, drainage and storm sewer improvements, and community tornado safe-rooms.

C.4.1 Safe Rooms

Safe rooms are specially constructed shelters intended to protect occupants from tornados and high winds. Constructed of concrete and steel, properly built safe rooms can provide protection against wind speeds of 250mph and airborne debris traveling as fast as 100mph.

A safe room can be incorporated into the construction of a new home or can be retrofitted above or below ground into an existing home. The cost of constructing a safe room is between $2,500 and $6,000, depending on the room size, location, and type of foundation on which the home is built. Safe rooms can function year-round as a usable area, such as a bathroom, closet, or utility room.

The State of Oklahoma, FEMA, and communities may offer reimbursement grants for construction of certain categories of Safe Rooms through the Hazard Mitigation Grant Program (HMPG).

FEMA 320, Taking Shelter From the Storm: Building a Safe Room Inside Your Home has specific designs for tornado and hurricane safe rooms. To obtain a copy of FEMA 320, refer to http://www.fema.gov/safe-room resources/fema-p-320-taking-shelter-storm-building-safe-room-your-home-or-small-business.

National Storm Shelter Association

The National Storm Shelter Association (NSSA) is an industry organization developed to ensure the highest quality of manufactured and constructed storm shelters. The NSSA has developed a program to verify that design, construction, and installation of storm shelters are in compliance with the most comprehensive and extensive safety standards available. Without full compliance with the standard, vulnerabilities may exist and safety may be compromised. Shelter-producing members of the NSSA submit shelter designs to the scrutiny of an independent third-party engineering company and have their shelters tested for debris impact resistance (FEMA 320 designs have been tested). In addition, they will file a certificate of installation with NSSA for each shelter.

Upon building or installing a storm shelter, the member applies a seal to the shelter certifying that it is designed, built, and installed to meet the NSSA standard. Only the shelter producer or an agency that carefully inspects the shelter design, construction, and installation may certify compliance with an applicable standard. Claims of "FEMA Certified" or "Texas Tech Certified" are misleading, since neither FEMA nor the Texas Tech Wind Science and Engineering Research Center (contributors to the FEMA standards for individual and community SafeRooms) certifies shelter quality.

This program not only provides assurance to the user of a storm shelter that it has been built to a certain performance standard, but it shifts some responsibility from the community to provide verification from building inspectors for compliance and reduces building inspectors' training requirements. Additional information on the NSSA certification program can be obtained at www.nssa.cc.

School Safe Rooms

In the past, a school's interior areas, especially hallways, have been designated as the best place to seek refuge from violent storms. However, in 1999 the hallways of two schools in Sedgwick County, Kansas received significant damage which could have resulted in student casualties had school been in session.

FEMA 361 publication "Design and Construction Guidance for Community Shelters" provides guidelines for constructing school safe rooms. A community shelter strong enough to survive a violent storm can also be used as a cafeteria, gymnasium, or other common area.

Schools, administration buildings, and institutions of higher learning are required to have written plans and procedures in place for protecting students, faculty, administrators, and visitors from natural and man-made disasters and emergencies.

To receive a copy of FEMA 361, see http://www.fema.gov/safe-room-resources/fema-p-361-design-andconstruction-guidance-community-safe-rooms.

C.4.2 Reservoirs and Detention

Reservoirs control flooding by holding high flows behind dams or in storage basins. After a flood peaks, water is released or pumped out slowly at a rate that the river can accommodate downstream. The lake created may provide recreational benefits or water supply (which could help mitigate a drought).

Reservoirs are suitable for protecting existing development downstream from the project site. Unlike levees and channel modifications, they do not have to be built close to or disrupt the area to be protected. Reservoirs are most efficient in deeper valleys where there is more room to store water or on smaller rivers where there is less water to store. Building a reservoir in flat areas and on large rivers may not be cost-effective, because large areas of land have to be purchased.

In urban areas, some reservoirs are simply manmade holes dug to store floodwaters. When built in the ground, there is no dam for these retention and detention basins and no dam failure hazard. Wet or dry basins can also serve multiple uses by doubling as parks or other open space uses.

C.4.3 Levees and Floodwalls

Probably the best-known flood control measure is an earthen barrier (levee) or concrete (floodwall) erected between the watercourse and the property to be protected. Levees and floodwalls confine water to the stream channel by raising its banks. They must be well designed to account for large floods, underground seepage, pumping of internal drainage, and erosion and scour.

Failure to maintain levees can lead to significant loss of life and property if they are stressed and broken or breached during a flood event. An inspection, maintenance, and enforcement program helps ensure structural integrity.

Levees placed along the river or stream edge degrade the aquatic habitat and water quality of the stream. They also are more likely to push floodwater onto other properties upstream or downstream. To reduce environmental impacts and provide multiple use benefits, a setback

levee (set back from the floodway) is the best project design. The area inside a setback levee can provide open space for recreational purposes and provide access sites to the river or stream.

C.4.4 Channel Improvements

By improving channel conveyance, more water is carried away at a faster rate. Improvements generally include making a channel wider, deeper, smoother, or straighter. Some smaller channels in urban areas have been lined with concrete or put in underground pipes.

C.4.5 Crossings and Roadways

In some cases, buildings may be elevated above floodwaters, but access to the building is lost when floodwaters overtop local roadways, driveways, and culverts or ditches. Depending on the recurrence interval between floods, the availability of alternative access, and the level of need for access, it may be economically justifiable to elevate some roadways and improve crossing points.

For example, if there is sufficient downstream channel capacity, a small culvert that constricts flows and causes localized backwater flooding may be replaced with a larger culvert to eliminate flooding at the waterway crossing point. The potential exacerbating of adjacent or downstream flooding needs to be considered before implementing any crossing or roadway drainage improvements.

C.4.6 Drainage and Storm Sewer Improvements

Man-made ditches and storm sewers help drain areas where the surface drainage system is inadequate or where underground drainageways may be safer or more practical. Storm sewer improvements include installing new sewers, enlarging small pipes, and preventing back flows. Particularly appropriate for depressions and low spots that will not drain naturally, drainage and storm sewer improvements usually are designed to carry the runoff from smaller, more frequent storms.

Because drainage ditches and storm sewers convey water faster to other locations, improvements are only recommended for small local problems where the receiving stream or river has sufficient capacity to handle the additional volume and flow of water. To reduce the cumulative downstream flood impacts of numerous small drainage projects, additional detention or run-off reduction practices should be provided in conjunction with the drainage system improvements.

C.4.7 Drainage System Maintenance

The drainage system may include detention ponds, stream channels, swales, ditches, and culverts. Drainage maintenance is an ongoing program to clean out blockages caused by an accumulation of sediment or overgrowth of weedy, non-native vegetation or debris, and remediation of stream bank erosion sites.

“Debris” refers to a wide range of blockage materials that may include tree limbs and branches that accumulate naturally or large items of trash or lawn waste accidentally or intentionally dumped into channels, drainage swales or detention basins. Maintenance of detention ponds may also require revegetation or repairs of a restrictor pipe, berms, or overflow structure.

Maintenance activities normally do not alter the shape of a channel or pond, but they do affect how well a drainage system can do its job. Sometimes it is a very fine line that separates debris that should be removed from natural material that helps form habitat.

C.4.8 Conclusions

1. Reservoirs can hold high flows of water that can later be released slowly or retained for recreational purposes or drought mitigation.
2. Levees and floodwalls are not as effective overall because of possible underground seepage, erosion, degradation of aquatic habitat and water quality, and ineffectiveness in large floods.
3. Channel improvements allow more water to be carried away faster.
4. The effectiveness of elevating buildings depends on the availability of alternative access when flooding occurs.
5. Crossing and roadway drainage improvements must take into account additional detention or run-off reduction.
6. Drainage and storm sewer improvements carry runoff from smaller, more frequent storms.
7. Drainage system maintenance is an ongoing project of removing debris that decreases the effectiveness of detention ponds, channels, ditches, and culverts.

C.4.9 Recommendations

Refer to Chapter 5: Mitigation Strategy, for a complete listing of all recommended mitigation measures by hazard and priority.

C.5 Property Protection

Property protection measures are used to modify buildings or property subject to damage from various hazardous events. The property owner normally implements property protection measures. However, in many cases technical and financial assistance can be provided by a governmental agency. Property protection measures typically include acquisition and relocation, flood-proofing, building elevation, barriers, retrofitting, safe rooms, hail-resistant roofing, insurance, and the like.

C.5.1 The City's Role

Property protection measures are usually considered the responsibility of the property owner. However, the City should be involved in all strategies that can reduce losses from natural hazards, especially acquisition. There are various roles the City can play in encouraging and supporting implementation of these measures.

Providing basic information to property owners is the first step in supporting property protection measures. Owners need general information on what can be done. They need to see examples, preferably from nearby.

Financial Assistance

Communities can assist owners by helping to pay for a retrofitting project, just like they pay for flood control projects. Financial assistance can range from full funding of a project to helping residents find money from other programs. Some communities assume responsibility for sewer backups and other flood problems that arose from an inadequate public sewer or drain system.

Less expensive community programs include low interest loans, forgivable low interest loans, and rebates. A forgivable loan is one that does not need to be repaid if the owner does not sell the house for a specified period, such as five years. These approaches do not fully fund the project but they cost the community treasury less and they increase the owner's commitment to the flood protection project.

Often, small amounts of money act as a catalyst to pique the owner's interest to get a self-protection project moving. Several Chicago suburbs have active rebate programs that fund only 20% or 25% of the total cost of a retrofitting project. These programs have helped install hundreds of projects that protect buildings from low flood hazards.

Acquisition Agent

The City can be a focal point for many acquisition projects. In most cases, when acquisition of a property is feasible the City is the ultimate owner of the property, but in other cases the school district or other public agencies can assume ownership and the attendant maintenance responsibilities.

Other Incentives: "Non-financial Incentives"

Sometimes only a little funding is needed to motivate a property owner to implement a retrofitting project. A flood insurance premium reduction will result if a building is elevated above the flood level. This reduction is not enough to take much of a bite out of the cost of the project, but it reassures the owner that he or she is doing the right thing. Other forms of floodproofing are not reflected in the flood insurance rates for residential properties, but they may help with the Community Rating System, which provides a premium reduction for all policies in the community.

Other incentives to consider are programs to help owners calculate the benefits and costs of a project and a "seal of approval" for retrofitted buildings. The latter would be given following an inspection that confirms the building meets certain standards. There are many other personal but non-economic incentives to protect a property from flood damage, such as peace of mind and increased value at property resale.

C.5.2 Insurance

Insurance has the advantage that, as long as the policy is in force, the property is protected and no human intervention is needed for the measure to work. There are three types of insurance coverage:

1. The standard homeowner's, dwelling, and commercial insurance policies cover against the perils of wildfire and the effects of severe weather, such as frozen water pipes.
2. Many companies sell earthquake insurance as an additional peril rider on homeowner's policies. Individual policies can be written for large commercial properties. Rates and deductibles vary depending on the potential risk and the nature of the insured properties.
3. Flood insurance is provided under the National Flood Insurance Program.

Flood Insurance

Although most homeowner's insurance policies do not cover a property for flood damage, an owner can insure a building for damage by surface flooding through the National Flood Insurance Program (NFIP). Flood insurance coverage is provided for buildings and their contents damaged by a "general condition of surface flooding" in the area.

Building coverage is for the structure. Contents coverage is for the removable items inside an insurable building. A renter can take out a policy with contents coverage, even if there is no structural coverage.

Some people have purchased flood insurance because the bank required it when they got a mortgage or home improvement loan. Usually these policies just cover the building's structure and not the contents.

In most cases, a 30-day waiting period follows the purchase of a flood insurance policy before it goes into effect. The objective of this waiting period is to encourage people to keep a policy at all times. People cannot wait for the river to rise before they buy their coverage.

C.5.3 Acquisition and Relocation

Moving out of harm's way is the surest and safest way to protect a building from damage. Acquiring buildings and removing them is also a way to convert a problem area into a commu-

nity asset and obtain environmental benefits.

The major difference between the two approaches is that acquisition is undertaken by a government agency so the cost is not borne by the property owner, and the land is converted to public use, such as a park. Relocation can be either government- or owner-financed.

While almost any building can be moved, the cost goes up for heavier structures, such as those with exterior brick and stone walls and large or irregularly shaped buildings. However, experienced building movers know how to handle any job.

Cost

An acquisition budget should be based on the median price of similar properties in the community, plus $10,000 to $20,000 for appraisals, abstracts, title opinions, relocation benefits, and demolition. Costs may be lower after a flood or other disaster. For example, the community may have to pay only the difference between the full price of a property and the amount of the flood insurance claim received by the owner.

One problem that sometimes results from an acquisition project is a "checkerboard" pattern in which nonadjacent properties are acquired. This can occur when some owners, especially those who have and prefer a waterfront location, prove reluctant to leave. Creating such an acquisition pattern in a community simply adds to the maintenance costs that taxpayers must support.

Relocation can be expensive, with costs ranging from $30,000 for a small wood frame building to over $60,000 for masonry and slab on grade buildings. Two-story houses are more expensive to move because of the need to relocate wires and avoid overpasses. Additional costs may be necessary for acquiring a new lot on which to place the relocated building and for restoring the old site. Larger buildings may have to be cut and the parts moved separately. Because of all these complications, there are cases where acquisition is less expensive than relocation.

Where Appropriate

Acquisition and relocation are appropriate in areas subject to:

- Flash flooding
- Deep waters
- Dam break flooding
- Landslides
- Potential hazardous materials spills
- Other high hazards that affect a specific area

Acquisition and relocation are not appropriate for hazards like tornados or winter storms because there are no areas safe from the hazard. Relocation is also preferred for large lots that include buildable areas outside the hazardous area or where the owner has a new lot in a safer area.

Acquisition (followed by demolition) is preferred over relocation for buildings that are difficult to move, such as larger slab foundation or masonry structures, and for dilapidated structures that are not worth protecting.

C.5.4 Building Elevation

Raising a building above the flood level is the best on-site property protection method for flooding. Water flows under the building, causing little or no damage to the structure or its contents. Alternatives are to elevate on continuous foundation walls (creating an enclosed space below the building) or elevation on compacted earthen fill.

C.5.5 Barriers

Barriers keep surface waters from reaching a building. A barrier can be built of dirt or soil ("berm") or concrete or steel ("floodwall"). In cases of shallow flooding, regrading a yard can provide the same protection as a separate barrier.

C.5.6 Retrofitting

This term covers a variety of techniques for modifying a building to reduce its susceptibility to damage by one or more hazards.

Where Appropriate

Some of the more common approaches are:

Floods and dam failures:

- Dry floodproofing keeps the water out by strengthening walls, sealing openings, or using waterproof compounds or plastic sheeting on walls. Dry floodproofing is not recommended for residential construction.
- Wet floodproofing—using water resistant paints and elevating anything that could be damaged by a flood—allows for easy cleanup after floodwaters recede. Accessory structures or garages below the residential structure are potential candidates for wet floodproofing.
- Installing drain plugs, standpipes, or backflow valves to stop sewer backup.

Tornado:

- Constructing an underground shelter or in-building "safe room"
- Securing roofs, walls, and foundations with adequate fasteners or tie-downs
- Strengthening garage doors and other large openings

High winds:

- Installing storm shutters and storm windows
- Burying utility lines
- Using special roofing shingles designed to interlock and resist uplift forces
- Installing/incorporating backup power supplies

Hailstorms:

- Installing hail-resistant roofing materials

Lightning:

- Installing lightning rods and lightning surge interrupters
- Burying utility lines
- Installing/incorporating backup power supplies

Winter storms:

- Adding insulation
- Relocating water lines from outside walls to interior spaces
- Sealing windows
- Burying utility lines
- Installing/incorporating backup power supplies

Extreme heat and drought:

- Adding insulation
- Installing water saver appliances, such as shower heads and toilets

Wildfires:

- Replacing wood shingles with fire-resistant roofing
- Adding spark arrestors on chimneys
- Landscaping to keep bushes and trees away from structures
- Installing sprinkler systems
- Installing smoke alarms

Earthquake:

- Retrofitting structures to better withstand shaking
- Tying down appliances, water heaters, bookcases, and fragile furniture so they won't fall over during a quake

Common Measures

From the above lists, it can be seen that certain approaches can help protect from more than one hazard. These include:

- Strengthening roofs and walls to protect from wind and earthquake forces
- Bolting or tying walls to the foundation to protect from wind and earthquake forces and the effects of buoyancy during a flood
- Adding insulation to protect for extreme heat and cold

- Anchoring water heaters and tanks to protect from ground shaking and flotation
- Burying utility lines to protect from wind, ice, and snow
- Installing backup power systems for power losses during storms
- Installing roofing that is hail-resistant and fireproof

C.5.7 Impact-Resistant Windows and Doors

Doors and windows can be the most vulnerable components of your home. During high wind events such as thunderstorms or tornados, wind-driven debris can easily penetrate unprotected or unreinforced windows and doors, breaching the secure envelope of the structure. The debris and rain may cause damage to interior furnishings or harm to residents, but the wind itself can create extreme pressures on the walls and ceiling, leading to catastrophic structural failure. This danger can be mitigated by the installation of impact-resistant windows and doors.

C.5.8 Windows

Today's impact-resistant glass sandwiches a laminated inner layer made of polyvinyl butyral, a plastic, between two sheets of glass. Stronger than a car windshield, the glass might shatter if a heavy object crashes into it, but it won't break to bits. That makes wind less likely to penetrate the envelope of a home and create interior pressure severe enough to blow a roof off. Impact-resistant windows are only as strong, though, as the frame in which they rest. "An impact-resistant window is tested as a unit that includes the glass, the frame as well as the attachment hardware and the installation method." (FLASH)

The second type of impact-resistant glass uses a film applied to the surface. Impact-resistant film is placed over the glass to keep windows from shattering into sharp particles if broken. Since these films are added to the glass, they may not be as effective as a standard impact-resistant system. Their durability depends on how well the glass and protective laminate stay in the frame and window assembly. They will be effective against smaller objects, but larger pieces of debris may still take the window out of the frame. For more information on protective window films and other technologies, visit the International Window Film Association's website.

(http://www.iwfa.com/ConsumerInfo/Safety-Security.aspx).

While costs for replacing window glass or using impact-resistant glass in new construction can be expensive, there are additional benefits that may be gained. Impact-resistant glass has been used successfully to reduce burglaries, vandalism, and break-ins with both homes and businesses. In addition, using an impact-resistant glazing that is also more energy efficient can produce substantial energy savings. According to the Partnership for Advancing Housing Technology (PATH), a public-private partnership between leaders in the homebuilding, product manufacturing, and insurance industries and several Federal agencies:

Special glass "...can be used to both make windows impact-resistant and more energy efficient. Low-E and solar control low-E (also called spectrally selective) coatings can be used to boost the energy efficiency of windows. Low-E double pane windows, most common in cold and moderate climates, are more energy efficient than clear windows because the low-E coating reduces heat loss through the window. Solar control glass, also called Low E2, is a good glass for hot climates because, in addition to improving the insulating ability of windows, it also limits solar heat gain by blocking

passage of infrared and some ultraviolet rays. Solar control glass allows a higher level of visible light to pass through a window with less solar heat gain reduction than tinted window coatings."

Garage Doors

Garage doors are particularly vulnerable, especially doublewide garage doors because of their long span and, frequently, lightweight materials. Reinforced garage door and track systems are available to help avoid that problem. Retrofit kits are also available to reinforce existing garage doors, but the retrofit kits do not provide the same level of protection as systems designed to be wind- and impact-resistant. (Source: Federal Alliance for Safe Homes – FLASH. www.flash.org.)

C.5.9 Lightning Protection Systems

The purpose of a lightning protection system is to intercept lightning and safely direct its current to ground. If the system is properly designed, installed, and maintained, it can provide almost 100% protection to buildings.

The system for an ordinary structure includes at least air terminals (lightning rods), down conductors, and ground terminals. These three elements of the system must form a continuous conductive path for lightning current. Many systems of air terminals now may not even be connected to the building. They may be comprised of freestanding cables or towers above or next to the building.

National Fire Protection Association document NFPA 780, Standard for the Installation of Lightning Protection Systems, describes lightning protection system installation requirements. NFPA 780 is available through http://www.nfpa.org/codes-and-standards/document-information-pages?-mode=code&code=780.

C.5.10 Surge and Spike Protection

The average home has 2,200 or more power surges annually, 60% of which are generated within the home. Most surges are caused by motors starting in air conditioners, garage doors, refrigerators, and other major appliances. Electronic appliances can be damaged or destroyed by over-voltage surges or spikes.

Whole house surge protectors offer the first line of defense against high-energy, high-voltage surges. These devices thwart the energy of the initial surge and reduce it before it reaches electrical appliances. In many cases this level of protection is enough to protect the home. Surge protectors should be sufficient to also provide "spike protection," which can defend against the extremely high spiking voltage created by lightning strikes. Many surge protectors, while effective against routine voltage fluctuations, may not defend against high level spikes.

Surge protection devices connected directly to appliances offer the second line of defense. They are the only defense against surges within the home as when, for example, a large appliance kicks in. The combination of whole house and point-of-use surge protection provides the best possible protection.

For more information on whole house and point-of-use surge protectors, refer to www.howstuffworks.com/surgeprotector.htm.

C.5.11 Landscaping for Wildfire Prevention

The chance of losing property due to wildfire can be reduced using fire prevention landscaping techniques. The amount of cleared space around a home improves its ability to survive a wildfire. A structure is more likely to survive when grasses, trees, and other common fuels are removed, reduced or modified to reduce

a fire's intensity and keep it away from the structure.

C.5.12 Conclusions

1. Acquisition and relocation of property is the most effective for property protection in the case of hazards that are expected to occur repeatedly in the same locations. Acquisition followed by demolition is preferable.
2. Other methods of property protection for flooding include raising building elevations and building berms and floodwalls.
3. Building modifications are also appropriate for some hazards.
4. Property insurance has the advantage of protecting the property without human intervention.
5. The City can help in reducing losses from natural hazards by providing financial assistance, having an acquisition program, and other incentives.

C.5.13 Recommendations

Refer to Chapter 5: Mitigation Strategy, for a complete listing of all recommended mitigation measures by hazard and priority.

C.6 Emergency Services

Emergency services measures protect people during and after a hazard event. Locally, Tulsa Area Emergency Management coordinates these measures in cooperation with emergency management in nearby counties and communities. Measures include preparedness, threat recognition, warning, response, critical facilities protection, and post-disaster recovery and mitigation.

C.6.1 Threat Recognition

Threat recognition is the key. The first step in responding to a flood, tornado, storm or other natural hazard is being aware that one is coming. Without a proper and timely threat recognition system, adequate warnings cannot be disseminated.

Emergency Alert System (EAS)

Using digital technology to distribute messages to radio, television, and cable systems, the EAS provides state and local officials with the ability to send out emergency information targeted to a specific area. The information can be sent electronically through broadcast stations and cable systems even if those facilities are unattended.

Floods

A flood threat recognition system provides early warning to emergency managers. A good system will predict the time and height of the flood crest. This can be done by measuring rainfall, soil moisture, and stream flows upstream of the community and calculating the subsequent flood levels.

On larger rivers, the National Weather Service hydrology office in Tulsa does the measuring and calculating. It is in the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) office. Flood threat predictions are disseminated on the NOAA Weather Wire or NOAA Weather Radio. NOAA Weather Radio is considered by the federal government to be the official source for weather information.

The National Weather Service issues notices to the public using two levels of notification:

Flood watch: conditions are right for flooding

Flood warning: a flood has started or is expected to occur

On smaller rivers, local rainfall and river gages are needed to establish a flood threat recognition system. The National Weather Service may issue a "flash flood watch." This means

the amount of rain expected will cause ponding and other flooding on small streams and depressions. These events are sometimes so localized and rapid that a "flash flood warning" may not be issued, especially if no gauges or other remote threat recognition equipment is available.

Meteorological Hazards

The National Weather Service (NWS) is the prime agency for detecting meteorological threats, such as tornados, thunderstorms, and winter storms. As with floods, the federal agency may focus on the large scale elements of a storm, e.g., whether conditions are appropriate for formation of a tornado. Local NWS offices focus on individual storms and the fine-tuned details in the moments of severe weather. They can provide more site-specific and timely recognition by sending out spotters to watch the skies when the Weather Service issues a watch or warning.

NOAA All-Hazard Radios

NOAA (the parent agency for the National Weather Service) maintains a nationwide network of radio stations broadcasting continuous weather information direct from regional National Weather Service offices. The NWS broadcasts warnings, watches, forecasts, Amber Alerts, and other hazard and safety information 24 hours a day. Post-event information is also broadcast for natural hazards (such as tornados and earthquakes) and environmental hazards (such as chemical releases or oil spills).

These broadcasts can be received by any radio capable of receiving the Weather Service frequency. NOAA All-Hazard Radios have the additional advantage of being activated by a pre-broadcast signal transmitted by the NWS, coming off standby and sounding an alert tone loud enough to wake sleeping individuals before transmitting the warning message. NOAA Weather Radio receivers can be purchased at many retail stores that sell electronic merchandise. Typical cost of a residential grade NOAA Weather Radio is between $20 and $200.

For more information on NOAA Weather Radios, see www.nws.noaa.gov/nwr/

C.6.2 Warning

After the threat recognition system tells the CEMA that a flood or other hazard is coming, the next step is to notify the public and staff of other agencies and critical facilities. Earlier and more specific warnings enable more people to implement protective measures. The following page highlights some of the more common warning methods.

Multiple or redundant systems are the most effective, because if people do not hear one warning, they may still get the message from another part of the system. Each has advantages and disadvantages. Outdoor warning sirens can reach the most people quickly (except those around loud noise, such as at a factory or during a thunderstorm), but they do not explain what hazard is coming and cannot be sounded unless a timely means of threat recognition exists. Radio and TV provide a lot of information, but people have to know to turn them on.

Telephone trees are fast, but can be expensive and do not work when phones lines are down. Just as important as issuing a warning is telling people what to do. A warning program should have a public information aspect. People need to know the difference between a tornado warning (when they should seek shelter in a basement) and a flood warning (when they should stay out of basements).

C.6.3 9-1-1 and 2-1-1

Some communities have expanded their basic 9-1-1 location identification telephone service

COMMON WARNING METHODS	
TV Broadcasts, Live-streaming, and EAS	Good tools for delivering an alert to a wide coverage area in real time but not well-suited for delivering "actionable" information to specific population segments. For an EAS to be effective, it is essential for the target audience to be tuned in to a regional station. Actual practice shows this is not always the case, particularly late at night when the general population is asleep.
Door-to-door Notification	Door-to-door notification would be an ideal way to communicate with specific individuals or neighborhoods. However, efficiency is impacted by the number of addresses to be contacted, the number of personnel available to "walk the streets," and the amount of time available prior to the event (i.e., evacuation). It is highly unlikely that sufficient public safety personnel would be available to effectively provide such door-to-door notification services. Door-to-door also has the potential of putting first responders in harm's way.
Mass Notification System	Mass notification systems can be used to reach large numbers of citizens quickly and efficiently with warning messages. Citizens are able to enter their contact preferences (phone, text, or email) and opt out of non-emergency messages.
Other Communications Devices	There are other communication devices available that may be able to receive emergency notifications. However, as with Weather Alert Radio, their level of penetration throughout the population is too low to ensure effective delivery. Selecting distinct population segments based on geography with such devices is also a problem.
Outdoor warning sirens	Sirens can be effective in their ability to alert people within hearing distance that a crisis or emergency situation may exist. Outdoor warning sirens and public address systems are commonly located in densely populated urban settings, but are not as useful in rural areas. Sirens are intended to alert the public to implement some pre-determined action (i.e., tune to radio and television for specific information on a hazard). However the public generally has no awareness of the need to do so and often will ignore sirens thinking they are a "test" unless they see the hazard approaching, which is often then too late to take appropriate action.
NOAA Weather Radio	Weather Alert Radio, while an invaluable tool, has limited applicability. Lacking proper feedback, public safety and emergency management officials have no way of being sure that everyone in their jurisdiction can be reached with such announcements because, similar to broadcast announcements, the audience must have a NOAA radio and be tuned in.
Sirens on Public Safety Vehicles	These have many of the same drawbacks as both door-to-door notification and outdoor warning sirens. Emergency vehicle sirens do not provide "actionable" information on how to respond. In addition, crucial emergency service personnel may be tied up when their services are more urgently needed for response.

to include features such as "enhanced 9-1-1" registering name, address, and a description of the building/site. Additionally, non-emergency 2-1-1 service can be used to have people call to get information, such as locations of cooling shelters during a heat wave. For information on coverage areas and contact information for area 2-1-1 systems, see www.211oklahoma.org. For Tulsa, HelpLine 2-1-1, at 918-836-2111, operates 2-1-1.

C.6.4 Emergency Telephone Notification Systems (ETNS)

It has become more common to use an "Emergency Telephone Notification System" (frequently referred to as reverse 9-1-1) with which a community can send out a mass telephone announcement to targeted numbers in the 9-1-1 system, effectively supplementing a community's other warning systems. An effective ETNS can offer certain advantages over other systems:

- ETNS systems provide the ability to precisely target populations in specific geographic locations better than existing alternatives, particularly when ETNS systems were integrated with geographic information systems (GIS) maps commonly used by 9-1-1 systems;
- The telephone, more than any other communications medium, allows officials to deliver specific actionable information that lets those in harm's way know exactly what to do, what to expect, or what to look for;
- The telephone is always on, providing the opportunity to reach nearly everyone in a target area either live or through voicemail;
- Many systems also offer the option of allowing people to call in and retrieve the same message or an updated one. This can reduce the subsequent number of calls to 9-1-1 from people who did not fully understand the message the first time. (Source: NENA Minimum Standards for Emergency Telephone Notification Systems, NENA 56-003, June 12, 2004)

C.6.5 Response

The protection of life and property is the foremost important task of emergency responders. Concurrent with threat recognition and issuing warnings, a community should respond with actions that can prevent or reduce damage and injuries. Typical actions and responding parties include the following:

- Activating the emergency operations room (emergency management)
- Closing streets or bridges (police or public works)
- Shutting off power to threatened areas (utility company)
- Holding children at school/releasing children from school (school district)
- Passing out sand and sandbags (public works)
- Ordering an evacuation (mayor)
- Opening evacuation shelters (Red Cross)
- Monitoring water levels (engineering)
- Security and other protection measures (police)

An emergency action plan ensures that all bases are covered and that the response activities are appropriate for the expected threat. These plans are developed in coordination with the agencies or offices that are given various responsibilities.

Emergency response plans should be updated annually to keep contact names and telephone numbers current and to make sure that supplies and equipment that will be needed are still available. They should be critiqued and revised after disasters and exercises to take advantage of the lessons learned and changing conditions. The end result is a coordinated effort implemented by people who have experience working together so that available resources will be used in the most efficient manner.

C.6.6 Emergency Operations Plan (EOP)

An EOP develops a comprehensive (multi-use)

emergency management program which seeks to mitigate the effects of a hazard, to prepare for measures to be taken which will preserve life and minimize damage, to respond during emergencies and provide necessary assistance, and to establish a recovery system in order to return communities to their normal state of affairs. The plan defines who does what, when, where, and how in order to mitigate, prepare for, respond to, and recover from the effects of war, natural disasters, technological accidents, and other major incidents / hazards.

The Comprehensive Preparedness Guide (CPG) 101: Developing and Maintaining Emergency Operations Plans version 2.0 is available from FEMA. The guide provides ideas and advice to state and local emergency managers in their efforts to develop and maintain an EOP. More information and complete copies of the guide are available through FEMA and its website at www.fema.gov/plan.

Funding for creating or updating an EOP is available from FEMA. For information on how to obtain funding, contact the Oklahoma Office of Homeland Security or go to www.ok.gov/homeland.

The State of Oklahoma's Emergency Operations Plan is published on www.ok.gov/OEM/Programs_&_Services/Planning/State_Emergency_Operations_Plan_-_EOP.html.

C.6.7 Incident Command System (ICS)

The Incident Command System is the model tool for the command, control, and coordination of resources at the scene of an emergency. It is a management tool of procedures for organizing personnel, facilities, equipment, and communications. ICS is based upon basic management skills managers and leaders already know: planning, directing, organizing, coordinating, communicating, delegating, and evaluating.

Continuity of Operations (COOP) planning should be addressed in the EOP. COOP ensures the essential functions of an organization, including government, can continue to operate during and after an emergency incident. An incident may prevent access to normally operating systems, such as physical plant, data or communication networks, or transportation. Government, business, other organizations, and families should be encouraged to prepare by regularly backing up computer drives, copying essential files, and storing these items in a separate location.

ICS is not a means to wrestle control or authority away from agencies or departments, a way to subvert the normal chain of command within a department or agency, nor is it always managed by the fire department, too big for small everyday events or restricted to use by government agencies and departments. ICS is an adaptable methodology suitable for emergency management as well as many other categories. If leadership is essential for the success of an event or a response, ICS is the supporting foundation for successfully managing that event.

The Incident Command System is built around five major management activities. These activities are:

- Command – sets objects and priorities and has overall responsibility at the incident or event.
- Operations – conducts tactical operations to carry out the plan and directs resources.
- Planning – develops the action plan to accomplish objectives and collects and evaluates information.
- Logistics – provides resources and services to support incident needs.
- Finance / Administration – monitors costs, provides accounting, reports time, and cost analysis.

The system can grow or shrink to meet changing needs. This makes it very cost-effective and efficient. The system can be applied to a wide variety of situations such as fires, multi-jurisdiction and multi-agency disasters, hazardous material spills and recovery incidents, pest eradication programs, and state or local natural hazards management.

C.6.8 Mutual Aid / Inter-agency Agreements

Local governments should establish mutual aid agreements for utility and communications systems, including 9-1-1. Mutual aid or inter-agency agreements have value for preventing or responding to other hazard or emergency situations, as fire and police departments often do.

C.6.9 CERT (Community Emergency Response Team)

After a major disaster, local emergency teams quickly become overwhelmed. CERT is designed to have trained groups of citizens in every neighborhood and business ready to assist first responders (police, firefighters, and EMSA) during an emergency.

CERT programs train and equip citizens in neighborhoods and businesses enabling them to "self-activate" immediately after a disaster. CERT teams are trained in:

- Disaster preparedness
- Light fire and suppression
- Light search and rescue
- Basic medical care

FEMA grants have been given to states for funding CERT programs or expanding existing teams. For more information on the CERT program, talk to your local emergency management official or visit www.fema.gov/community-emergency-response-teams.

C.6.10 Debris Management

The tornados of May 3, 1999 left an estimated 500,000 cubic yards of debris. Debris in the aftermath of a disaster poses significant health and safety risks. Debris can include fuel containers, chemicals, appliances, and explosives.

Two key considerations regarding debris management are the need for rapid removal and protection of the public health and environment. Before a disaster strikes, communities should set up staging area(s) where citizens and cleanup crews can take debris prior to final disposal.

Community members can participate in debris control by securing debris, yard items, or stored objects that my otherwise be swept away, damaged, or pose a hazard if floodwaters would pick them up and carry them away. Additionally, a community can pass and enforce an ordinance regulating dumping.

C.6.11 Critical Facilities Protection

"Critical facilities" generally fall into three categories:

- Buildings or locations vital to the response and recovery effort, such as police and fire stations and telephone exchanges;
- Buildings or locations that, if damaged, would create secondary disasters, such as hazardous materials or utility facilities or water treatment plants; and
- Locations that would require extraordinary response or preparedness measures, such as hospitals, retirement homes, or childcare facilities.

In addition, since September 11, FEMA has also included financial institutions as critical facilities because of the potential devastating effect on the community infrastructure upon their loss.

Protecting critical facilities during a disaster is the responsibility of the facility owner or operator. However, if they are not prepared for an emergency, the rest of the community could be impacted. If a critical facility is damaged, workers and resources may be unnecessarily drawn away from other disaster response efforts. If the owner or operator adequately prepares such a facility, it will be better able to support the community's emergency response efforts.

Most critical facilities have full-time professional managers or staff who are responsible for the facility during a disaster. These people often have their own emergency response plans. Many facilities would benefit from early disaster warning, disaster response planning, and coordination with community disaster response efforts.

Schools are critical facilities not only because of the special population they accommodate but because they are often identified as shelter sites for a community. Processes and procedures can be developed to determine mitigation priorities incorporated into capital improvement plans that will ensure these buildings function after an event.

C.6.12 Site Emergency Plans

Communities can encourage development and testing of internal emergency plans and procedures, including continuity planning, by businesses and other organizations.

Communities should develop and test site emergency plans for schools, factories, office buildings, shopping malls, hospitals, correctional facilities, stadiums, recreation areas, and other similar facilities.

C.6.13 Post-Disaster Recovery and Mitigation

After a disaster, communities should undertake activities to protect public health and safety, facilitate recovery, and help people and property for the next disaster. Throughout the recovery phase, everyone wants to get "back to normal." The problem is "normal" means the way they were before the disaster. Measures needed include the following:

Recovery Actions

- Patrolling evacuated areas to prevent looting
- Providing safe drinking water
- Monitoring for diseases
- Vaccinating residents for tetanus
- Clearing streets
- Cleaning up debris and garbage
- Regulating reconstruction to ensure that it meets all code requirements, including the NFIP's substantial damage regulations Mitigation Actions
- Conducting a public information effort to advise residents about mitigation measures they can incorporate into their reconstruction work
- Evaluating damaged public facilities to identify mitigation measures that can be included during repairs
- Acquiring substantially or repeatedly damaged properties from willing sellers
- Planning for long-term mitigation activities
- Applying for post-disaster mitigation funds

Requiring permits, conducting inspections, and enforcing the NFIP substantial improvement/substantial damage regulations can be very difficult for local, understaffed overworked offices after a disaster. If these activities are not carried out properly, not only does the municipality miss a tremendous opportunity to redevelop or clear out a hazardous area, it may be violating its obligations under the NFIP.

C.6.14 StormReady Communities

StormReady, a program started in Oklahoma in

1999, helps arm America's communities with the communication and safety skills needed to save lives and property before and during an event. StormReady communities are better prepared to save lives from the onslaught of severe weather through better planning, education, and awareness.

StormReady has different guidelines for different sized communities. To be 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.

The economic investment in StormReady will depend on current assets. There is currently no grant funding for becoming StormReady. However, the Insurance Services Organization (ISO) may provide community rating points to StormReady communities. Those points may be applied toward lowering flood insurance rates.

C.6.15 Conclusions

1. Using solid, dependable threat recognition systems is first and foremost in emergency services.
2. Following a threat recognition, multiple or redundant warning systems and instructions for action are most effective in protecting citizens.
3. Good emergency response plans that are updated yearly ensure that well-trained and experienced people can quickly take the appropriate measures to protect citizens and property.
4. To ensure effective emergency response, critical facilities protection must be part of the plan.
5. Post-disaster recovery activities include providing neighborhood security, safe drinking water, appropriate vaccinations, and cleanup and regulated reconstruction.

C.6.16 Recommendations

Refer to Chapter 5: Mitigation Strategy, for a complete listing of all recommended mitigation measures by hazard and priority.

C.7 Natural Resource Protection

Natural resource protection activities are generally aimed at preserving and restoring the natural and beneficial uses of natural areas. In doing so, these activities enable the beneficial functions of floodplains and drainageways to be better realized. These natural functions include:

- Storage of floodwaters
- Absorption of flood energy
- Reduction of flood scour
- Infiltration and aquifer/groundwater recharge
- Removal/filtration of excess nutrients, pollutants, and sediments from floodwaters
- Habitat for flora and fauna
- Recreation and aesthetic opportunities
- Opportunities for off-street hiking and biking trails

This Section reviews natural resource protection activities that protect natural areas and mitigate damage from other hazards. Integrating these activities into the hazard mitigation program will not only reduce the City's susceptibility to flood damage but will also improve the overall environment.

C.7.1 Wetlands Protection

Wetlands are often found in floodplains and low-lying areas of a watershed. Many wetlands receive and store floodwaters, thus slowing and reducing downstream flows. They also serve as a natural filter, which helps to improve water quality and provide habitat for many species of fish, wildlife, and plants.

Wetlands are regulated by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency under Section 404 of the Clean Water Act. Before a "404" permit is issued, the plans are reviewed by several agencies, including the Corps and the U.S. Fish and Wildlife Service. Each of these agencies must sign off on individual permits. There are also nationwide permits that allow small projects that meet certain criteria to proceed without individual permits.

C.7.2 Erosion and Sedimentation Control

Farmlands and construction sites typically contain large areas of bare exposed soil. Surface water runoff can erode soil from these sites, sending sediment into downstream waterways. Sediment tends to settle where the river slows down and loses power, such as when it enters a lake or a wetland.

Sedimentation will gradually fill in channels and lakes, reducing their ability to carry or store floodwaters. When channels are constricted and flooding cannot deposit sediment in the bottomlands, even more is left in the channels. The result is either clogged streams or increased dredging costs.

Not only are the drainage channels less able to do their job, but also the sediment in the water reduces light, oxygen, and water quality and often brings chemicals, heavy metals, and other pollutants. Sediment has been identified as the nation's number one nonpoint source pollutant for aquatic life.

Practices to reduce erosion and sedimentation have two principal components:

1. Minimize erosion with vegetation
2. Capture sediment before it leaves the site

Slowing surface water runoff on the way to a drainage channel increases infiltration into the soil and reduces the volume of topsoil eroded from the site. Runoff can be slowed down by measures such as terraces, contour strip farming, no-till farm practices, sediment fences, hay or straw bales, constructed wetlands, and impoundments (e.g., sediment basins and farm ponds).

Erosion and sedimentation control regulations mandate that these types of practices be incorporated into construction plans. They are usually oriented toward construction sites rather than farms. The most common approach is to require applicants for permits to submit an erosion and sediment control plan for the construction project. This allows the applicant to determine the best practices for the site.

One tried and true approach is to have the contractor design the detention basins with extra capacity. They are built first so they detain runoff during construction and act as sediment catch basins. The extra capacity collects the sediment that comes with the runoff until the site is planted and erosion is reduced.

C.7.3 River Restoration

There is a growing movement that has several names, such as "stream conservation," "bioengineering" or "riparian corridor restoration." The objective of these approaches is to return streams, stream banks, and adjacent land to a more natural condition, including the natural meanders. Another term is "ecological restoration," which restores native indigenous plants and animals to an area.

A key component of these efforts is using ap-

propriate native plantings along the banks that resist erosion. This may involve "retrofitting" the shoreline with willow cuttings, wetland plants, and/or rolls of landscape material covered with a natural fabric that decomposes after the banks are stabilized with plant roots.

Studies have shown that after establishing the right vegetation, long-term maintenance costs are lower than if the banks were concrete. The Natural Resources Conservation Service estimates that over a ten-year period the combined costs of installation and maintenance of a natural landscape may be one-fifth of the cost for conventional landscape maintenance, e.g., mowing turf grass.

C.7.4 Best Management Practices

Point source pollutants come from pipes such as the outfall of a municipal wastewater treatment plant. State and federal water quality laws have reduced the pollutants that come from these facilities.

Nonpoint source pollutants come from non-specific locations and are harder to regulate. Examples are lawn fertilizers, pesticides, and other farm chemicals, animal wastes, oils from street surfaces and industrial areas, and sediment from agriculture, construction, mining, and forestry. These pollutants are washed off the ground's surface by stormwater and flushed into receiving storm sewers, ditches, and streams.

Best management practices (BMPs) are measures that reduce nonpoint source pollutants that enter the waterways. BMPs can be implemented during construction and as part of a project's design to permanently address nonpoint source pollutants.

There are three general categories of BMPs:

1. Avoidance—Setting construction projects back from the stream.
2. Reduction—Preventing runoff that conveys sediment and other water-borne pollutants, such as planting proper vegetation and conservation tillage.
3. Cleansing—Stopping pollutants after they are en route to a stream, such as using grass drainageways that filter the water and retention and detention basins that let pollutants settle to the bottom before they are drained.

In addition to improving water quality, BMPs can have flood-related benefits. By managing runoff, they can attenuate flows and reduce the peaks after a storm. Combining water quality and water quantity measures can result in more efficient multi-purpose stormwater facilities.

Because of the need to clean up our rivers and lakes, there are several laws mandating the use of best management practices for new developments and various land uses. The furthest reaching one is the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System (NPDES) requirements.

C.7.5 Dumping Regulations

NPDES addresses liquid pollutants. Dumping regulations address solid matter, such as shopping carts, appliances and landscape waste that can be accidentally or intentionally thrown into channels or wetlands. Such materials may not pollute the water, but they can obstruct even low flows and reduce the channels' and wetlands' ability to convey or clean stormwater.

Many cities have nuisance ordinances that prohibit dumping garbage or other "objectionable waste" on public or private property. Waterway dumping regulations need to also apply to "non-objectionable" materials, such as grass clippings or tree branches which can kill ground cover or cause channel obstructions.

Many people do not realize the consequences of their actions. They may, for example, fill in

the ditch in their front yard not realizing that it is needed to drain street runoff. They may not understand how regrading their yard, filling a wetland, or discarding leaves or branches in a watercourse can cause a problem to themselves and others. Therefore, a dumping enforcement program should include public information materials that explain the reasons for the rules as well as the penalties.

Regular inspections to catch violations also should be scheduled. Finding dumped materials is easy; locating the source of the refuse is hard. Usually, the owner of property adjacent to a stream is responsible for keeping the stream clean. This may not be fair for sites near bridges and other public access points.

C.7.6 Conclusions

1. Wetlands play an important role in the natural course of flood control, preservation of water quality, and wildlife habitation, making a strong case for their protection.
2. Erosion can be reduced by use of vegetation. Sedimentation should be captured before it leaves its original location with oversized detention basins.
3. Vegetation used along riverbanks works more effectively in river maintenance than using banks made of concrete.
4. Nonpoint source pollutants are best managed by keeping construction projects away from streams, reducing sediment runoff, and using grass drainageways and detention basins for filtration.
5. Dumping regulations need to be communicated to the public and enforced.
6. The establishment and maintenance of wildlife habitat and natural ecosystems should be an important aspect of any drainage system program the City may implement in regards to floodplain management. This can be developed in cooperation with the Oklahoma Department of Wildlife Conservation, allowing aquatic plants and wildlife to be established in stormwater detention ponds and floodways.

C.7.7 Recommendations

Refer to Chapter 5: Mitigation Strategy, for a complete listing of all recommended mitigation measures by hazard and priority.

APPENDIX D: Public Engagement

D.1.1 Public Participation

Project Website

A project website was developed to support public participation, launch the community survey, and provide a repository for plan information during the planning process. The website recorded a total of 1,249 visits from 522 unique users between June 2023 and June 2024.

Stakeholder Participation

A wide range of technical stakeholders were involved in the planning process. Table D-1 lists all stakeholder participants.

Table D-1: Stakeholder Participants

	AGENCY	NAME	TITLE
1	Muscogee Creek Nation	Bobby Howard	Emergency Management Director
2	City of Tulsa	Gary McCormick	Senior Special Project Engineer
3	USACE	Bill Smiley	Chief Emergency Manager
4	National Weather Service	Steve Piltz	Meteorologist
5	Tulsa Public Schools	Helen Lee	Manager of Strategic Operations
6	Up With Trees*	Steve Grantham	Executive Director
7	City of Tulsa	Kycia Davison	311 Manager
8	City of Tulsa	Lara Weber	Communications Officer
9	City of Tulsa	Destinee Love	Office Admin
10	City of Tulsa	Christan Bengel	City Council Member- District 6
11	Tulsa County	Alex Mills	County Engineer
12	National Weather Service	Nicole McGavock	Service Hydrologist
13	City of Tulsa	Dustin Wright	Infrastructure Supervisor
14	Fox 23 and SDHMAB	Michael Grogan	Meteorologist
15	Citizen	Timothy Lovell	Retired Director of Disaster Resilience Network
16	City of Tulsa	Mary Kell	Architect
17	Tulsa Fire Department	Julie Lynn	Deputy of Support Services
18	City of Tulsa	David Hall	Disaster Recovery Architect
19	USACE	David Williams	Chief, HH Branch
20	City of Tulsa	Patrick Huycke	Stormwater Design Engineer
21	Tulsa County	Kerrick Edenborough	Zoning Officer
22	Tulsa County	Sherry Langston	Tulsa County Commissioner Dist #2
23	Tulsa Police Department	Mark Ohnesorge	Captain
24	Tulsa Police Department	Ryan Woods	Captain

	AGENCY	NAME	TITLE
25	City of Tulsa	James Wagner	Department of City Experience Director
26	Tulsa Health Department	Alicia Etgen	Manager of Emergency Preparedness
27	City of Tulsa	John Galchik	Information Technology Operations Manager
28	City of Tulsa	Michael Dellinger	Chief Information Officer
29	OCS/Mesonet	Kevin Kloesel	Director
30	City of Tulsa	Michael Ling	Floodplain Manager
31	City of Tulsa*	Krystal Reyes	Chief Resilience Officer
32	City of Tulsa	Paul Zachary	City Engineer
33	City of Tulsa	Thomas Chandler	Building Operations Manager
34	City of Tulsa	Roy Teeters	Street and Stormwater Manager
35	City of Tulsa	Joan Gausvik	Water and Sewer Asset Manager
36	City of Tulsa	Angenette DeBose	Resilience Program Manager
37	City of Tulsa	Scott VanLoo	Operations Manager
38	Up With Trees*	Diana Knocke	Associate Director
39	City of Broken Arrow	Jamie Ott	Emergency Manager
40	Tulsa Transit	Valerie Courchesne	Transportation Director
41	Partner Tulsa*	Ashley Chaney	Business Liaison Service Manager
42	City of Tulsa	Aaron Johnson	Engineer
43	Meshek and Associates	Janet Meshek	Consultant
44	City of Tulsa	Trey Wilson	Engineer
45	Meshek and Associates	Allison Whitsitt	Consultant
46	Propeller	Barrett Waller	Consultant
47	Tulsa Area Emergency Management	Joe Kralicek	Executive Director
48	City of Tulsa	Brooke Caviness	Senior Engineer
49	City of Tulsa	Freddy Dahmash	Water Resources Engineer

** These represent organizations that work with underserved communities.*

Public Meetings

The public was invited to two meetings to hear updates regarding the Hazard Mitigation Plan:

- **Public Meeting #1- Hazard Mitigation Plan Update**
  July 25, 2023
- **Public Meeting #2- Hazard Mitigation Plan Update**
  December 18, 2023

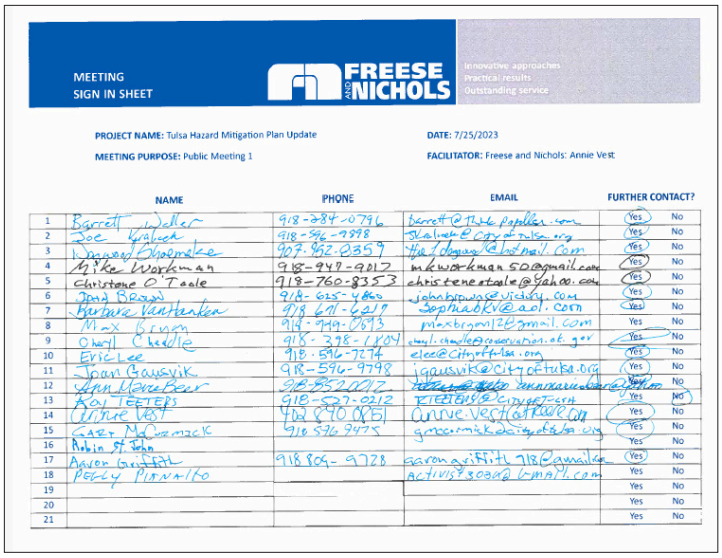
Additional meeting details are included below.

Public Meeting Sample Agenda

City of Tulsa Hazard Mitigation Plan Update
Public Meeting

I. 6:00-6:10 Welcome and Introductions
II. 6:10- 6:20 Overview of 2024 Hazard Mitigation Plan Update
III. 6:20-6:45 Insights from Tulsa Area Emergency Management Agency
IV. 6:45-7:15 Feedback Activity
V. 7:15-8:00 General Q&A/Open House
VI. 8:00 Close

Public Meetings: Sign-in Sheet, Photos and Handouts



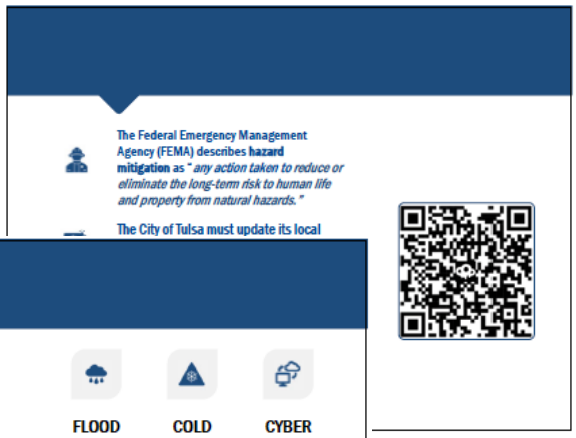
MEETING
SIGN IN SHEET

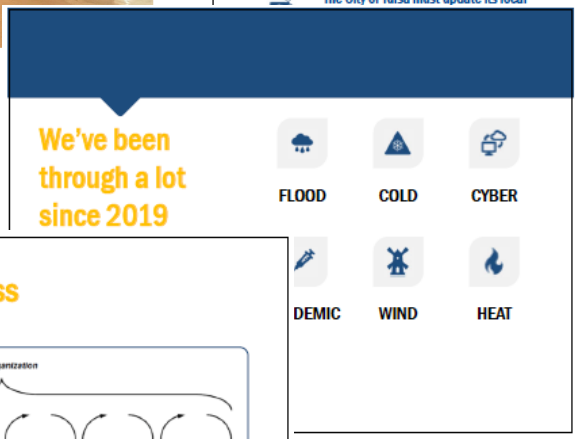
FREESE AND NICHOLS

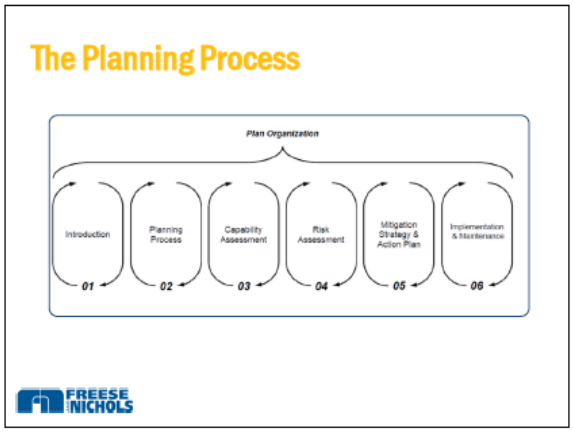
Innovative approaches
Practical results
Outstanding service

PROJECT NAME: Tulsa Hazard Mitigation Plan Update
DATE: 7/25/2023
MEETING PURPOSE: Public Meeting 1
FACILITATOR: Freese and Nichols: Annie Vest

	NAME	PHONE	EMAIL	FURTHER CONTACT?
1	Barrett Weller	918-284-0796	barrett@tulsapolice.com	Yes No
2	Joe Walker	918-596-7998	jkwalker@cityoftulsa.org	Yes No
3	Howard Shoemake	907-952-8859	hshoemake@hotmail.com	Yes No
4	Mike Workman	918-949-9017	mkworkman50@gmail.com	Yes No
5	Christene O Teale	918-760-8353	christeneoteale@yahoo.com	Yes No
6	Jon Brown	918-625-4860	jonbrown@visitjt.com	Yes No
7	Barbara VanHenken	918 671-6219	SophiaBKV@aol.com	Yes No
8	Max Brown	918-749-0693	maxbrown128@gmail.com	Yes No
9	Cheryl Cheadle	918-398-1404	cheryl.cheadle@conservation.ok.gov	Yes No
10	Eric Lee	918-596-7274	elee@cityoftulsa.org	Yes No
11	Joan Gaussvik	918-596-9798	jgaussvik@cityoftulsa.org	Yes No
12	Ann MoreBear	918-852-0017	annmorebear@yahoo.com	Yes No
13	Kol Teeters	918-527-0212	KTEETERS@cityoftulsa.org	Yes No
14	Annie Vest	918 810 0051	ANNIE.VEST@AECOM.COM	Yes No
15	Gary McCormack	918 576 9475	gmccormick@cityoftulsa.org	Yes No
16	Robin St. John			Yes No
17	Aaron Griffith	918 804- 9728	aaron.griffith.918@gmail.com	Yes No
18	Peggy Pinnato			Yes No
19				Yes No
20				Yes No
21				Yes No







Stakeholder Workshops

Stakeholders were invited to participate in a series of 3 workshops throughout the planning process:

- Stakeholder workshop #1- Kickoff workshop, threats and impacts workshop
  June 29, 2023
- Stakeholder workshop #2- Capabilities and Hazard Assessment, Intro to Mitigation Strategies
  November 2, 2023
- Stakeholder Workshop #3- Mitigation Action Items
  January 25, 2024

Additional meeting details are included below.

Workshop #1 Agenda

Stakeholder Workshop #1, June 29, 2023

Meeting Agenda

I. 1:00-1:30 Welcome and Introductions
(Annie Vest and Chance Sparks, AICP)

II. 1:30-2:00 Introducing Hazards and Resilience
(Dr. Kevin Kloesel and Caitlin Admire, AICP)

Break

III. 2:15-3:15 Activity 1 Assess the Problem

a. Exercise 30 Minutes

b. Discussion 30 Minutes

Break

IV. 3:30-4:30 Activity 2 Assess the Impacts

a. Exercise 30 Minutes

b. Discussion 30 Minutes

V. 4:30-5:00 Final Comments and Closing

Workshop #1: Invitation, Sign-in Sheet and Photos

City of Tulsa
A New Kind of Energy.

ENGINEERING SERVICES DEPARTMENT

June 7, 2023

Re:2024 City of Tulsa FEMA Hazard Mitigation Plan Update

Dear Stakeholders,

You are cordially invited to the first Stakeholder Workshop for the 2023/4 City of Tulsa Hazard Mitigation Plan Update. The workshop will be held on June 29, from 1:00 to 5:00 pm at Centennial Center at Veterans Park.

The Hazard Mitigation Plan Update serves as an inclusive framework that identifies and evaluates the hazards impacting Tulsa, offering strategies to mitigate their potential impacts. This plan is essential for Tulsa to maintain eligibility for specific FEMA funding opportunities. Notably, since 2018, the City has been granted nearly $30 million in FEMA Hazard Mitigation Assistance funds due to the implementation of this plan.

In the context of this Hazard Mitigation Plan, stakeholders are defined as individuals, groups, or organizations that have an interest or are affected by the plan's development, implementation, or outcomes. This includes government agencies, community organizations, private sector entities, educational institutions, tribal nations, environmental and conservation groups, healthcare and social services providers, and the public.

We recognize the importance of engaging stakeholders like yourselves throughout the planning process. Your diverse perspectives, local knowledge, and expertise will help ensure that the updated Hazard Mitigation Plan reflects the needs and priorities of our community.
If you have any questions or require further information, feel free to contact our planning consultant, Annie Vest, with Freese and Nichols, at annie.vest@freese.com or (402) 890-0851.

Thank you for your dedication to the well-being of Tulsa and your commitment to building a resilient community. We eagerly anticipate your participation in the first Stakeholder Workshop.

Sincerely,

City of Tulsa

Paul Zachery, PE
City Engineer - Director of Engineering Services

Cc: Gary McCormick, City of Tulsa
Annie Vest, Freese and Nichols

2317 South Jackson Avenue • Tulsa, OK 74107 • Office 918.596.9565
www.cityoftulsa.org

MEETING SIGN IN SHEET

FREESE AND NICHOLS

PROJECT NAME: Tulsa Hazard Mitigation Plan Update
MEETING PURPOSE: Stakeholder Meeting 1
PROJECT NUMBER: TUL23485
DATE: 6/29/2023
FACILITATOR: Freese and Nichols-Annie Vest

	NAME	ORGANIZATION	TITLE	PHONE
1	Jonah Vasquez	Freese + Nichols	Hazard Mit planner	405-618-
2	Abby Howard	MCW	HMP	539-244-
3	Gary McCormick	COT	Sr. Spec. Proj. Eng	918-596-
4	Bill Smiley	USACE	Chief Em	918-430-
5	Steve Piltz	NWS	MIC	918-832-
6	Helen Lee	Tulsa Public Schools	manager of strategic operations	918-746-
7	Steve Gauthier	Up With Trees	Executive Director	918 344-
8	Kycia Dawson	COT	311 Manager	918-576-
9	Lara Weber	COT	Communications Officer	918-596-
10	Destinee Love	COT	OFFICE ADMIN II	918-596-
11	Joel Hensley	COT	Neighborhood Liaison	918 638
12	CHRISTIAN [illegible]	COT	CITY COUNCIL	
13	ALEX MILLS	TULSA CO	COUNTY ENGR	918.596
14	Nicole McGavock	NWS	Service Hydrologist	918-832-
15	Dustin Wright	COT	Infrastructure Supervisor	918-596-
16	Michael Grogan	FOX23+SDHMAP	Meteorologist	219-508-
17	[illegible]	CITIZEN	RETIRED	918-403-
18	Mary Kell	City of Tulsa	Architect PM	918-596-
19	Winford Sterling	City of Tulsa	Engineer	
20	Julie Lynn	Tulsa Fire	Deputy of Support Serv.	918-313-
21				

MEETING SIGN IN SHEET

FREESE AND NICHOLS
Innovative approaches
Practical results
Outstanding service

PROJECT NAME: Tulsa Hazard Mitigation Plan Update
MEETING PURPOSE: Stakeholder Meeting 1
PROJECT NUMBER: TUL23485
DATE: 6/29/2023
FACILITATOR: Freese and Nichols-Annie Vest

	NAME	ORGANIZATION	TITLE	PHONE	EMAIL
1	David Hall	City of Tulsa	Disaster Recovery Ad.	918-596-1370	[illegible]@cityoftulsa.org
2	DAVID WILLIAMS	USACE	CHIEF, HH BRANCH	918-669-7091	david.j.williams@usace.army.mil
3	Patrick Hugle	City of Tulsa	Engineer	918 596 9237	phugle@cityoftulsa.org
4	Kerrick Edenborough	Tulsa County	Zoning officer	918 596 5293	kedenborough@tulsacounty.org
5	Sherry Langston	Tulsa County	Com Health	918 596 5016	slangston@tulsacounty.org
6	MARK OHNESORGE	TULSA PD	CAPT/INT CMDR	918-703-3145	mohnesorge@cityoftulsa.org
7	RYAN WOODS	TULSA PD	CAPT/INT		rwoods@cityoftulsa.org
8	James Wagner	COT	Dir-Dept City Experience	918 596 5578	jwagner@cityoftulsa.org
9	Alicia Etgen	Tulsa Health Dep	Mgr Emergency Prep	918 595 4554	aetgen@tulsa-health.org
10	Jon Gatlik	COT	[illegible] Oper Mgr	918 596 7243	jgatlik@cityoftulsa.org
11	Michael Dellinger	COT	CIO		mdellinger@cityoftulsa...
12	Kevin Kloesel	OCS/Mesonet	Dir.	405-397-9652	longhorn@ou.edu
13	MICHAEL LING	COT	FLOOD PLAIN MANG.	918 596-7285	MLING@CITYOFTULSA.ORG
14	KRYSTAL Reyes	COT	CRO	918 695-5238	KREYES@cityoftulsa.org
15	Paul ZACHARY	COT	City Engineer	918 596 9565	pzachary@cityoftulsa.org
16					
17					
18					
19					
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21					

Workshop #2 Agenda

Stakeholder Workshop #2, November 2, 2023

Meeting Agenda

I. 1:00-1:20 Welcome, Introductions and Recap (Gary McCormick, City of Tulsa, and Annie Vest, Freese and Nichols)

II. 1:20-2:30 Hazard Overview and Discussion

a. 2019 Hazard Assessment

b. Public Survey Responses

c. Group Activity: Grouping 2024 Hazards by Impact

10 Minute Break

III. 2:40-3:40 Mitigation Strategy

a. Group Activity: Shared Solutions to Multiple Hazards (30)

b. Discussion (30)

10 Minute Break

IV. 3:50-4:20 2024 Capability Assessment Overview and Interactive Discussion (Jake Lange, Freese and Nichols)

V. 4:20-4:30 Final Comments and Closing

a. Upcoming Meetings:

i. Public Meeting: TBD

ii. Stakeholder Workshop 3: January 25, 2024, 1:00-5:00

Adjourn

Workshop #2: Activity

Activity 1: "Mitigating the Impact
Duration: 30 minutes

- Flip chart
- Markers
- Sticky notes

Introduction (3 minutes):

Briefly describe the purpose of the activity: "While we're aware of the potential hazards in Tulsa, our focus today is to dive deep into the impacts of these hazards. How do they affect our essential services, and what can we do to mitigate these effects?"

Brainstorming the Hazards (5 minutes):

Even though the group is familiar with the hazards, take a few minutes to list them out as a refresher.
Make sure the group understands the hazards.

Essential Services/Facilities Discussion (10 minutes):

Ask the question: "What services do we offer that must remain intact after a disaster occurs? What places do we want to protect?"
Provide participants with sticky notes.
Ask them to write down essential services (one per sticky) that should not be disrupted.
It's okay for these facilities to be historic or cultural sites.
Once done, have them place their sticky notes on the board.

Impacts Discussion (9 minutes):

For each hazard, discuss potential impacts on the community's essential services.
Example: "If flooding were to occur, how might it disrupt our transportation or healthcare services?"
Do you find the group concerned about multiple hazards causing the same impacts? (power outage for example caused by high wind and ice)
Capture key impacts, next to each hazard on the board and highlight impacts that overlap

Workshop #3 Agenda

Stakeholder Workshop #3, January 25, 2024

Meeting Agenda

I. Welcome, Introductions and Recap (1:00 – 1:20 pm); Gary McCormick, City of Tulsa and Dawn Warrick, FNI

a. Confirm hazards

II. Goals (1:20 – 1:45 pm)

a. FEMA Goals

b. City of Tulsa Goals

c. Group Activity (10 min): 2019 Goals – review, adjust, add

d. Discussion (15 min)

III. Climate Impacts and Resilience Actions (1:45 – 2:20 pm); Kevin Kloesel, OK Climate Survey Director

10 MINUTE BREAK

IV. Actions (2:30 – 3:20 pm)

a. Group Activity (20 min): 2109 Actions review, new actions

b. Discussion (30 min)

10 MINUTE BREAK

V. Tasks and Projects (3:30 – 4:20 pm)

a. Group Activity (20 min): Add specificity to each action

b. Discussion (30 min)

VI. Final Comments and Closing (4:20 – 4:30 pm)

a. Upcoming Meeting – Final Public Meeting: TBD

ADJOURN

Workshop #3: Stakeholder Guide, Presentation Samples, Sign-In Sheets

2024 City of Tulsa Hazard Mitigation Plan Update
Stakeholder Meeting 3 Resource Guide

Hazard Mitigation Plan Goals:

The relationship between the Plan's goals and actions that the City and Partners will need to accomplish to successfully implement the plan is shown below:

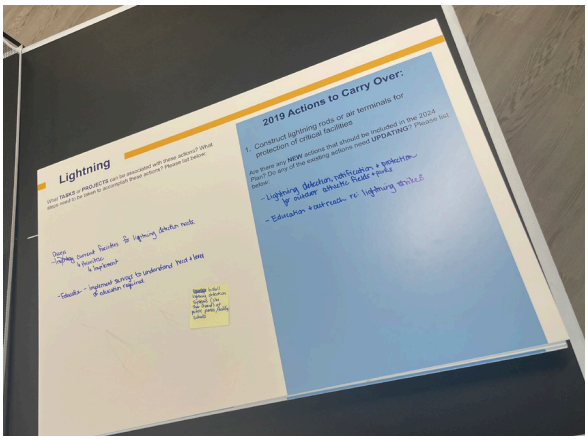
2019 HMP Goals:

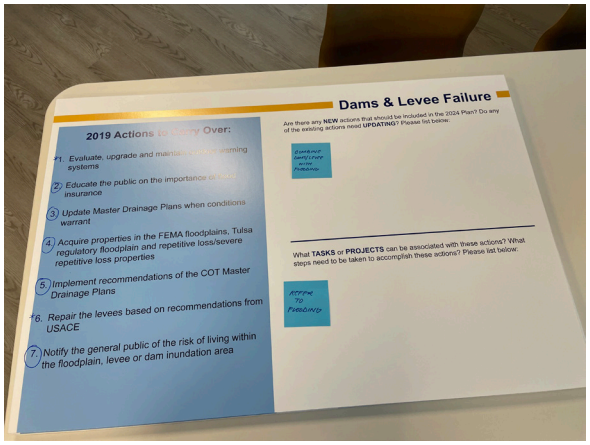
1. Minimize loss of life and property from natural hazard events;
2. Protect public health and safety;
3. Increase public awareness of risk from natural hazards;
4. Reduce risk and effects of natural hazards;
5. Identify hazards and assess risk for local areas;
6. Ascertain historical incidence and frequency of occurrence;
7. Determine increased risk from specific hazards due to location and other factors;
8. Improve disaster prevention;
9. Improve forecasting of natural hazard events;
10. Limit building in high-risk areas;
11. Improve building construction to reduce the dangers of natural hazards;
12. Improve government and public response to natural hazards.

FEMA Hazard Mitigation Assistance Grant Programs

Program Name	Cost Share	Availability
Flood Mitigation Assistance Grant (FMA)	▪ 0% Local/100% Federal, for projects involving Severe Repetitive-Loss Properties ▪ 10% Local/90% Federal, for projects involving Repetitive-Loss Properties ▪ 25% Local/75% Federal, for projects involving NFIP-insured properties	$700 million available from FY2022 through FY2026

1





MEETING SIGN IN SHEET — FREESE AND NICHOLS — Innovative approaches · Practical results · Outstanding service

PROJECT NAME: City of Tulsa Hazard Mitigation Plan **DATE:** 1/25/2024

MEETING PURPOSE: Stakeholder Workshop 3 **FACILITATOR:** Freese and Nichols

	NAME	PHONE	EMAIL
1	Kevin Kloesel	405-397-9652	
2	THOMAS CHANDLER	918 527 0209	
3	Ray Teeters	918 527 0212	
4	Joan Gausvik	918-596-9798	
5	Annette DeBose	918-724-4164	
6	Scott Van Cop	918-521-0211	
7	Diana Knocke	918-610-8733	
8	Jamie Ott	918-451-8809	
9	Valerie Courechesne	918-955-3216	
10	Nicole McGavock	918-832-4115	
11	Ashley Chaney	918-514-3570	
12	Destined Love	918-596-9498	
13	Aaron Johnson	918-586-5482	
14	Traci Mesker	918-688-1400	
15	Troy Wilkes	918-596-9246	
16	Dawn Whitshell	918 738 5617	
17	Barrett Waller	918-384-0796	
18			
19			
20			
21			

MEETING SIGN IN SHEET — FREESE AND NICHOLS — Innovative approaches · Practical results · Outstanding service

PROJECT NAME: City of Tulsa Hazard Mitigation Plan **DATE:** 1/25/2024

MEETING PURPOSE: Stakeholder Workshop 3 **FACILITATOR:** Freese and Nichols

	NAME	PHONE	EMAIL	FURTHER CONTACT?
1	Joe Kracken	918-596-9898		Yes / No
2	Sherry Langston	918-596-5015		Yes / No
3	Mark Ohlrogge	918-779-9410		Yes / No
4	Lara Weber	918-277-0124		Yes / No
5	Brooke Cameron	918-596-9498		Yes / No
6	Freddy Fahmy	918-596-9459		Yes / No
7	Michael Grogan	219-508-9894		Yes / No
8	Patrick Murphy	918-596-9257		Yes / No
9				Yes / No
10				Yes / No
11				Yes / No
12				Yes / No
13				Yes / No
14				Yes / No
15				Yes / No
16				Yes / No
17				Yes / No
18				Yes / No
19				Yes / No
20				Yes / No
21				Yes / No

Department of City Experience

September 5, 2023

The project team met with James Wagner, Director of the Department of City Experience, and Krystal Reyes and Angenette DeBose from the Mayor's Office of Resilience and Equity (now housed within the newly created Department of City Experience). The discussion was centered around ways to integrate the department and its various divisions into the planning process as well as implementation of the adopted plan. Resilience Hubs were identified as a recommended project in the previous All-Hazards Mitigation Plan in 2019 and have been challenging for the city to implement. Additional resources may allow these hubs to serve as a valuable resource for citizens during times of emergency and recovery from various hazardous events. The program continues to be a priority for the city and is aligned well with the updated Multi-Hazard Mitigation Plan. Equity indicators were also discussed as a way to measure progress in plan implementation and a tool for identifying populations and geographic locations within Tulsa that suffer inequitable exposure and impacts during hazardous events. The plan update will include the City's Resilient Tulsa Strategy as well as other long-range plans the department manages to align as many efforts as possible to leverage resources and improve outcomes.

PlaniTulsa (Tulsa's Comprehensive Plan)

May 31, 2023

Before a reorganization of several city departments in mid-2023, the comprehensive plan, PlaniTulsa, was managed by INCOG, Tulsa's MPO (Metropolitan Planning Organization). The project team met with John Tankard, an INCOG project manager and planner who led the PlaniTulsa update which was adopted in June 2023. The updated plan utilized current demographic data as well as other long-range plans, including the 2019 All-Hazard Mitigation Plan and the Resilient Tulsa Strategy to advance concepts of both hazard mitigation and resiliency in the community's comprehensive plan, which had not been a priority in the previous plan. During this conversation, we brainstormed ways to address the city's planning program into the Multi-Hazard Mitigation Plan update process, which is reflected in the Capabilities Assessment and Action Plan within this document.

Partner Tulsa

December 5, 2023

Partner Tulsa is an organization that grew from the City of Tulsa's Economic Development office and is now a separate entity, still very focused on advancing economic prosperity and opportunities for the city. When we met with Kian Kamas, former Executive Director, she told the project team about strategic initiatives Partner Tulsa is working to implement, including redevelopment plans for city-owned property in the north Tulsa area comprising the Greenwood and Kirkpatrick Heights neighborhoods. A (national award-winning) master plan was adopted in December 2022 that identifies three development sites that can advance the planned revitalization of the area. One designated property (the Green Stitch – Stormwater Resiliency Park) currently serves as part of the city's regional flood control system for the Dirty Creek watershed. The plan states:

"The northern portion of the site is designed into a community memorial that will tell the story of the site's past while offering space for gathering and remembrance. The southern portion of the site will be redesigned as a public park focused on active recreation and youth programming. Both areas will continue

to serve the stormwater management function. It is recommended during the design development phases that more engineering studies of stormwater capture and compatibility with the proposed land uses are considered and those more advanced design concepts are presented to stakeholders for additional input." (https://www.ourlegacytulsa.org/)

Large acreages around the Tulsa International Airport (TUL) is positioned well for new development that supports airport activities and contributes positively to the local economy. A TIF (tax increment financing) district has been adopted to provide some funding for infrastructure and other development-related expenses. Additional growth in this area is expected and possible impacts from natural hazards will need to be addressed during any development review or entitlement processes.

An industrial park in east Tulsa is well positioned for large land users such as a data center. The extension of necessary utilities is something the city will need to coordinate through CIP projects and/or development agreements. There is a substantial amount of property in east Tulsa that is within a designated flood plain or flood-prone areas. Mitigation may be needed to support economic development and to ensure new development is located appropriately, protected where possible, and insured to address potential impacts.

Up with Trees

August 3, 2023

Steve Grantham, the Executive Director of Up with Trees, met with the project team in August 2023 to discuss the 2015 Urban Forest Master Plan for the city. Discussion also centered around the derecho that impacted Tulsa two months prior to the meeting, as his organization and the city were still working hard to document and clean up damage from that storm event. This partner organization has worked through the implementation action plan for their plan and needs to begin the process of updating the plan for the coming decades. Maintaining a healthy urban forest is critical to addressing the impacts of heat, wind, erosion, and many other hazards. Supporting this master planning process is an important step to providing a safe and resilient community. (https://upwithtrees.org/master-plan)

Welcoming Week

The City of Tulsa's Mayor's Office of Resilience and Equity distributed postcards providing information about the Multi-Hazards Mitigation Plan and a QR code for the community survey during "Welcoming Week" events (September 8-17, 2023), with the focus to engage the City's immigrant and refugee communities with the planning process and gather feedback from this under-represented community of residents.

Public Meetings

Public Meeting #1, July 25, 2023

The City of Tulsa hosted a public meeting on July 25, 2023. This gave community members an opportunity to learn about the planning process and provide feedback on the Plan's overarching goal, and the City's strengths, opportunities, aspirations and desired results from the Plan update. Residents also ranked the identified hazards from most to least preparedness. An online public survey was also made available to gather community feedback.

Public Meeting #2, December 18, 2023

The project team participated in a town hall meeting for City Council District 2 to provide an overview of the plan, planning process and opportunities to offer feedback and participate in the community survey.

Public Meeting #3, September 2024

A final public meeting will be conducted in September 2024, prior to City Council action to adopt the plan. During this meeting, city staff and the project team will provide an overview of the planning process, the plan elements and recommended action items. In addition to the presentation, a variety of input boards will be posted as a self-guided tour of the plan content. Public comments will be collected during the meeting. Feedback and plan adjustments resulting from this meeting will be presented to the City Council for consideration as they deliberate adoption of the plan. The meeting's agenda is included below: (before plan adoption, add this agenda and adjust this paragraph if necessary to reflect outcomes from the final public meeting)

Meeting Agenda

APPENDIX E: Major Employers

COMPANY NAME	SIZE
AAON, Inc.	1000 & Above
Amazon Fulfillment Center	1000 & Above
American Airlines Maintenance Base	1000 & Above
Ascension St. John	1000 & Above
AT&T & DirecTV	1000 & Above
Bank Of Oklahoma	1000 & Above
Blue Cross Blue Shield Of Oklahoma	1000 & Above
City of Tulsa	1000 & Above
Family & Children's Services	1000 & Above
Hillcrest Healthcare System	1000 & Above
Integrated Service Company LLC	1000 & Above
Navistar/IC Bus of Oklahoma LLC	1000 & Above
NORDAM Group	1000 & Above
ONEOK, Inc.	1000 & Above
OSU Medical Center	1000 & Above
Public Service Company of Oklahoma	1000 & Above
Quiktrip Corporation	1000 & Above
River Spirit Casino	1000 & Above
Saint Francis Health System	1000 & Above
The Williams Companies	1000 & Above
Tulsa Community College	1000 & Above
Tulsa County	1000 & Above
Tulsa Public Schools	1000 & Above
Union Public School District	1000 & Above
University of Tulsa	1000 & Above
Whirlpool Corporation	1000 & Above
Airgas USA, LLC	500 to 999
Ameristar Perimeter Security	500 to 999
Arvest Bank - Multiple Locations	500 to 999
Avantive Solutions	500 to 999
Cap Tulsa	500 to 999
Cox Communications	500 to 999
cxLoyalty	500 to 999

COMPANY NAME	SIZE
Enovation Controls	500 to 999
Greenheck Group	500 to 999
Helmerich & Payne, Inc.	500 to 999
Hilti North America	500 to 999
LufthansaTechnik Component Service/Bizjet International	500 to 999
Lumen	500 to 999
Manhattan Construction	500 to 999
Melton Truck Lines	500 to 999
ONE Gas	500 to 999
Oral Roberts University	500 to 999
Osage Casinos	500 to 999
OSU-Tulsa and OSU Center for Health Sciences	500 to 999
ResourceOne	500 to 999
Spirit Aerosystems	500 to 999
T.D. Williamson, Inc	500 to 999
The Bama Companies Inc.	500 to 999
TTCU Federal Credit Union	500 to 999
Tulsa Technology Center	500 to 999
United Parcel Service Inc	500 to 999
Verizon Business	500 to 999
YMCA of Greater Tulsa	500 to 999
Alorica, Inc.	250 to 499
BNSF Railway Co	250 to 499
Capital One Auto Finance	250 to 499
CommunityCare	250 to 499
ConsumerAffairs	250 to 499
DXC Technology	250 to 499
Emergency Medical Services Authority (EMSA)	250 to 499
Extract Companies, LLC	250 to 499
Fabricut Inc	250 to 499
HireRight	250 to 499
Imperial Inc	250 to 499
Kaiser-Francis Oil Company	250 to 499

COMPANY NAME	SIZE
L3Harris	250 to 499
Latshaw Drilling & Exploration	250 to 499
Matrix Service Company	250 to 499
Mazzio's Italian Eatery	250 to 499
McElroy Manufacturing, Inc.	250 to 499
Muncie Power Products, Inc.	250 to 499
Navico Inc	250 to 499
NOV, Inc.	250 to 499
Oklahoma Cancer Specialists & Research Institute	250 to 499
Oklahoma Surgical Hospital	250 to 499
Parkside Psychiatric Hospital	250 to 499
Pepsi Bottling Group	250 to 499
Tulsa City-County Library - Administrative Offices	250 to 499
Tulsa World Publishing Co	250 to 499
US Cellular	250 to 499
Walden's Machine	250 to 499
Zayo Group	250 to 499

APPENDIX F: High Hazard Potential Dam (HHPD) Amendment

F.1 Introduction

Spavinaw Lake Dam, situated in Mayes County, and Eucha Dam, residing in Delaware County, are owned, and operated by the City of Tulsa and provide critical drinking water supply to the citizens of Tulsa along with locations all over Tulsa County. Spavinaw Lake Dam is about 55 miles northeast of Tulsa, and Lake Eucha Dam is about 68 miles northeast. While these lakes and potential breach inundation limits are not within city limits, they are considered a critical resource. Both lakes also provide recreational use and economic impact for their communities. Each is considered a High Hazard Potential Dam and inspected yearly. Spavinaw Lake Dam is just south of the town of Spavinaw on Highway 20, while Eucha Dam lies southeast of Jay. Constructed in 1922, Spavinaw Lake Dam covers 1,584 acres of water surface area with a storage capacity of 30,590 acre-ft. of water. This 100-year-old facility requires critical repairs to mitigate catastrophic loss and damage in case of a breach. Eucha Dam was built in 1950 and spans 3,192 acres of water surface area with a storage capacity of 80,000 acre-feet of water. Eucha Dam is also in need of critical repairs to mitigate damage, downstream loss of life, and loss of water supply in the event of a catastrophic event. Both facilities were damaged in the April 2017 flooding event, and while repairs have been undertaken, each has been rated as "fair" according to the last inspection completed in December of 2021. Various noted required repairs have been identified, and the City of Tulsa is moving forward to identify mitigation actions to support plans for repair of the facilities.

F.2 Hazard Profile: High Hazard Potential Dam

F.2.1 Definition

A dam is an artificial barrier constructed across a stream channel to impound water. Timber, rock, concrete, earth, steel, or a combination of these materials may be used to build the dam. Dams require a spillway system to safely convey normal stream and flood flows over, around, or through the dam. Spillways are commonly constructed of non-erosive materials such as concrete. Dams should also have a drain or other water-withdrawal facility for control of the pool or lake level and serve to lower or drain the lake for normal maintenance and emergency purposes. A dam that impounds water upstream is called a reservoir and the amount of water impounded is measured in acre-feet. An acre-foot is the volume of water that covers an acre of land to a depth of one foot. As a function of upstream topography, even a small dam may impound or detain a large number of acre-feet of water. Two factors influence the potential severity of a full or partial dam failure: the amount of water impounded, and the density, type, and value of development and infrastructure located downstream.

A dam incident is the release, collapse, breach or other failure resulting in downstream flooding. A break in a dam produces an extremely dangerous flood situation because of the high

velocities and large volumes of water released. In the event of a dam breach or dam failure, the potential energy of the water stored behind the dam itself can cause substantial property damage as well as loss of life if there are people in the inundation area.

OWRB uses the classification system to rate dams in Oklahoma, shown in Table F-1. Both Lake Eucha Dam and Spavinaw Lake Dam are considered High Hazard Potential dams.

F.2.2 Coordination & Shared Information

Along with annual inspections, all owners of high hazard-potential dams are required by FEMA (Federal Emergency Management Agency) and OWRB (Oklahoma Water Resources Board) to develop an Emergency Action Plan (EAP), in case of a dam breach or failure. These plans are submitted to OWRB, local law enforcement agencies and emergency management officials, and must be updated annually. Additionally, these EAPs (Emergency Action Plan) must be accompanied by breach inundation maps which show the areas downstream that would be inundated by at least one foot of water over the non-breach condition. A breach or break in the dam is shown in two different scenarios: (1) incidents that are not storm-related, called Sunny Day breaches, and (2) dam incidents resulting from a water surface elevation during peak outflow from the 75% PMF. OWRB Title 785:25-3-6 states that large dams that are more than 50 years old, are to be constructed to pass a 75% PMF breach with no minimum freeboard. To depict these situations, inundation maps provided below were extracted from the Eucha Dam EAP and assume a "cascade-effect" breach of Spavinaw Dam. The OWRB maintains these maps in their files, and in the planning area, all high-hazard dams have approved EAPs and are required to be updated annually. For dams classified as HHPD, OWRB completes an annual inspection and provides those findings to the jurisdiction.

F.2.3 Incorporation of Existing Plans, Reports, etc.

The development of the 2023 HHPD Amendment, outlined in this Appendix, involved coordination between the Oklahoma Water Resources Board (OWRB) and the City of Tulsa. Through a series of email conversations as well as phone calls, OWRB provided updates and information on the latest dam inspection reports and safety ratings in an effort to determine eligibility for rehabilitation projects for the Eucha/Spavinaw dam system. An example of OWRB coordination with the City of Tulsa was the February 9, 2023 conference call between OWRB, City of Tulsa, ICF, and members of the Meshek Planning Department. On this call, Zachary Hollandsworth, Engineering Manager with OWRB, outlined the process and requirements in which funding

Table F-1 Hazard-Potential Dam Classifications as Defined by the OWRB

HAZARD-POTENTIAL CLASSIFICATION	RISK INVOLVED WITH DAM FAILURE	INSPECTION FREQUENCY
HIGH	Probable loss of human life	Annually, by a registered professional engineer
SIGNIFICANT	No probable loss of human life but can cause economic loss or disruption of lifeline facilities	Every three years by a registered professional engineer
LOW	No probable loss of human life and low economic loss	Every five years

applicants can become eligible for rehabilitation projects and funding from the State. It was explained that the criteria for subrecipients to be eligible are those whose dams retain safety ratings of "poor" or "unsatisfactory" are the ones who are first in line to receive financial assistance through grants. Those with ratings of "fair" or "satisfactory" would then be considered by OWRB should funding dollars still remain available. Through extensive coordination and partnership with OWRB, the City of Tulsa aims to move forward with structural repairs and maintenance of Eucha Dam with the assistance of this High Hazard-Potential Dam Amendment.

F.2.4 Local Policy/Capabilities

The City of Tulsa is a nation-wide leader in flood management and mitigation efforts. Currently, the city is one of only two locations in the United States with a CRS (Community Rating System) Class 1 certification. Tulsa's 2019 Hazard Mitigation Plan Update identifies several programs and policies aimed at reducing impact from flooding events and other natural hazards. Several departments within the city contain staff who are trained and knowledgeable about probable hazards and potential impacts. These departments and staff collaborate to update ordinances, building codes and floodplain ordinances to maintain and improve a high standard of mitigation effort. These policies can be updated to include mitigation activities specifically in inundation and impact zones of the two high hazard potential dam locations identified in this document. Including this HHPD Amendment supports those goals.

The Spavinaw Dam Emergency Action Plan and Eucha Dam Emergency Action Plan document equipment, labor and materials used in an emergency event. Each EAP identifies resources including heavy equipment, sand and gravel supply, lumber, heaters, propane, and building material along with location and contact information for quick reference during a breach event. The EAP's also includes a call down notification plan in the event of a breach with noted escalation levels highlighted regarding when to call and whom shall be notified.

F.3 Location and Extent

Eucha and Spavinaw Dams are two high hazard-potential dams that have varying degrees of impact on the City of Tulsa and surrounding areas. Table F-2 summarizes some of the basic information pertaining to each of these dams while Figure F-1 shows the locations of these dams in relation to the City of Tulsa. In addition to their physical location, the extent to which these HHPD structures pose threats to the region are identified through inundation maps, also provided in this section. Extent is also determined by the severity of breach. Minor dam breaches occur when seepage results in water being contained downstream within normal riverbanks. Major breaches are large enough to exceed the river or creek channel's capacity, and overflow results in damage to homes, businesses, critical facilities, state buildings while putting people at risk. Each EAP contains tables outlining the travel times and depths of inundation from each of the high hazard-potential dams.

F.3.1 Inundation Maps

Dam inundation mapping in the Planning Area was based on available analysis and the maps profiled in this HHPD Amendment have mapping criteria based on State guidance. Incidents for these dams are subject to measurements under 75% Probable Maximum Flood (PMF) and/or Sunny Day Breaches. A 75% PMF failure covers an area of flooding created by 75% of the PMF resulting in a dam incident/failure. A Sunny Day Breach refers to an incident not caused by inflows, including structural, mechanical, or other types of failures.

Table F-2 Lake Eucha Dam Location and Description

Location	9 miles upstream from Spavinaw, OK in Delaware County (Legal Location: SE1/4 NE1/4 Section 22, T22N R22E)
Source	Spavinaw Creek
Drainage Basin	358 square miles
Owner/Operator	City of Tulsa, OK
Year Built	1950
Length/ Height	2,050 ft./99 ft.
Surface Area	3,192 acres (normal), 4,300 acres (maximum)
Construction Material	Earthen dam, concrete non-overflow section, gated and overflow spillway
Use of Dam	Water Supply
Capacity	80,000 acre-feet (normal), 89,000 acre-feet (maximum)
	1000 & Above
Results of Failure and/or High Release	Areas subject to inundation are seven (7) private residences, the Claremore Club, Tulsa Ozark Club, Spavinaw Club and Spring Valley Ranch (property may not be inundated but escape roadway could be). Roadways to the north and west of the dam and along Spavinaw Creek are subject to inundation, as well as the town of Spavinaw.
Emergency Action Plan (EAP)	Yes

Table F-3 Spavinaw Lake Dam Location and Description

Location	Near Spavinaw, OK in Mayes County
Source	(Legal Location: SW1/4 SE1/4 Section 15, T22N R21E)
Drainage Basin	Spavinaw Creek
Owner/Operator	390 sq. Miles (358 of which are controlled by Eucha Dam)
Year Built	City of Tulsa, OK
Length/ Height	1922
Surface Area	2,400 ft. / 50 ft.
Construction Material	1,584 Acres
Use of Dam	Earthen Dam, Concrete Spillway
Capacity	Water Supply
	30,590 Acre-Feet (normal)
Results of Failure and/or High Release	Areas subject to inundation are numerous homes, Spavinaw State Park, Spavinaw City Hall, Spavinaw Fire Station, Spavinaw Community Center, a growing facility, Bradford's BBQ, SYNC, Lakeview Lodge & Cabin, and a couple of churches.
Emergency Action Plan (EAP)	Affected roadways are Highway 20 west of the dam and south of Tulsa Ave., and most of the roadways throughout the town of Spavinaw.
	Yes

Figure F-1 Locations of Spavinaw and Eucha Dams in Relation to Tulsa

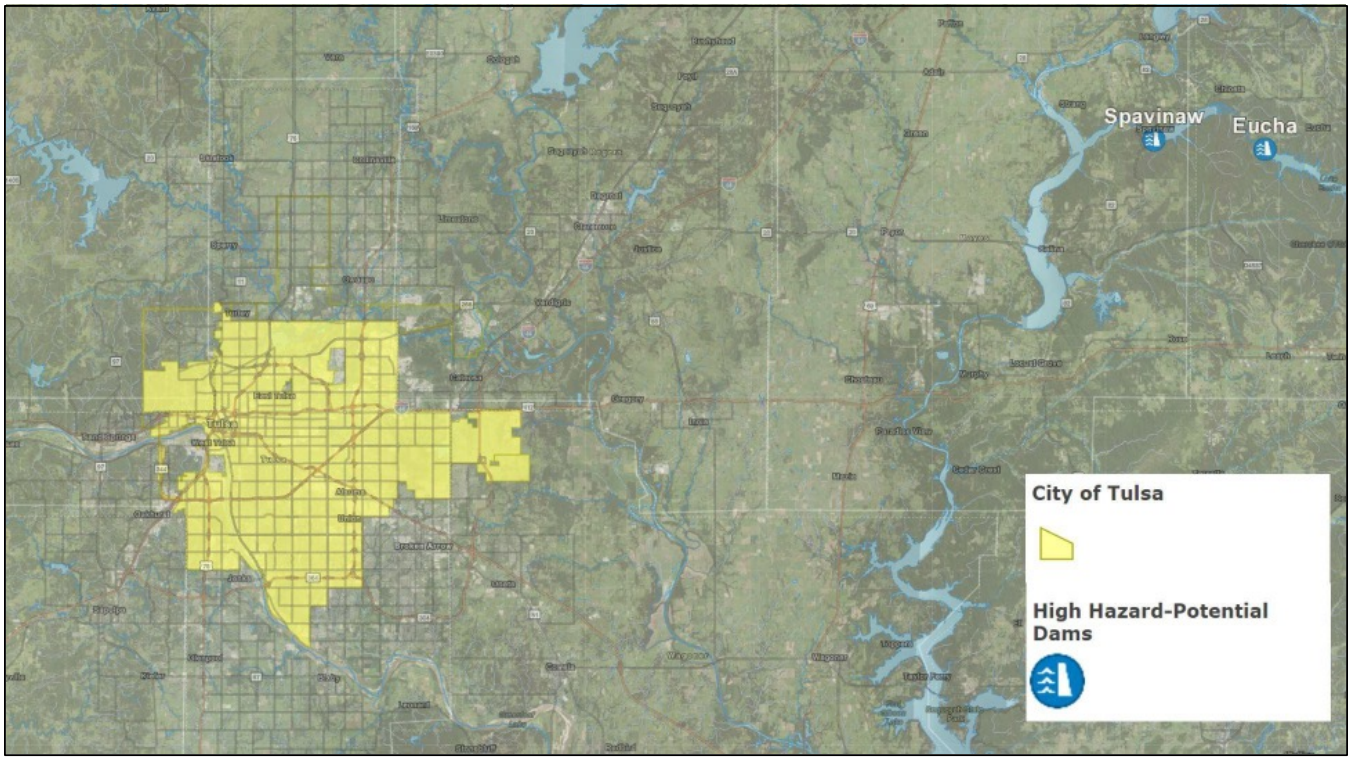


Figure F-2 Lake Eucha Dam Breach Inundation Maps (1 of 6)

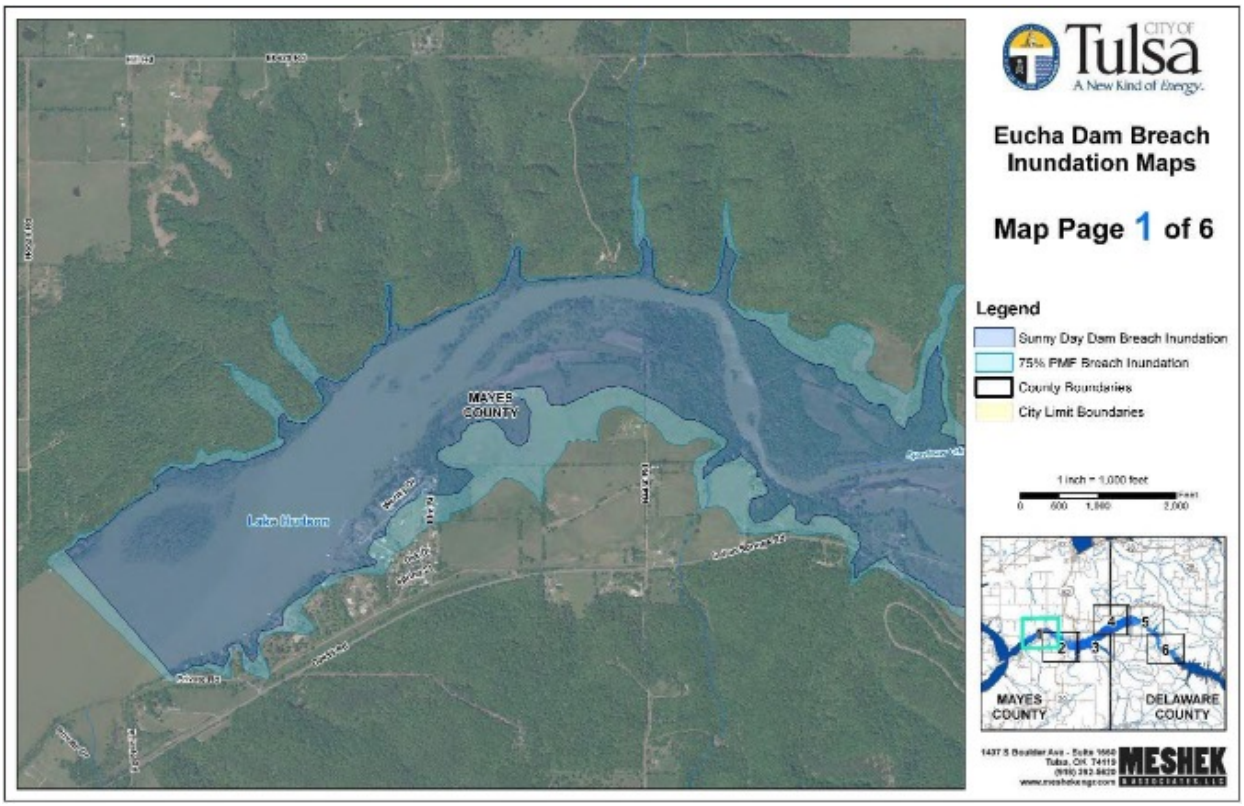


Figure F-3 Lake Eucha Dam Breach Inundation Maps (2 of 6)

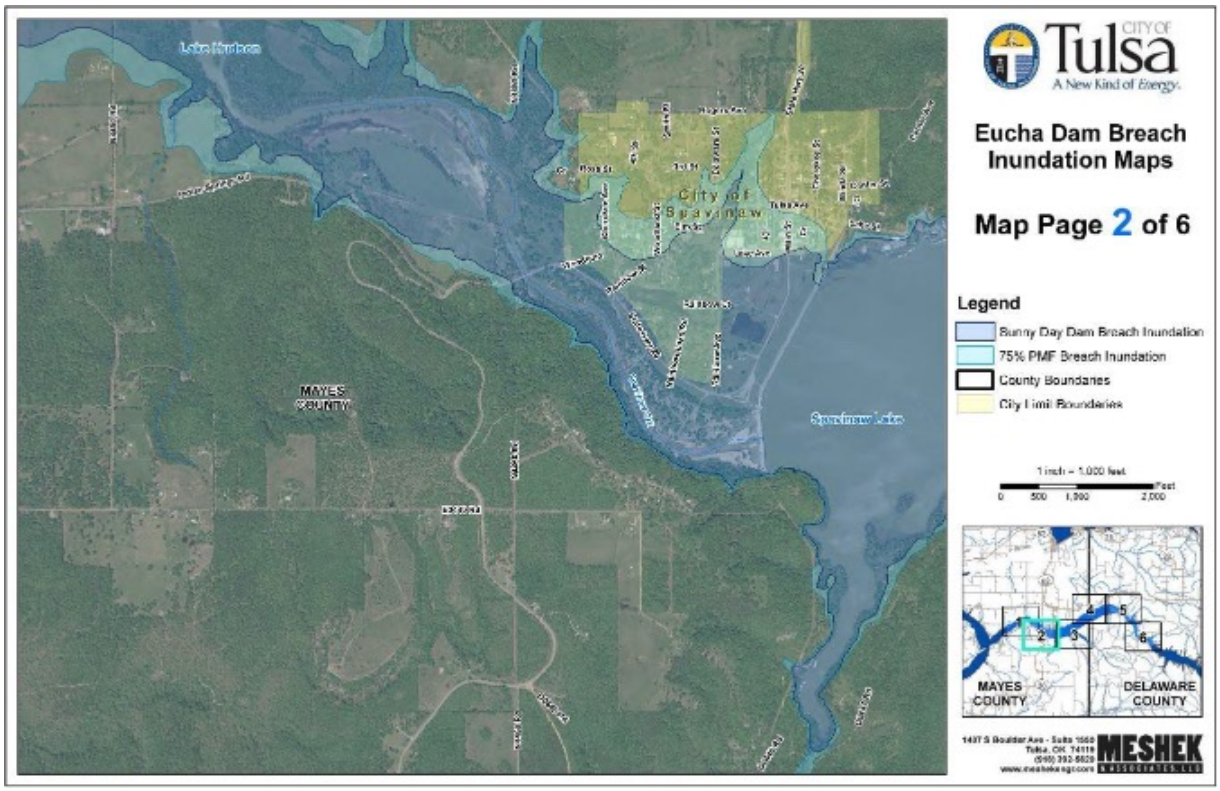


Figure F-4 Lake Eucha Dam Breach Inundation Maps (3 of 6)

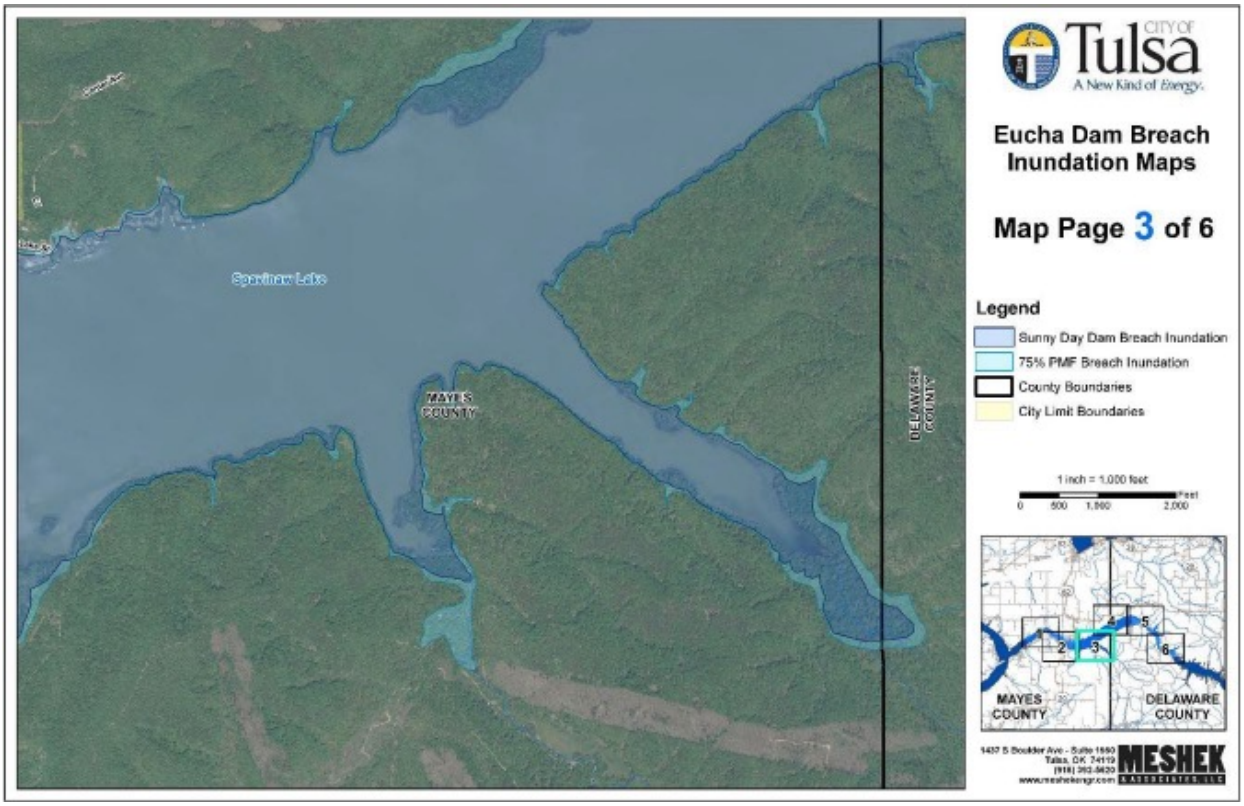


Figure F-5 Lake Eucha Dam Breach Inundation Maps (4 of 6)

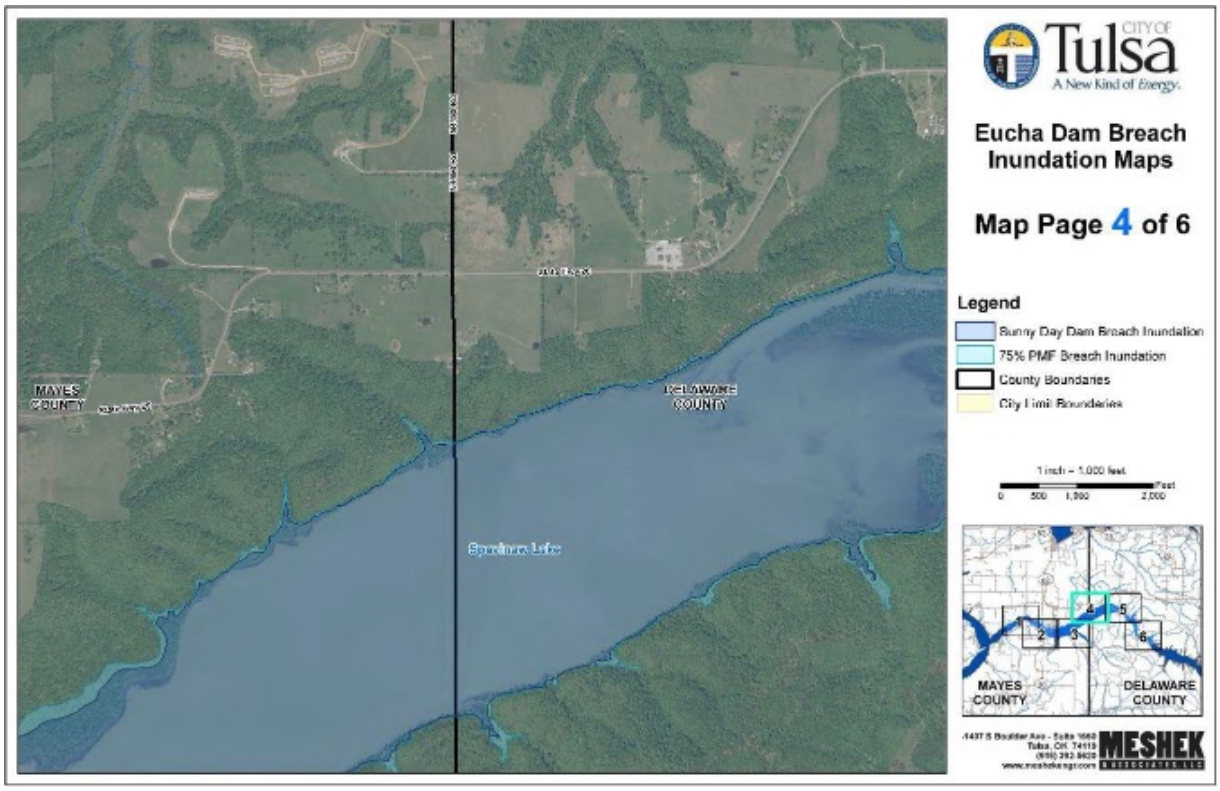


Figure F-6 Lake Eucha Dam Breach Inundation Maps (5 of 6)

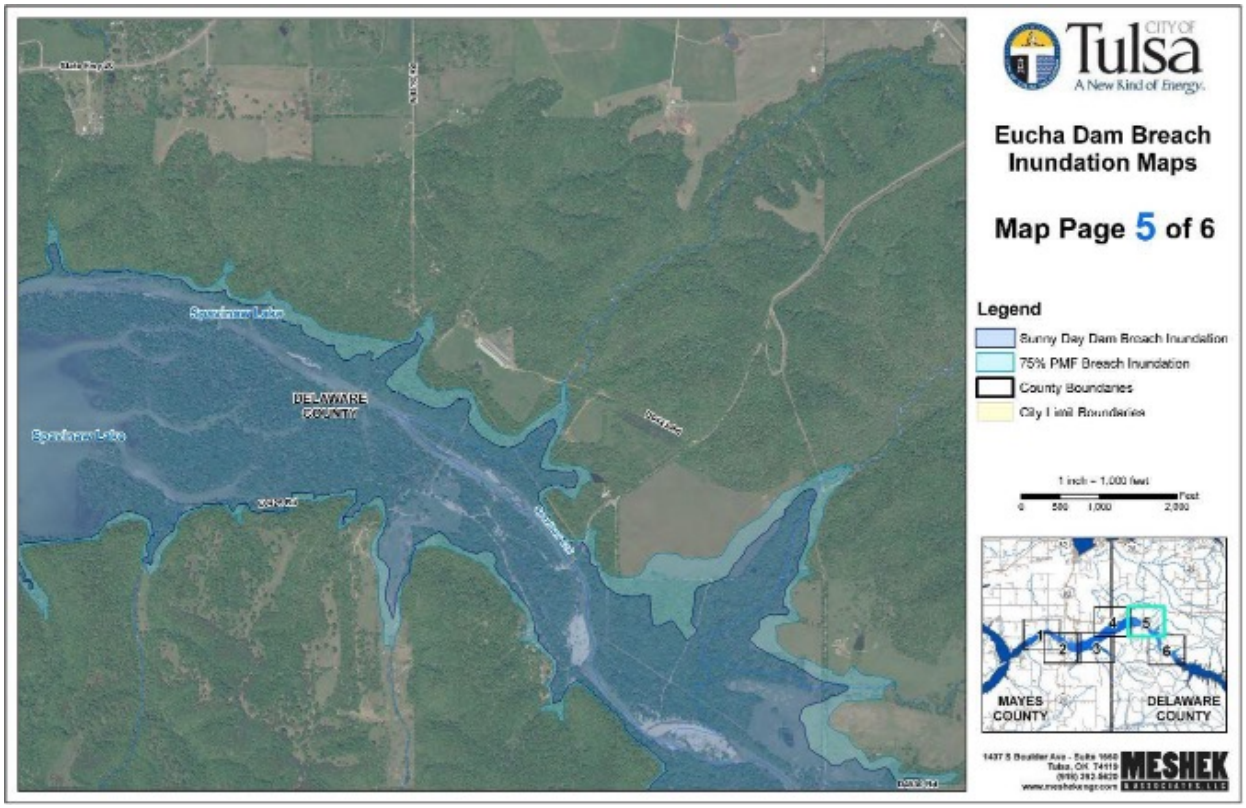
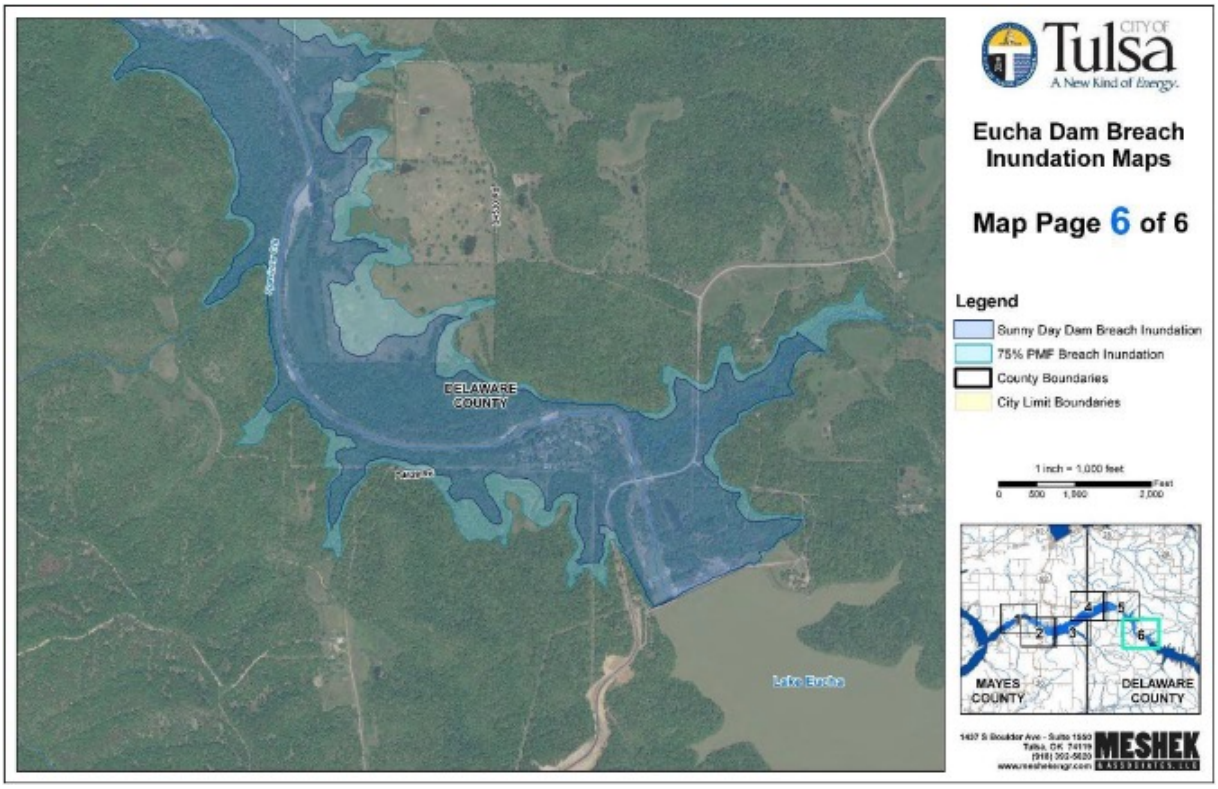


Figure F-7 Lake Eucha Dam Breach Inundation Maps (6 of 6)



F.4 Probability of Future Occurrences

No historical failures or dam breaches have been noted at either Spavinaw Lake or Lake Eucha. While Chapter 4 of the City's HMP lists dam/levee incidents as "occasionally likely", this assessment does not carry over to these two dams due to their ages and condition assessments. Historically speaking, there has been no breach or evidence of failures in either Spavinaw or Eucha dams. As such, the probability of future occurrences is unlikely, but if a failure/breach occurs, downstream impacts to communities in the direct vicinity are significant. In addition to areas of inundation, other impacts from such a scenario include substantial economic impact. Due to these factors, the significance of a failure remains high. See the City of Tulsa HMP Chapter 4 for complete definitions of probability and significance categories.

F.5 Vulnerability & Risk Assessment

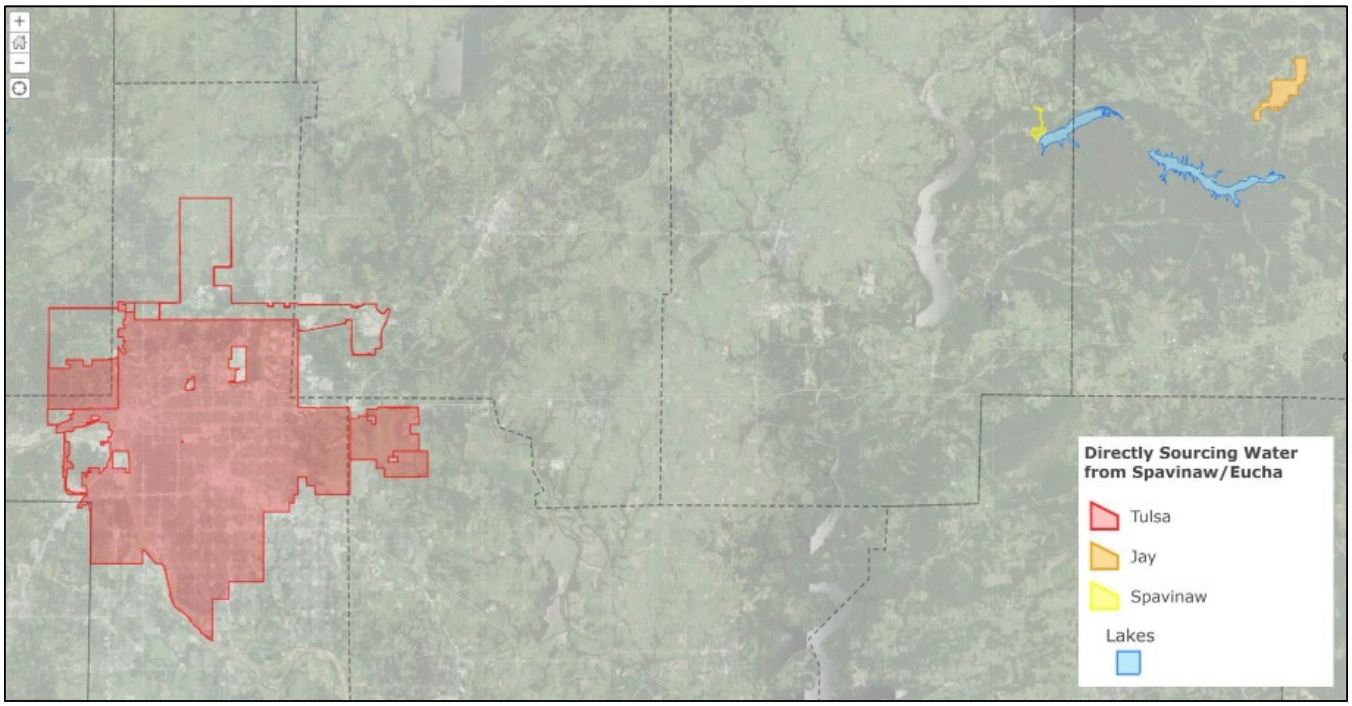
Two high-hazard dams that provide water to the City of Tulsa, other communities in Tulsa County, and communities elsewhere have breach impacts on Mayes and Delaware Counties as shown in the breach analysis report. The Emergency Action Plans for both Spavinaw and Eucha Dams contain lists of the impacted downstream structures from flooding. No breach flooding impacts have been shown for the City of Tulsa or Tulsa County. However, the loss of water supply to the City of Tulsa, Tulsa County, and surrounding communities would be catastrophic. There are no identified public-school systems impacted by floodwaters, but a secondary impact of potential interruption or loss of water supply to schools throughout the City of Tulsa is expected should a breach occur.

Eucha Dam: In their 2022 Dam Inspection Report, the Keithline Engineering (KE) inspection team determined that a moderate probability of failure of Eucha Dam exists. They stated "The overall 2022 condition of Dam was evaluated to be in fair condition by the KE inspection team. Except for the gates, the dam condition was noted to be slightly worse overall compared to the condition noted in the 2021 inspection, due to continual downstream concrete deterioration."

A stability analysis was conducted as part of a 2021 preliminary engineering report that verified the findings of a 2017 report, which concluded that the Eucha Dam embankment meets dam safety stability criteria set forth by OWRB (OAC 785-25), but that the overflow spillway, gated spillway, and left non-overflow sections of the dam do not meet stability requirements as determined by OWRB and USACE (United States Army Corps of Engineers).

Spavinaw Dam: Should Eucha Dam fail, Spavinaw Dam would experience a high probability of failure due to their proximity to one other, as well as the ages of both dams. This assumption is based on guidance from the Oklahoma Water Resources Board (OWRB) and controls. Spavinaw Dam received a Satisfactory rating in the 2022 Annual Inspection. However, due to the cascading effect, there is a moderate probability of failure of Spavinaw Dam if Eucha Dam experiences a failure first.

Figure F-8 Cities/Towns that Directly Source Water from Either Lake



F.5.1 Population at Risk

This section will examine the risks presented by failures at Spavinaw and Eucha Dams to people, economy, infrastructure, and other critical lifelines determined by FEMA. Of those critical lifelines determined by FEMA, the planning team has assessed that there are negligible risks to energy and hazardous materials for this scenario. While some minor or isolated effects may be experienced in this scenario, the scope of effects to these lifelines are not expected to reach a level of significance that would warrant examination.

Table F-4 Residents/Businesses/Highways at Risk from Inundation[1]

HOUSE/ BUSINESS NO.	RESIDENT/ BUSINESS	ADDRESS	DISTANCE DOWN-STREAM FROM DAM (FT.)	TRAVEL TIME** (HR.)	MAX WATER DEPTH ABOVE 1ST FLOOR (FT.)
1	Claremore Club	Eucha, OK	<1,000	<1	Submerged
2	Spavinaw Club	Eucha, OK	1,000 – 2,000	<1	Submerged
3	Spavinaw Wildlife Mgt. Area	Eucha, OK	1,000 – 2,000	<1	Submerged
4	Alfred Stevens (Spring Valley Ranch)	42301 CR 510 Eucha, OK	1,000 – 2,000	<1	Submerged
5	Kendall & Betty Watson	43029 CR 524 Eucha, OK	1,000 – 2,000	<1	Submerged
6	Ronnie & Pat Wiese	43341 CR 524 Eucha, OK	1,000 – 2,000	<1	Submerged
7	Keith & Gayla McDonald	Osage Beach, MO	1,000 – 2,000	<1	Submerged
8	William Fitter	42877 CR 524 Eucha, OK	1,000 – 2,000	<1	Submerged
9	Darwin & Ruth Haggard	4114 E 440 Rd. Eucha, OK	1,000 – 2,000	<1	Submerged
10	Sydney Dove	Eucha, OK	1,000 – 2,000	<1	Submerged

1 Taken from page 54 of the Eucha Dam EAP

Table F-5 Homes/Businesses/Highways at Risk from Inundation[1]

HOUSE/ BUSINESS NO.	RESIDENT/ BUSINESS	ADDRESS	DISTANCE DOWN-STREAM FROM DAM (FT.)	TRAVEL TIME** (HR.)	MAX WA-TER DEPTH ABOVE 1ST FLOOR (FT.)
1	Growing Facility (old school)	100 Lake Ave. Spavi-naw, OK	<1,000	<1	Submerged
2	Spavinaw City Hall	119 S. Main Spavinaw, OK	<1,000	<1	Submerged
3	United Methodist Church	212 Lake St. Spavi-naw, OK	<1,000	<1	Submerged
4	Spavinaw Hills House of Worship	5699 N. 445 Dr. Spavi-naw, OK	<1,000	<1	Submerged
5	SYNC	100 Main St. Spavi-naw, OK	<1,000	<1	Submerged
6	Spavinaw Com-munity Center	Main Street, Spavi-naw, OK	<1,000	<1	Submerged
7	Spavinaw State Park	N/A	<1,000	<1	Submerged
8	Numerous Homes	See page 9 of EAP	<1,000	<1	Submerged

Table F-4 and Table F-5 describe the various structures which may be impacted from a major flood caused by a sudden breach of either Spavinaw or Eucha dam as listed in both EAPs. It is estimated that inundation waters will impact seven (7) private residences, the Claremore Club, Tulsa Ozark Club, Spavinaw Club and Spring Valley Ranch (property may not be inundated but escape roadway could be). Roadways to the north and west of the dam and along Spavinaw Creek are subject to inundation, as well as the town of Spavinaw. All these properties are in Mayes and Delaware Counties. Tulsa and Tulsa County would not be impacted by flooding.

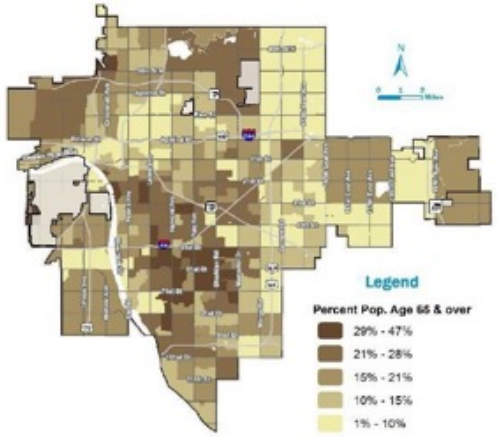
It should be noted that while the City of Tulsa and Tulsa County have no jurisdictional areas that would be impacted by inundation waters, the significance and relevance of these two HHPD structures is supported by the fact that both contribute to a substantial portion of the City and County's water consumption.[2] The City of Tulsa's water intake and water pump station (according to the OWRB) is located on the southwestern shoreline of Spavinaw Lake (see Figure F-10), and while this critical facility does not bear significance to Spavinaw or immediate communities surrounding the lake, floodwaters at this structure could interrupt or disrupt water supply from making its way to Tulsa.

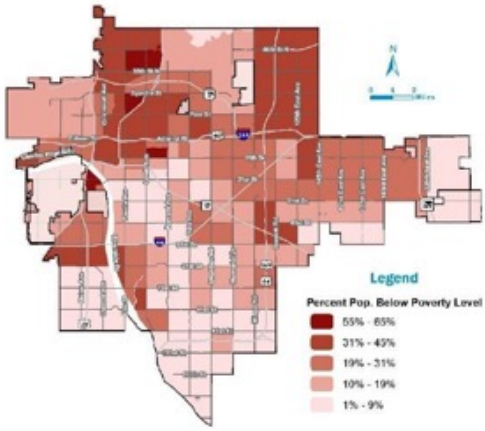
Additionally, the town of Jay also obtains its water directly from Eucha Lake.

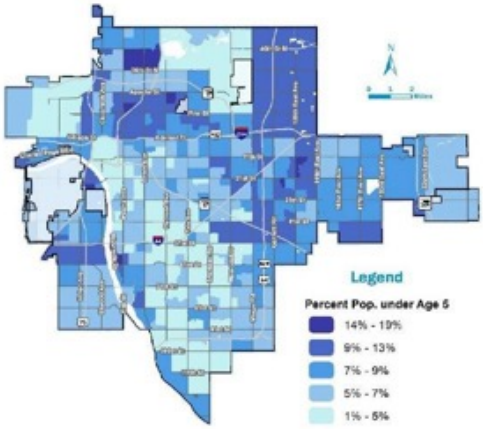
1 Taken from page 54 of the Spavinaw EAP

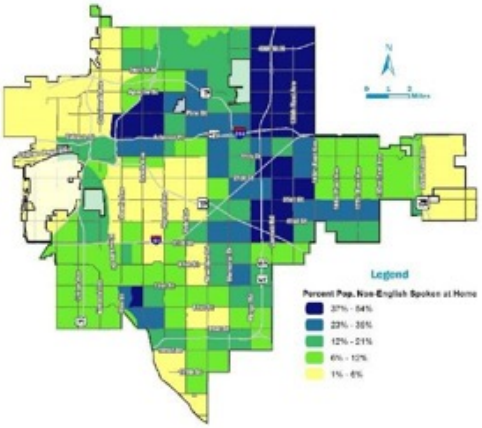
2 The exact percentage of population is not known from OK DEQ website

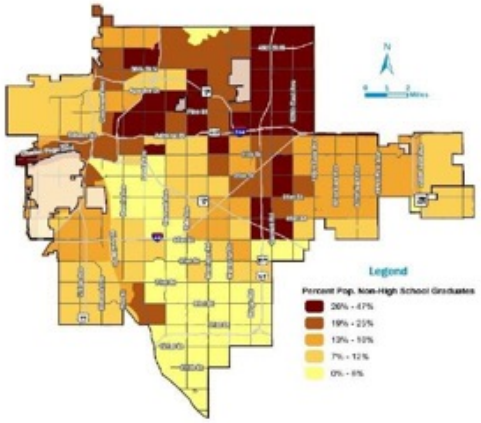
Figure F-9 Vulnerable Populations in the City of Tulsa[1]











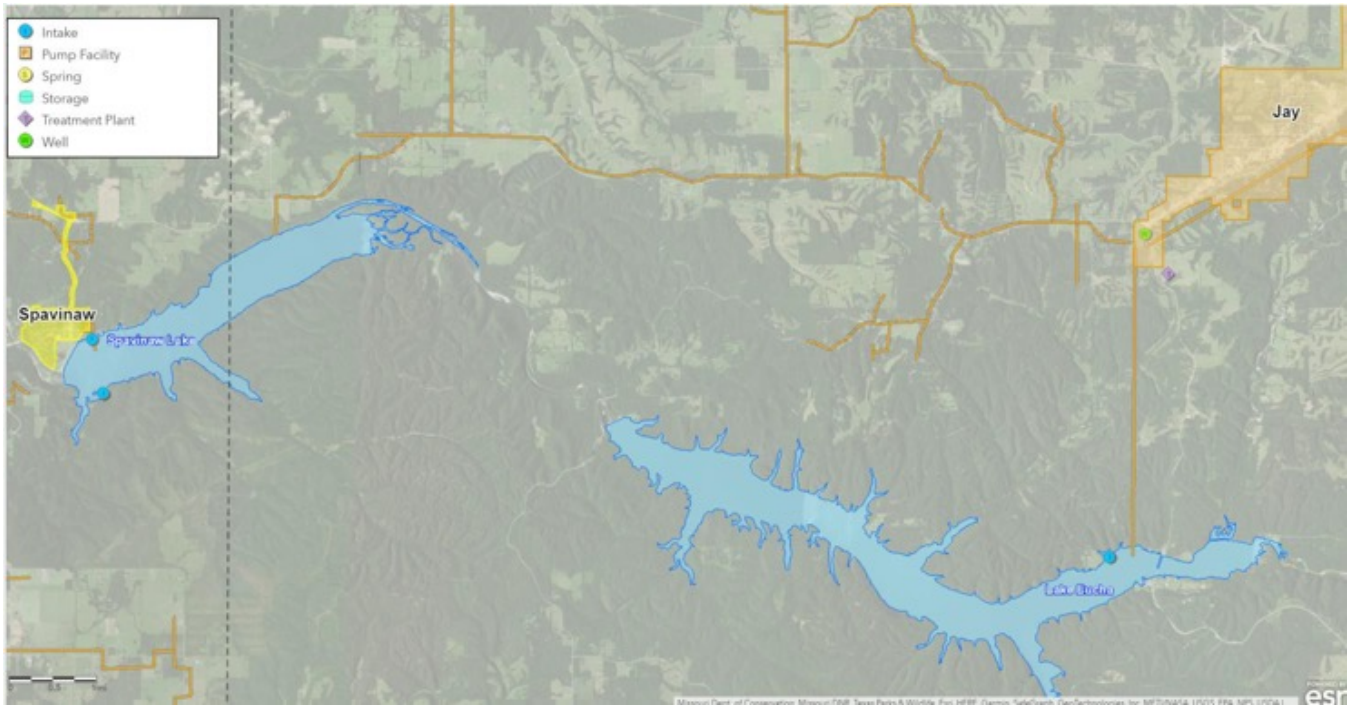
1 Mapping was extracted from the 2019 Multi-Hazard Mitigation Plan Update for the City of Tulsa

Vulnerable populations are identified by FEMA as those that fall into one of the following seven categories: those younger than five years of age, those older than 65, those who speak other than English at home, those that did not graduate from high school, those whose race is non-white, those with one or more disabilities, and those living below the poverty line. Figure F-9 shows where these population subsets are found within the City Limits, however, additional studies of these groups are needed in the area of inundation downstream of Eucha and Spavinaw along with critical facility identification. A dam incident at Spavinaw/Eucha would impact the Tulsa vulnerable populations only by a potential loss (or interruption) of water supply – floodwaters from either dam breach pose no direct threat to citizens of Tulsa.

There are other communities outside of the City of Tulsa that also draw their water from these lakes, as seen in Figure F-10. A dam breach and /or failure of these dams would result in a loss or interruption of water supply to both Spavinaw and Jay. The loss of water service, however, would affect many households. To ascertain alternative sources of water should the City's Spavinaw source become compromised would require the development of new water supplies, which would be measured in years and could potentially cost billions of dollars. In the meantime, should Spavinaw's source of water become inoperable, Tulsa would rely on other sources of water, like Oolagah, which serves as the primary source of water for the City[1]. Additional studies are needed to determine the exact impact this scenario would have on the Tulsa community.

1 http://sdwis.deq.state.ok.us/DWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=715985&tinwsys_st_code=OK&wsnumber=OK1020418

Figure F-10 OWRB Water Facilities/Structures Associated with Spavinaw/Eucha Lakes



F.5.2 Lifelines at Risk

The built environment includes infrastructure and structures across the region, many of which revolve around critical facilities and FEMA Lifelines. Critical facilities are those that officials have identified as being crucial to the basic functioning of the community in the City of Tulsa. FEMA's community lifelines are essential to a community's basic functioning needs by supporting key government, business, and/or other essential functions. The community lifelines outlined by FEMA are described in Table F-6 below. This section spotlights each of these lifelines and summarizes impacts possible following a dam failure or breach.

Table F-6 FEMA Lifelines

	Safety and Security	Law Enforcement/Security, Fire Service, Search and Rescue, Government Service, Community Safety
	Food, Water, Shelter	Food, Water, Shelter, Agriculture
	Health and Medical	Medical Care, Public Health, Patient Movement, Medical Supply Chain, Fatality Management
	Communications	Infrastructure, Responder Communications, Alerts Warnings and Messages, Finance, 911 and Dispatch
	Transportation	Highway/Roadway/Motor Vehicle, Mass Transit, Railway, Aviation, Maritime
	Hazardous Material	Facilities, HAZMAT, Pollutants, Contaminants

Safety and Security

A dam failure at either or both dams would have profound and adverse effects on several components of this lifeline, most notably Search and Rescue and Community Safety. Aside from downstream communities who would see flooding impacts, the City of Tulsa as well as the Tulsa County rural water districts outlined in Table F-7 are also at risk for seeing community safety impacts from a failure or breach of Spavinaw/Eucha dams. Search and rescue operations would

necessarily have to be activated, which would further put officials in law enforcement/security, fire service, and government service at risk in having to be physically present in a dangerous situation.

Food, Water, Shelter

All singular components of this lifeline would be severely impacted. None would be significantly more affected than any other. Since Lakes Eucha and Spavinaw serve as reservoirs which provide water service to many customers, that lifeline would experience severe interruption. Also, the Grand River Pumping Station is just south of the intersection of Spavinaw Creek with Grand River/Lake Hudson. A significant, quickly moving influx of water rushing into this facility has the

potential to overwhelm it, which would then compromise a critical water resource for Mayes County RWD (Rural Water District) #6 and any other water distributors who may rely on this facility to distribute water to their customers. Any agricultural activities downstream of these dams within the inundation zone would suffer losses and destruction. Also, agricultural activities that rely on these reservoirs for irrigation would be severely impacted, too. This would further affect access to food, which would also be affected by roadways being inundated or washed away, preventing food supplies from reaching grocery store shelves. Residential structures within the inundation zone are at risk of severe damage or destruction, with the potential for mold and bacteria in any structures left standing remaining as a long-term threat.

Health and Medical

A dam breach would place a strain on medical care resources, depending on the number of people needing treatment because of this scenario. Public health would be compromised by the growth of mold and bacteria in any structures affected by flooding. Fatality management would be strained too, as the potential for high fatalities resulting from complete dam failure exists. The supply chain for medical supplies and equipment, as well as the capacity for efficient patient

movement, would also be interrupted, as ground transportation networks would be compromised and potentially destroyed.

Communications

The most impacted components of this lifeline would be responder communications, 911 and Dispatch, and Alerts Warnings and Messages. The planning team noted no significant effects on communications infrastructure or. Responder communications would become compromised since mobile communications towers often become overloaded during emergencies. The effects on 911 and Dispatch are notably a sharp increase in the volume of calls and activity requiring

official response. Call centers can suddenly become overburdened, and individuals needing emergency assistance could potentially be forced to wait. This makes for a critical situation where the capacity to provide a quick response is crucial and would be compromised due to a shortage in capacity. Alerts, warnings, and messages notifying people in the path of the wall of water that would come rushing their way would be necessary prior to the realization of the event. This would require constant and consistent monitoring of these dams, and an awareness of the signs that a failure is about to occur.

Transportation

While impacts on rail, mass transit, and aviation would be negligible to zero in this scenario since there are no interests for these modes of transportation in or proximal to the inundation zone, there would be noticeable impacts on some roads and bridges as well as water transit. Any boats or crafts on either lake would either be washed ashore or be caught in the downstream flow toward Lake Hudson and the Grand River. Any crafts on Lake Hudson or Grand River could potentially be washed

downstream or even capsized. The limits of the studies used in these analyses do not include Lake Hudson, so further studies would be needed to analyze the effects of a dam breach on interests in this area. The same can be said for impacts to transportation on OK-20 along the Salina Levee, as well as the town of Salina. OK-20 crosses Lake Hudson/Grand River, and parts of Salina are vulnerable to a rise in river/lake levels. Closer to Spavinaw Dam, OK-20 crosses Spavinaw Creek just west of the town of Spavinaw. This bridge would be submerged, and destroyed, by the wall of water rushing from a dam failure here. Additionally, OK-20 and all streets and roads around Spavinaw, including Indian Springs Road which runs south of Spavinaw Creek to the west of town, would be inundated, further inhibiting transportation in this area. Further upstream, closer to Eucha Dam, there are two bridges: Low Water Bridge on E0425 Road, which would certainly be inundated, and High Bridge on County Road 530. It does not appear that the latter would be inundated in a dam failure scenario at Eucha Dam, but further studies are needed for the effects on this bridge to analyze the full effects on this bridge, including its support structure, and whether that can withstand the strong force of water that would certainly rush its way.

Hazardous Materials

Hazardous materials may enter floodwaters, particularly in areas of urban inundation where substantial amounts of chemicals, oils, and other pollutants can be absorbed. Inundations of Eucha could result in hazardous runoff materials entering Spavinaw water sources. In addition to any man- made hazardous materials that are introduced to water systems, downstream impacts would also include an assortment of debris and other material. These potential scenarios directly impact

communities near/downstream of Eucha and Spavinaw, and they also threaten the City of Tulsa as their water source on Spavinaw Lake would pull in hazardous materials into its intake pump.

F.5.3 Economic, Environmental and Social Impacts

Economic impacts to the community can be direct or indirect. Direct impacts appear immediately following a dam failure event and typically include the need to repair and rebuild structures and infrastructure and reopen businesses. Indirect economic impacts that might be identified during the consequence assessment include unemployment leading to population shifts, difficulty in attracting new businesses to the area, the need for governmental assistance, and lower property tax revenues. An indirect impact may include the closure of an industry outside the inundation area that depends upon the output of a facility within the inundation area that would potentially be destroyed by the dam failure scenario under consideration. Dam failure can cause significant and long-term social effects, resulting in changes to the quality of life in the affected community. Social impacts may include a loss in the public's confidence in public officials, difficulty delivering necessary social or medical services to the community, or the loss of connections among community members that provide support and enrichment. A dam failure can also have negative environmental impacts, such as the pollution of surface or ground water, air, and soil, the release of hazardous materials, or the destruction of environmentally sensitive areas. Long-term vulnerabilities to the community, reservoir, recreation areas, environment, and cost to rebuild or develop a new source of potable water, etc. No historical failures, nor any reported damages, were found on record for either dam on Lake Eucha or Spavinaw Lake.

These dams provide the City of Tulsa with a portion of its water supply.[1] Water supply from Spavinaw Lake is treated at the Mohawk Water Treatment Plant (WTP) in Tulsa, one of two water treatment plants which serve the City of Tulsa. Mohawk WTP has a 100-MGD treatment capacity. Given the high number of people served by Tulsa Metropolitan Utility Authority, and subsequently Tulsa Water Works, the potential impact of a breach scenario, such as that from the dams at Spavinaw or Eucha, would have incredibly significant impacts economically, environmentally, and socially. A loss of water output from these reservoirs would nearly halve the water output produced by the City of Tulsa water treatment system, as the water treatment facility that draws from these sources, Mohawk Water Treatment Plant, would necessarily be forced to cease operations. This would lead to cascading impacts, which are discussed in the following section.

1 Tulsa Water Treatment Process | Tulsa Water Testing (tulsawaterworks.com)

F.5.4 Cascading Impacts

The loss of water service to a sizable portion of the City of Tulsa would have effects on many businesses and residents. The City's Mohawk water treatment plant serves many different public water systems in the region. Table F-7 outlines the various water systems that rely on water from Spavinaw Lake, either directly or indirectly, through the City of Tulsa's Mohawk Water Treatment Facility and other sources.

Closer to both Spavinaw and Eucha dams, inundation would submerge and destroy several residences, both near Eucha and in the town of Spavinaw. Spavinaw Wildlife Management Area and Spavinaw State Park would both become submerged, affecting, and destroying plant and animal life there. Downstream, additional water influx into the Grand River would affect interests and communities along its banks, including Grand River Pumping Station, Salina, Salina Levee, and Kerr Dam.

Additionally, transportation on OK-20/82 west of Spavinaw would be inhibited, as the bridge over Spavinaw Creek would be washed out and potentially destroyed. Debris becoming caught up in the rush of water would also affect downstream interests.

F.5.5 Limitations/Deficiencies

Similar to the rest of the country, Oklahoma

Table F-5 Homes/Businesses/Highways at Risk from Inundation

PUBLIC WATER SYSTEM	SOURCES OF WATER	POPULATION (HOUSEHOLDS/ACCOUNTS) SERVED[1]
Harmony Brook Inc.	· Tulsa Mohawk	50 (residential)
Owasso	· Tulsa Mohawk	23,000 (residential)
SAR Water Corp.	· Tulsa Mohawk	3,000 (residential)
Skiatook	· Tulsa Mohawk	63 (residential)
Spavinaw PWS	· Spavinaw Lake	432 (residential)
Sperry	· Tulsa Mohawk	1,200 (residential) 40 (wholesale)
Tulsa	· Tulsa AB Jewell (Oolagah Lake) · Tulsa Mohawk (Spavinaw Lake	471,000 (residential) 33,613 (wholesale)
Tulsa-Spavinaw	· Spavinaw Lake	100 (residential)
Tulsa Co. RWD #2	· Sand Springs · Sapulpa rural water company · Tulsa AB Jewell · Tulsa Mohawk	467 (residential)
Tulsa Water Improvement District #3	· Tulsa Mohawk	2,475 (residential)
USAF Plant #3	· Tulsa Mohawk	3,276 (transient)
City of Jay PWS	· Eucha Lake · Emergency Wells	2,482 (residential) 498 (wholesale)

1 http://sdwis.deq.state.ok.us/DWW/JSP/WaterSystems.jsp?PointOfContactType=none&number=&name=&county=Tulsa
Non-transient = industrial/agricultural, medical facility, school
Residential = residential areas, mobile home park, municipality
Transient = recreation area, highway rest area, hotel/motel
Wholesale = seller of water

joined the drive for flood control in the 1940s & 1950s by placing dams in locations all around the state. These facilities provide flood control and supply drinking water and hydroelectric power for communities across America. Considered critical infrastructure, these aging facilities are in desperate need of repair. As they age, needed repairs and rehabilitation efforts are identified by acting authorities, but the rate of disrepair is escalating and the ability of local jurisdictions to provide adequate funding to complete mitigation efforts is dwindling. Rehabilitation and/or repair of large and small deficiencies is costly. Recent changes to federal guidance allow for grant funding to bridge this gap and will be utilized by this community to bring Lake Spavinaw Dam and Lake Eucha Dam into compliance, providing critical resources for not only the City of Tulsa, but surrounding communities for decades to come.

E.5.6 Observations and Recommendations

This section outlines an overview of observations and recommendations drawn from this section. It is intended to provide the reader with a summary of vulnerabilities related to the high hazard potential for dams on Lake Eucha and Spavinaw Lake, with recommendations to mitigate against each.

Table F-8 Summary of Observations and Recommendations

OBSERVATION	RECOMMENDATION	ACTION(S)
Information on the specific size and nature of populations affected by the closure of Mohawk Water Treatment Plant has not been included in any EAP documents to date.	Update the EAPs for Eucha and Spavinaw to include impacts on the specific size and nature of populations affected by a closure of Mohawk Water Treatment Plant due to cessation of water delivery to this facility from these reservoirs.	33
The Eucha Dam EAP identifies several recommendations and structural repair projects.	Follow the Recommendations of the Eucha Dam Anchoring and Concrete Repairs, TMUA-W 190-01, Preliminary Engineering Report to provide stability improvement to the three sections consisting of post-tensioned anchors.[1]	30,31
The exact number of households that would be impacted if the Spavinaw/Eucha water source is lost is unknown. Additional studies are outside the scope of this amendment but would help ascertain the exact impact to the City of Tulsa, Tulsa County and other water users.	Develop a contingency plan for a scenario where Spavinaw's water sources are lost due to catastrophic failure for the City of Tulsa, including alternative water sources, costs of development, and implementation processes.	32
Spavinaw Dam is 100 years old, and with continuing use is experiencing the degradation of some dam inspection items from Satisfactory condition to Fair Condition. With time more items will be identified as needing potentially urgent action.	Provide a study with recommendations to repair Spavinaw Dam based on deficiencies identified in the annual dam inspection reports, to include other potential catastrophic structural failure scenarios.	34

1 A conceptual level cost range of $9 to $14.6 million was estimated for the anchoring portion of the project at this preliminary study phase.

F.6 Mitigation Strategy

A mitigation strategy describes how a community will accomplish the overall purpose, or mission, of the planning process. This mitigation strategy is made up of three main required components: mitigation goals, mitigation actions, and a plan for implementation. These provide the framework to identify, prioritize, and implement actions to reduce risk to hazards. In the 2019 City of Tulsa Hazard Mitigation update, the following Mission Statement was established: "To create a disaster-resistant community and improve the safety and well-being of Tulsa by reducing deaths, injuries, property damage, environmental and other losses from natural and technological hazards in a manner that advances community goals, quality of life, and results in a more livable, viable, and sustainable community."

The City of Tulsa's Mitigation Goal is to identify community policies, actions, and tools for long-term implementation to reduce risk and future losses stemming from natural and technological hazards that are likely to impact the community. Specifically,

- Minimize loss of life and property from natural hazard events
- Protect public health and safety
- Increase public awareness of risk from natural hazards
- Reduce risk and effects of natural hazards
- Identify hazards and assess risk for local area
- Ascertain historical incidence and frequency of occurrence
- Determine increased risk from specific hazards due to location and other factors
- Improve disaster prevention
- Improve forecasting of natural hazard events
- Limit building in high-risk areas
- Improve building construction to reduce the dangers of natural hazards
- Improve government and public response to natural hazard disasters

Adding this HHPD Amendment supports and expands the established mission statement, along with the goals identified in 2019. HHPD priority mitigation actions are added to address reducing vulnerability from the two HHPD's discussed in this document.

F.7 Recommended Mitigation Actions

The existing Recommended Mitigation Actions found in Chapter 5 shall be amended to include the following action items. The planning team conducted a review of existing EAP and dam studies and extracted the following proposed mitigation actions from these documents.

ACTION 30: FOLLOW THE RECOMMENDATIONS OF THE EUCHA DAM ANCHORING AND CONCRETE REPAIRS, TMUA-W 190-01, PRELIMINARY ENGINEERING REPORT, FIRST MAJOR COMPONENT, TO PROVIDE STABILITY IMPROVEMENT TO THE THREE SECTIONS CONSISTING OF POST-TENSIONED ANCHORS.[1]	
Principle(s)	Improve building construction and enforce current building codes to reduce the dangers of natural hazards
Action Type	Structural Project
Priority	High
Hazard(s) Addressed	Dam/Levee Incidents
Lead Agency (Partners)	City of Tulsa/Tulsa Municipal Utility Authority
Planning Jurisdiction(s) Affected	Tulsa, Tulsa County, Spavinaw, Jay, and other unincorporated communities downstream in the AOI
Funding Sources	Local/General, FEMA HHPD
Timeframe	2023 - 2026

1 A conceptual level cost range of $9 to $14.6 million was estimated for the anchoring portion of the project at this preliminary study phase.

ACTION 31: FOLLOW THE RECOMMENDATIONS OF THE EUCHA DAM ANCHORING AND CONCRETE REPAIRS, TMUA-W 190-01, PRELIMINARY ENGINEERING REPORT, SECOND MAJOR COMPONENT, TO PROVIDE ASSESSMENT AND REPAIRS OF THE DOWNSTREAM CONCRETE SURFACES OF THE DAM.[1]	
Principle(s)	Improve building construction and enforce current building codes to reduce the dangers of natural hazards
Action Type	Preventative Activity
Priority	Medium
Hazard(s) Addressed	Dam/Levee Incidents
Lead Agency (Partners)	City of Tulsa/Tulsa Municipal Utility Authority
Planning Jurisdiction(s) Affected	Tulsa, Tulsa County, Spavinaw, Jay, and other unincorporated communities downstream in the AOI
Funding Sources	Local/General
Timeframe	2027 - 2028

1 A conceptual level cost range of $5.6 to $7.5 million was estimated for the concrete repair portion of the project from the preliminary study phase.

ACTION 32: DEVELOP A CONTINGENCY PLAN FOR A SCENARIO WHERE THE SPAVINAW AND LAKE EUCHA WATER SOURCES ARE LOST DUE TO CATASTROPHIC FAILURE FOR THE CITY OF TULSA, INCLUDING ALTERNATIVE WATER SOURCES, COSTS OF DEVELOPMENT, AND IMPLEMENTATION PROCESSES.	
Principle(s)	Improve governmental and public response to hazards, Protect public health and safety
Action Type	Preventative Activity
Priority	Medium
Hazard(s) Addressed	Dam/Levee Incidents
Lead Agency (Partners)	City of Tulsa/Tulsa Municipal Utility Authority/Tulsa County
Planning Jurisdiction(s) Affected	Tulsa (and communities who purchase water sourced at Spavinaw)
Funding Sources	Local/ State and Federal HMGP funds, FEMA HHPD
Timeframe	2023 - 2026

ACTION 33: UPDATE THE EAPS FOR EUCHA AND SPAVINAW TO INCLUDE IMPACTS ON THE SPECIFIC SIZE AND NATURE OF POPULATIONS AFFECTED BY A CLOSURE OF MOHAWK WATER TREATMENT PLANT DUE TO LOSS OF WATER DELIVERY TO THIS FACILITY FROM SPAVINAW AND EUCHA RESERVOIRS BECAUSE OF CATASTROPHIC FAILURE OF THE DAMS.	
Principle(s)	Improve governmental and public response to natural hazards
Action Type	Preventative Activity
Priority	Medium
Hazard(s) Addressed	Dam/Levee Incidents
Lead Agency (Partners)	City of Tulsa/Tulsa Municipal Utility Authority/Tulsa County
Planning Jurisdiction(s) Affected	Tulsa, Tulsa County, and communities who purchase water sourced at Spavinaw
Funding Sources	Local/ State and Federal HMGP funds, FEMA HHPD
Timeframe	2023 - 2026

ACTION 34: PROVIDE A STUDY WITH RECOMMENDATIONS TO REPAIR SPAVINAW DAM BASED ON DEFICIENCIES IDENTIFIED IN THE ANNUAL DAM INSPECTION REPORTS, TO INCLUDE OTHER POTENTIAL CATASTROPHIC FAILURE SCENARIOS.	
Principle(s)	Improve building construction and enforce current building codes to reduce the dangers of natural hazards
Action Type	Preventative Activity
Priority	Medium
Hazard(s) Addressed	Dam/Levee Incidents
Lead Agency (Partners)	City of Tulsa/Tulsa Municipal Utility Authority
Planning Jurisdiction(s) Affected	Tulsa, Tulsa County, Spavinaw, and other unincorporated communities downstream in the AOI
Funding Sources	Local/General, FEMA HHPD
Timeframe	2023 - 2026

CITY OF
TULSA