Chapter III

ANALYSIS OF HAZARD CONDITIONS

In order to evaluate various potential hazard mitigation alternatives for the City of Milwaukee and select the most effective and feasible hazard mitigation strategies, the existing potential hazard problems in the City must first be analyzed and the vulnerability to such hazards documented. Accordingly, this chapter provides the following:

- Identification of the hazards likely to affect the City of Milwaukee;
- Profiles of the extent and severity of hazard events which occurred in the City;
- Assessment of the vulnerability and risk associated with each type of hazard; and
- Identification of the potential for changes in hazard severity and risk under future conditions.

The vulnerability assessment focused on the City and community assets described in Chapter II.

In preparing this updated plan, the analysis of the existing potential hazard problems and the documentation of vulnerability to such hazards were reviewed and updated as warranted. This review and updating included:

- Reevaluation of the identification of the hazards likely to affect the City of Milwaukee;
- Updating of the data upon which the profiles of the extent and severity of hazard events that occurred in the City were based;
- Reassessment in light of the updated data of the vulnerability and risk associated with each type of hazard; and
- Reevaluation as warranted by the updated assessments of the potential for changes in hazard severity and risk under future conditions.

HAZARD IDENTIFICATION

The process of identifying those hazards which should be specifically addressed in the City of Milwaukee hazard mitigation plan was based upon consideration of a number of factors. The process included input from the City of Milwaukee Hazard Mitigation Steering Committee,[1] including a priority rank ordering of hazards; review of the hazard identification set forth in the State hazard mitigation plan; review of documentation of past hazard events; and review of related available mapping, plans, and assessments. It is important to note that the Milwaukee County Pre-Disaster Mitigation Plan was reviewed and utilized as a resource, as part of the hazard identification and assessment in terms of the natural hazards analyses relevant to the City of Milwaukee. As part of the updating process, the identification of hazards likely to affect the City of Milwaukee was reviewed and reevaluated. The reevaluation included additional input from the City of Milwaukee Hazard Mitigation Local Planning Team.

Local Input

The City of Milwaukee Hazard Mitigation Plan was developed through a collective effort of a number of agencies, organizations, and community representatives under the guidance of the City of Milwaukee Hazard Mitigation Steering Committee, which was created by the City of Milwaukee Department of Public Works (DPW) specifically for plan development purposes. That committee is comprised of appointed officials and public representatives from throughout the City and County knowledgeable about, and directly involved in, hazard mitigation matters (see Appendix A).

During the drafting of the initial plan, two meetings of the Milwaukee Hazard Mitigation Steering Committee were devoted, in part, to hazard identification. At the first meeting, an initial listing of hazards to be considered was presented. The Steering Committee was asked to expand upon that listing, and each Steering Committee member was asked to select the three hazards which were considered most important. The hazards identified in the Milwaukee County Pre-Disaster Mitigation Plan were also reviewed and incorporated for use in the City plan. The listing of the potential hazards identified at the initial and second meeting, along with the number of committee members who indicated the importance of each hazard, is shown in Table III-1.

As part of the updating process, the Local Planning Team reevaluated the hazards to be considered using a hazard and vulnerability assessment tool. A copy of this tool is included in Appendix A. Members of the Local Planning Team indicated the likelihood of each hazard occurring in the City of Milwaukee and evaluated the severity of each hazard on the basis of possible impacts to people, property, and business. Finally, the Local Planning Team

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[1] *For the development of the initial plan and the 2010-2011 update, this group was called the City of Milwaukee All Hazards Mitigation Plan Steering Committee. For the current plan update, the name of this group has been changed to the City of Milwaukee Hazard Mitigation Local Planning Team to reflect the current terminology used by FEMA.*

evaluated that relative state of preparedness for each hazard. The ratings given by the Local Planning Team for each hazard were used to derive a perceived level of risk posed by each hazard. Following this, the hazards were ranked by perceived level of risk. The results from this assessment tool are shown in Table III-2 for the first plan update and Table III-3 for the current plan update.

Summary of Hazard and Vulnerability Assessment Tool Results

Methods

The assessment tools were completed at the October 5, 2016 meeting of the City of Milwaukee Hazard Mitigation Plan Local Planning Team, with 13 surveys being returned and analyzed. For each hazard in each survey, a risk was computed using the formula:

Risk(in %) = [(Probability/3) x (Human impact + Property impact + Business impact + Preparedness)/(4*3)]* 100

Where Probability (likelihood that an event would occur), Human impact (possibility of death or injury), Property impact (physical losses and damages), Business impact (interruption of services), and Preparedness (preplanning) were each assigned a number from 0 to 3, with 0 indicating "not applicable", 1 indicating low, 2 indicating moderate, and 3 indicating high.

The interpretation of the result returned by this formula is that the perceived threat increases with increasing percentage risk.

For each hazard, an average risk was calculated using the results of all the returned surveys. The hazards were then ranked by average risk, with a rank of 1 indicating the highest perceived risk. For each hazard, minimum and maximum risks were calculated. The results from the assessment tool were analyzed for 39 hazards.

In order to assess the degree of agreement among Local Planning Team members in the assessment of average risk, the interquartile range was calculated for each hazard. This quantity indicates the range of the half of the responses that are in middle. A smaller interquartile range indicates greater agreement among Task Force members as to the level of risk, while a larger interquartile range indicates less agreement.

Results

The results from the assessment tool are summarized in Table III-3. The average level of perceived risk for hazards ranged from a low of 9 percent for earthquakes to a high of 66.9 percent for stormwater flooding. The 10 highest average perceived risks belonged to hazards stemming from various causes. Five of the 10 highest ranked hazards were related to meteorological causes associated with winter weather or severe storms. The remaining five of the 10 highest ranked hazards were related to transportation-related events such as roadway accidents and railroad-related hazardous materials incidents, human behavior-related events such as civil unrest and workplace violence, and technological events such as cyber-attacks. The interquartile ranges for the 10 hazards with the highest average risks tended to be relatively large, indicating a diversity of opinion among Local Planning Team members as to the level of risk posed by each of these hazards. The Local Planning Team members generally agreed, however, on risks being relatively high for hazards posed by snow storms and ice storms.

The 10 lowest average perceived risks were associated with a variety of hazards, including natural hazards related to geological and meteorological events such as earthquakes and droughts, utility-related hazards such as water contamination and sewerage system loss, transportation-related hazards such as aircraft accidents and railway accidents, hazardous material incidents, and hazards related to structural failures. The interquartile ranges for the 10 hazards with the lowest average risks tended to be low, indicating strong agreement among Local Planning Team members as to the level of risk posed by each of these hazards.

Past Hazard Experience

Past experiences with disasters are an indication of the potential for future disasters for which the City of Milwaukee could be vulnerable. Accordingly, a review was made of the hazards that have faced Milwaukee in the past and a ranking by risk was made based upon disaster history and emergency management experience. As part of this plan update, the review of hazards faced by the City was updated to include experiences that have occurred since the original plan was drafted and the ranking by risk was reevaluated in light of this updated disaster history.

If disaster damages exceed the capabilities of local, County, and State agencies, Federal assistance will be requested. Federal disaster assistance may be offered through a variety of programs. Assistance may be directed to individuals and families, businesses, agricultural producers, or local governments. Table III-4 provides a summary of estimated damages from Presidential declared disasters and emergencies that affected the City of Milwaukee, from 1969 through 2016. Information on estimated damages and fatalities is included where available.

Between 1969 and 2016, the City of Milwaukee and environs had 13 presidential disaster declarations and three presidential emergency declarations. The total documented estimated damages of these events were five deaths and approximately $306 million as shown in Table III-4. Since these estimated property damage totals were inclusive of the entire County, the actual amount of damages specifically within the City of Milwaukee is unknown.

It should be noted that this amount significantly underestimates the sum of all losses in the Greater Milwaukee Area from natural hazards. In some years there are significant weather events causing millions of dollars of damage for which no Federal disaster assistance was requested. Thus, losses from hazards in Milwaukee County are significantly greater than the $306 million estimate shown in Table III-4. Major indicators of hazard severity are the deaths, injuries, and economic losses resulting from natural hazards and disasters. The National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) publishes National Weather Service (NWS) data describing recorded weather events and resulting deaths, injuries, and damages. To illustrate the broader hazard damage potential, since 1950 the Milwaukee County has experienced 763 weather hazard events resulting in 160 fatalities and 443 injuries reported, as shown in Table III-5. These records indicate that just over $400 million in property damages accumulated over this time period.

As summarized in Chapter II of this report, less than 1 percent of the land area in the City of Milwaukee is agricultural land. Historical urbanization has reduced the threat of an agricultural related hazard event. Considering the low risk and lack of historic incidents, agricultural related damages from hazards will not be addressed further in this plan. The NWS data summarized in Table III-5 shows that thunderstorms and high winds, followed by winter storms, hail storms, and temperature extremes, are the most frequent weather hazards. Flooding, followed by thunderstorms and high winds, and tornadoes, are the most damaging weather hazards; and extreme temperature, primarily heat, followed by winter storms and thunderstorms and high winds, are the most deadly weather hazards. In addition, it should be acknowledged that weather events are often complex and damages may occur from multiple hazards, such as when hail, rain, wind, and tornadoes strike during a single storm.

Improved weather forecasting and warning systems, as well as stronger building codes, help explain why tornado-related mortality has not been prevalent in the recent past, although tornadoes remain a very serious threat to human life. The emergence of temperature extremes as a leading cause of hazard-related mortality is most likely due to a combination of improved recordkeeping by health organizations and the longer life expectancy of individuals. Mortality from heat waves disproportionately affects the elderly.

To illustrate the potential frequency of thunderstorms and tornadoes, a review was made of the warnings historically issued by the National Weather Service, as shown in Table III-6. Over the period 1982 through 2014, there were 468 thunderstorm-related watches or warnings and 111 tornado-related watches or warnings issued for Milwaukee County. On average, the National Weather Service offices in Wisconsin issue less than one tornado warning, and six to seven severe thunderstorm warnings for Milwaukee County per year.

A similar review can be performed for human-induced and technological hazards. As with the meteorological hazards summarized in Table III-5, the major indicators of hazard severity are fatalities, injuries, and economic losses resulting from hazard events and disasters. Several agencies compile data on individual human-induced hazards and technological hazards and make it publicly available. For example, the U.S. Department of Transportation Office of Pipeline Safety complies and makes available data on hazardous material incidents involving pipelines and transportation. Based upon the two technological hazard categories for which data were available, the City of Milwaukee has experienced 1,750 technological hazard events since 1971. These events are summarized in Table III-7. They are estimated to have caused three fatalities, 147 injuries, and over $20 million in economic losses.

Summary and Ranking of Hazards

There are several ways the list of specifically considered hazards can be ranked and summarized in the City of Milwaukee hazard mitigation plan. Current guidance for all hazard mitigation plans promotes comprehensive consideration of all natural hazards. These hazards have been ranked by consideration of their frequency, amount of damage, and death and injuries incurred, as well as by concerns and degree of importance assigned by the collective judgment of the City of Milwaukee Hazard Mitigation Local Planning Team.

In addition, selected hazards other than natural hazards have been identified for consideration in the City of Milwaukee hazard mitigation plan based upon input from the City Hazard Mitigation Local Planning Team. The hazards to be specifically considered in the plan and their ranking are summarized in Table III-8, along with qualitative information on the hazard severity. As part of the updating process, the ranking of hazards to be considered in the initial plan was reevaluated giving consideration to the perceived risk associated with each hazard as summarized in Table III-3 to data related to the occurrence of hazards since the original plan as summarized in Tables III-5 and III-7.

Clearly, hazard severity can be assessed and ranked in a variety of ways. The purpose of ranking hazards is to help set priorities and direct more resources to address those hazards of the greatest severity. However, the kinds of mitigation actions that will be needed and warranted depend on the type of vulnerability to be addressed. Some hazards, such as excessive heat and lightning, are unlikely to cause a disaster, but can be fatal and, therefore, are serious hazards. Vulnerability to such hazards can best be addressed by preventative measures, such as public information to encourage hazard awareness and personal protection. Other hazards, such as flooding, are pervasive and devastating, and may require a variety of tools—mapping, building codes, zoning laws, insurance, elevation or acquisition of floodprone structures, and public awareness—to effectively reduce the risk of disaster. However, flooding might not result in more fatalities than a heat wave. In general, ranking hazards by the number of deaths that they cause shifts the focus away from major and largely avoidable disasters, such as floods. Weather hazards that have caused past City of Milwaukee disasters are probably the hazards that will cause future disasters. However, the types of natural hazards that result in fatalities remain a public health and safety concern.

The summary listing of hazards in Table III-8 does not include some hazards that were considered by the Local Planning Team, but found either to have minimal chance of occurring or causing damages, to offer only limited applicable mitigation options, or to be better addressed in some other context than hazard mitigation planning. The identified hazards listed below will not be addressed in the subsequent sections of the report.

Natural Hazards

Earthquakes

An earthquake is a shaking or sometimes violent trembling of the earth that results from the sudden shifting of rock beneath the earth's crust. This sudden shifting releases energy in the form of seismic waves or wave-like movement of the earth's surface. Earthquakes can strike without warning and may range in intensity from slight tremors to great shocks lasting a few seconds to over five minutes. The actual movement of the ground during earthquakes is seldom the direct cause of injury or death. Casualties may result from falling objects and debris, and disruption of communications, electrical power supplies, and gas, sewer, and water lines should be expected from earthquakes. The severity of an earthquake can be measured by comparing the peak acceleration associated with the horizontal shaking it produces to the normal acceleration a falling object experiences due to the force of gravity. This is usually expressed as a percentage of g, the acceleration due to gravity. The level of risk due to earthquake can be expressed as the percentage of g for which there is a 2 percent probability of being exceeded in a 50-year period. Depending on location, sites in the City of Milwaukee have a 2 percent probability of experiencing earthquakes in a 50-year period in which the peak acceleration associated with horizontal shaking exceeds between 4 percent and 8 percent of g.[2] These are low values. While these levels of shaking can be noticeable, they are rarely associated with damages to structures. The earthquake threat to the State of Wisconsin and the City of Milwaukee is considered to be low. Because of this, the Local Planning Team decided to remove earthquakes from the set of hazards addressed by this plan.

Human-induced Hazards

Civil Unrest

Civil unrest is a broad term that is typically used to describe one or more forms of disturbance caused by a group of people. It includes incidents which threaten public safety or disrupt community affairs. Examples of civil unrest include riots, labor disputes and strikes, and public demonstrations. These incidents may arise due to economic conditions, unpopular political actions, tensions between groups with opposing social or political viewpoints, shortages of critical supplies such as food or fuel, racial issues, or celebrations that get out of hand. Because these incidents usually involve large groups of people, they are more likely to occur in populated, urban areas.

Guidance for conducting planning processes to respond to and mitigate the impacts of civil unrest emphasize that these efforts should focus on developing broad community-wide relationships and encouraging extensive

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[2] U.S. Geological Survey, "2008 United States National Seismic Hazard Maps," USGS Fact Sheet 2008-3018, April 2008.

participation in processes to address the underlying problems that lead to civil unrest.[3] Such efforts require a collaborative planning process that identifies and engages public officials, community leaders, and other stakeholders. A comprehensive approach to dealing with civil unrest may need to address a variety of issues, including the responses to an incident, the immediate aftermath of an incident, and the long-term aftermath and impacts of an incident as well as the underlying issues which may cause or lead to such incidents. Because the focus of hazard mitigation planning is to reduce the impacts of hazard incidents when they occur, the scope of a hazard mitigation planning effort is too narrow to encompass the comprehensive approach required to address civil unrest. Given that addressing civil unrest is beyond the scope of what can be accomplished in a hazard mitigation plan, this plan will not address civil unrest as a hazard.

Cyber attack

The threat of cyber attack is an emerging threat to the security and reliability of information technology systems used by businesses, educational institutions, governments, and private citizens in many of their operations and activities. In information technology systems, computers are connected to one another through networks, such as local area networks in an office or larger networks like the internet. This places them at risk of cyberattack. The nature of such an attack may vary. In some instances, an attack may be a deliberate effort to gain access to an entity's systems or processes. In other instances, an attack may be the result of a randomly initiated threat, such as a computer virus or an electronic mail phishing attempt. Unlike physical threats that are often readily apparent and prompt immediate action, cyberattacks can be difficult to identify and recover from. A cyberattack is a disruption of an information system. Such a disruption can take several forms, depending on the motives of the attacker, the technological means available to the attacker, and the weakness of the information system that is attacked. The forms that a cyber attack could take include: disabling an information system, stealing information or sensitive data, modifying outputs of the system, altering data stored within the system, or taking control of a system by an unauthorized user.

The options available to local government for mitigating the impacts of cyber-attacks are limited. While there are steps that the City can take to reduce the vulnerability of its information technology systems to cyber attacks, most of the information technology infrastructure within the City is privately owned and not under the control of any unit of government. Because of the limited mitigation options, cyber attack will not be considered further in subsequent sections of this report.

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[3]*See, for example, The Ohio State University Moritz College of Law,* Planning in Advance of Civil Unrest, *2015 and The Ohio State University Moritz College of Law,* Key Considerations for Community Leaders Facing Civil Unrest: Effective Problem-Solving Strategies that Have Been Used in Other Communities, *2016.*

VULNERABILITY ASSESSMENT ANALYSIS METHODS AND PROCEDURES

In the previous section of this report the hazards considered applicable to the City of Milwaukee were identified and ranked. This section of the report develops a vulnerability assessment for the identified hazards, including vulnerable asset description, hazard event profiling, and estimated losses information. This vulnerability assessment provides the basis for developing mitigation strategies which address the identified vulnerabilities.

This section of the report, which includes a description of the methods and procedures utilized in developing the vulnerability assessment, is followed by the assessment for each of the identified hazards. The vulnerability assessment for each hazard includes, where applicable, a profile of hazard events, a description of potentially affected assets, and estimates of potential losses. In addition, the potential for future changes in the vulnerability of the hazard to the City is included for each of the identified hazards. Since the hazard mitigation plan involves one municipality, no specific multi-jurisdictional variance of risk is included. Where there is a specific variance of risk involved within the City of Milwaukee, it is noted.

The procedures utilized in the vulnerability analyses are based upon guidance provided by the Federal Emergency Management Agency (FEMA) and the Wisconsin Department of Military Affairs, Division of Emergency Management.[4] The analysis includes three components: 1) profile of hazard events, 2) inventory of assets, and 3) estimation of losses. In addition, where applicable, potential changes in vulnerability under future conditions and the variance of vulnerability within the City of Milwaukee is analyzed.

In general, the procedures utilized in this analysis focused upon the methodology consistent with the Hazard U.S. (HAZUS) software as maintained by the Federal Emergency Management Agency. In many cases, the mapping of assets and problem areas was done utilizing the detailed mapping and orthophotography available for the City of Milwaukee in both hard copy and digital form, including general base maps, large-scale topographic and cadastral maps, and year 2010 and 2015 large-scale orthophotographs. All of the mapping was done utilizing geographic information system (GIS) ArcMap software.

With regard to the community assets, the basic City of Milwaukee inventory data set forth in Chapter II include data and mapping on existing and planned land use, demographics, and economic characteristics of the City;

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[4]*Federal Emergency Management Agency,* State and Local Mitigation Planning How-to Guide*, "Understanding Your Risks, Identifying Hazards and Estimating Losses," Publication No. FEMA 386-2, August 2001; Federal Emergency Management Agency,* Local Multi-Hazard Mitigation Planning Guidance, July 1, 2008. *Federal Emergency Hazard Agency,* Local Mitigation Planning Handbook, *March 1, 2013; See also Federal Emergency Management Agency,* State and Local Plan Interim Criteria Under the Disaster Mitigation Act of 2000*, July 11, 2002.*

property value; flood hazard mapping; Lake Michigan coastal erosion hazard areas; transportation and utility systems; public safety facilities and services; and critical community facilities. These data have been used and supplemented with information obtained from the National Oceanic Atmospheric Administration (NOAA) National Climatic Data Center (NCDC); the Wisconsin Department of Military Affairs, Division of Emergency Management; and more hazard-specific local data, such as building-specific structure values, as the basis for the community asset data base. The profiling of hazard events was developed by utilizing HAZUS methodology, data available on the FEMA and NOAA NCDC web sites; data provided by the Wisconsin Department of Military Affairs, Division of Emergency Management; and file data available from the City of Milwaukee and the Southeastern Wisconsin Regional Planning Commission (SEWRPC).

Data and estimated losses and vulnerability were developed utilizing standard risk assessment methodology as set forth in FEMA and State Division of Emergency Management guidelines for hazard mitigation planning where hazards can be estimated spatially and by order of magnitude over a range of events. All damage estimates cited have been adjusted to constant 2016 dollars using the Consumer Price Index. For hazards which cannot be quantified, alternative approaches have been used relying on qualitative measures.

A vulnerability description has been included for each of the applicable hazards listed in Table III-8.

Assessments of Potential Future Changes in Hazard Conditions Relative to Climate Change

The risk to the City of Milwaukee posed by many of the natural hazards profiled in this plan have been estimated based largely upon the history of occurrence of, and impacts attributed to, the hazard within the City. For example, the estimates given below for the number of thunderstorms and thunderstorm-related hazards that would be expected to impact the City and the amount of damages to property in the City reflect the average number of occurrences of these storms and the associated damages that were reported over a recent 25-year period. Over the short term, such as the five-year period covered by this plan, estimates of risk and damages derived in this manner should serve as reasonably reliable indicators of the degree of risk associated with various hazards. Over longer periods of time, climate change may render estimates of risk based on historical occurrences and impacts unreliable. Recent assessments have documented changes in Wisconsin's climate over the late 20th century.[5] Projections of Wisconsin's climate based on downscaled data from 14 global climate models indicate that additional changes will occur through the 21st century.[6] The following subsections describe the changes that have

[5]*For example, Christopher J. Kucharik, Shawn P. Serbin, Steve Vavrus, Edward J. Hopkins, and Melissa M. Motew, "Patterns of Climate Change across Wisconsin from 1950 to 2006,"* Physical Geography, *Volume 31, pages 1-28, 2010.*

[6]*Wisconsin Initiative on Climate Change Impacts,* Wisconsin's Changing Climate: Impacts and Adaptation, *Nelson Institute for Environmental Studies, University of Wisconsin-Madison and Wisconsin Department of Natural Resources, 2011.*

occurred in Wisconsin's climate since 1950 and the changes that are projected to occur by the middle of the 21st century. For those hazards whose frequency of occurrence or impacts are likely to be affected by the changes in climate, these descriptions will form the basis of evaluating potential long-term changes in hazard conditions.

Average annual temperatures in Wisconsin increased over the last half of the 20th century. Between 1950 and 2006, average annual temperature in the State increased by an average of 1.1ºF.[7] In the City of Milwaukee the increase was between 1.5ºF and 2.5ºF. Much of this increase in average temperature occurred in the form of higher night-time low temperatures. For example, over the period 1950 through 2006, the average number of days in the City of Milwaukee in which the daily low temperature fell below 0ºF decreased by about 7 days per year. The greatest increase in temperatures occurred during winter and spring months. Depending on location, average winter temperatures in the City increased by 3.0°F to 3.5ºF over this period.

The consensus of downscaled results from climate models projects that average annual temperatures will continue to increase through the 21st century.[8] Depending on location, it is projected that average temperatures in the State of Wisconsin will increase by between 4.0ºF and 9.0ºF over the period 1980 through 2055. This increase is projected to be on the order of 5.5ºF to 6.0ºF in the City of Milwaukee. The greatest changes are projected to occur during winter months, with average winter temperatures being projected to increase by about 7.5ºF in the City. By contrast, average temperatures in the City during the summer are projected to increase by about 5.5ºF. Changes in extreme temperatures will accompany these changes in average temperature. The frequency of extreme daily high temperatures is projected to increase. The average number of days per year with daily high temperatures greater than 90ºF is currently about 12 in southern Wisconsin. This is likely to double to about 25 days per year by 2055. By contrast, the frequency of extreme daily low temperatures is projected to decrease. The average number of days per year with daily low temperatures below 0ºF is currently about 15 in southern Wisconsin. This is projected to decrease to about nine days per year by 2055.

Average annual precipitation in Wisconsin increased over the last half of the 20th century. Between 1950 and 2006, average annual precipitation in the State increased by an average of about 3.1 inches.[9] It should be noted that there was substantial variability in the change in precipitation across the State, with some areas experiencing

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[7]*Kucharik and others, 2010,* op. cit.

[8]*Wisconsin Initiative on Climate Change Impacts, 2011,* op. cit. *Downscaling is an analysis approach that enables climatological data generated by Intergovernmental Panel on Climate Change general circulation models developed at a relatively coarse geographic scale (e.g., climate change data for several large regions in an entire state) to be modified to represent a finer geographic scale (e.g., at the scale of a county or smaller).*

[9]*Kucharik and others, 2010,* op. cit.

increases of up to 7.0 inches and some areas in northern Wisconsin experiencing decreases. In the City of Milwaukee, annual precipitation increased over this period by between 3.0 inches and 7.0 inches, with smaller increases occurring in the northwestern portion of the City and larger increases occurring in the southeastern portion of the City. Much of the increase in average precipitation occurred during autumn months. In the City of Milwaukee, average precipitation during autumn months increased by between 1.5 inches and 2.0 inches over the period from 1950 through 2006. Increases in precipitation also occurred during winter, spring, and summer. The frequency and magnitude of heavy precipitation events has also been increasing in Wisconsin. Extreme rainfall patterns in the City of Madison illustrate this trend. In the decade between 2001 and 2010, there were 24 days per decade in which 2.0 inches or more of precipitation fell in a single event. This is twice the previous maximum of 12 days in the 1950s.

The consensus from downscaled results of climate models projects several changes in precipitation through the 21st century.[10] Most of the models project an increase in average annual precipitation in southeastern Wisconsin of about 1.5 inches to 2.0 inches. The projections indicate that the amount of precipitation falling during winter is likely to increase by about 25 percent. Due to the projected increase in temperatures, it is projected that a greater amount of precipitation occurring during the winter will fall as rain rather than snow.[11] This will be accompanied by both an increase in the likelihood of freezing rain events and decreases in snow depth and snow cover. Model projections also show that Wisconsin will receive more precipitation and more frequent intense precipitation events during the spring, especially during early spring. As in winter, it will become more likely for early spring precipitation to fall as rain rather than snow. The amount of precipitation occurring during the summer is not projected to change much. The projections also indicate that the frequency of intense rainfall events will increase. In southern Wisconsin, the frequency of precipitation events in which two or more inches fall in a 24-hour period is expected to increase from about 12 events per decade to 15 events per decade by the middle of the 21st century. These changes will be concentrated in the spring and fall. The projections indicate that the magnitude of the heaviest precipitation events will also increase. The shift to more heavy rainfall events but little change in total summertime precipitation implies that more dry days will occur in Wisconsin during the summer. More dry days, coupled with higher summer temperatures and the increases in evapotranspiration that are likely to result from higher temperatures, will lead to an increase in the likelihood of summer droughts.

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[10]*Wisconsin Initiative on Climate Change Impacts, 2011,* op. cit.

[11]*Michael Notaro, David J. Lorenz, Daniel Vimont, Stephen Vavrus, Christopher Kucharik, and Kristie Franz, "21st Century Wisconsin Snow Projections Based on an Operational Snow Model Driven by Statistically Downscaled Climate Data,"* International Journal of Climatology, *Volume 31, pages 1615-1633, 2011.*

VULNERABILITY ASSESSMENT FOR FLOODING AND ASSOCIATED STORMWATER DRAINAGE PROBLEMS

Flooding is a significant hazard in the City of Milwaukee. As described in Chapter II, there are approximately 61 miles of major streams in the City of Milwaukee, located within five watersheds: the Milwaukee River, Menomonee River, Kinnickinnic River, Oak Creek, and Root River watersheds. A sixth watershed encompasses those areas adjacent to Lake Michigan which drain directly into the Lake through intermittent streams. Aside from Lake Michigan, no other major lakes (those over 50 acres) exist in the City of Milwaukee.

Floodplains are the wide, gently sloping areas contiguous to, and usually lying on both sides of, a stream channel. For planning and regulatory purposes, floodplains are normally defined as the areas subject to flood inundation by the one-percent-annual-probability (100-year recurrence interval) flood event. The floodplains shown on Map II-4 in Chapter II of this report have been identified by the City of Milwaukee, the Southeastern Wisconsin Regional Planning Commission, and the Federal Emergency Management Agency. Approximately three square miles, not including surface water in existing stream channels, or about 3 percent of the total area of the City, is located within the one-percent-annual-probability flood hazard area.

In addition to flooding, stormwater drainage problems exist on a scattered basis throughout the City of Milwaukee. The distinction between stormwater drainage, stormwater management, and flood control is not always clear. For the purpose of this report, flood control is defined as the prevention of damage from the overflow of natural streams and watercourses. Drainage is defined as the control of excess stormwater on the land surface before such water has entered stream channels. The term “stormwater management” encompasses both stormwater drainage and nonpoint source pollution control measures. The focus of this section is on the flooding hazard, with stormwater drainage issues discussed as required for particular storm events.

In order to evaluate various potential flood mitigation alternatives for the City of Milwaukee and select the most effective and feasible flood mitigation strategies, the existing flooding problems in the City must first be analyzed. Accordingly, this section summarizes the extent and severity of the flooding problems within the City and the potential for these problems to increase in the future, and sets forth analyses of such problems as developed under detailed floodplain management system planning programs as described in the Flood Mitigation Plan for the City of Milwaukee revised in 2003,[12] various Milwaukee Metropolitan Sewerage District watercourse system plan reports, and subsequent analyses and reports.

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[12]*SEWRPC Community Assistance Planning Report No. 261,* Flood Mitigation Plan for the City of Milwaukee, Milwaukee County, Wisconsin*, October 2000, revised April 2003.*

Historical Flooding Problems

As noted earlier in this chapter, a number of major flooding events, including several that caused significant damage, have been recorded in the area now encompassed by the City of Milwaukee, as well as in the watershed areas partly encompassed within the City, since the areas involved were settled by Europeans in the 19th Century. Below is a list and brief description of the historical major flood events between 1897 and 1986 that have affected the City of Milwaukee as summarized in the Milwaukee County Pre-Disaster Mitigation Plan[13] and the City of Milwaukee Flood Hazard Mitigation Plan.[14] The descriptions of the floods during that time period are presented chronologically by event, followed by watershed-specific descriptions. Those descriptions are followed by a review of more-recent floods that have occurred from 1993 to the present.

- March 1897—This flood event inundated approximately a 1.7-mile-long reach of the Menomonee River beginning just north of present-day W. Wisconsin Avenue in Milwaukee County and extending downstream into the Menomonee River industrial valley. Considerable economic loss was incurred.

- March 1912—This flood event occurred in the Kinnickinnic River watershed and is the earliest major flood of record within the watershed for which any significant amount of information is available. This flood was caused by snowmelt. Damage caused by this flood was concentrated in the 0.77-mile-long reach of the Kinnickinnic River between present-day S. 6th Street and present-day S. 16th Street. Damage to homes along that reach totaled thousands of dollars, with floodwaters reported above the windowsills of some of the structures.

- June 1917—This flood event caused extensive damage in the lower Menomonee River watershed, particularly in the Menomonee River industrial valley. The Menomonee River floodplain below what is now the Wisconsin Avenue viaduct was subjected to very serious flooding that drove almost every resident from the area. Several businesses with major facilities in the Menomonee River industrial valley, including the Chicago, Milwaukee, St. Paul & Pacific Railroad and the Falk Corporation, incurred significant flood damage. Serious flooding also occurred in the Kinnickinnic River watershed in an area encompassing several blocks near the eastern edge of the watershed immediately west of Humboldt Park. A portion of the roadway at the intersection of S. Howell Avenue and E. Oklahoma Avenue was washed out.

- January 1938—This flood event, while significant, is known to have affected only scattered areas along the lower Kinnickinnic River and along Wilson Park Creek. The Kinnickinnic River

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[13]*Milwaukee County Office of Emergency Management,* Milwaukee County Hazard Mitigation Plan, *draft, October 19, 2017.*

[14]*SEWRPC Community Assistance Planning Report No. 261,* op. cit.

overflowed its banks near a railway bridge crossing at S. 18th Street extended, depositing large blocks of ice on the tracks, and flooded a railroad bridge located directly west of S. 20th Street. Although this flood occurred in January, it was attributed to the occurrence of heavy rainfall.

- June 1940—This flood event inundated and caused damage to areas primarily along the Menomonee River with scattered occurrences of flooding also reported along Honey Creek, Underwood Creek, and the Little Menomonee River. The S. 84th Street bridge over Honey Creek in the City of Milwaukee was washed out. Near the confluence of the Menomonee and Little Menomonee Rivers in Milwaukee, rising flood waters forced segments of what is now N. Mayfair Road and W. Hampton Avenue to close.

- March/April 1960—This flood event primarily occurred in the Kinnickinnic River and Menomonee River watersheds as the result of a snowmelt-rainfall event. The event caused widespread damage in the City of Milwaukee along the Kinnickinnic River and scattered problems in the City along Wilson Park Creek. The flood caused problems along the Kinnickinnic River as far west as S. 43rd Street and along Wilson Park Creek as far south as General Mitchell Field (now General Mitchell International Airport). Basements of residential and commercial buildings were flooded, collapsing walls in some cases. At the time, the U.S. Department of Agriculture, Soil Conservation Service (now the Natural Resources Conservation Service) estimated flood damages in the Menomonee River watershed resulting from this flood at about $2.9 million (about $23.5 million in 2016 dollars).

- August 1960—This flood event caused extensive flooding along the Kinnickinnic River downstream of S. 43rd Street. A portion of the flood flow from the Kinnickinnic River was diverted from the stream at W. Montana Street extended and flowed five blocks in an easterly direction along the Chicago & North Western Railway right-of-way to S. 12th Street, where the flow turned northward, moving about two blocks along S. 12th Street to rejoin the Kinnickinnic River. Considerable flood damage occurred in basements located along this route, including damage to appliances and other contents. Farther upstream, residential structures along W. Manitoba Avenue again experienced flood damage and numerous basements were flooded and at least one incident of basement wall collapse was reported.

- September 1972—This flood event caused by a relatively large quantity of rainfall occurring under wet antecedent moisture conditions resulted in significant flood damage and disruption in the Kinnickinnic River watershed within the City of Milwaukee. Most of the damage and disruption involved was confined to the reach of the Kinnickinnic River between S. 6th Street and S. 16th Street in the City. The flood problems were restricted largely to this reach because of the considerable channel modifications that had been completed by this time within the watershed on the Kinnickinnic

River, Wilson Park Creek, Lyons Park Creek, and other tributaries, thereby providing for the control of the relatively high flows that were experienced. Floodwaters overtopped the low point of the roadways of the 10 bridges that then crossed the Kinnickinnic River beginning with and including S. 7th Street and extending through S. 15th Street, extending as much as one city block away from the River. Floodwaters overtopped the S. 43rd Street bridge over the Kinnickinnic River in the City, damage occurred to residential and commercial buildings.

- April 1973—This major flood event caused flood problems throughout most of the seven-county Southeastern Wisconsin Region, with certain areas, such as the Kinnickinnic River and Menomonee River watersheds, experiencing severe flood damages. The flooding that occurred was somewhat more serious than what would ordinarily be expected under the relatively moderate levels of rainfall involved because of the existence of very wet antecedent moisture conditions.

- August 1986—This flood event centered in a one to four-mile-wide band extending northwesterly from the City of Oak Creek through General Mitchell International Airport to the northern portion of the City of Wauwatosa. It resulted in a maximum rainfall of 6.84 inches in 24 hours, the single day record at the General Mitchell International Airport recording station. As shown in Figure III-1, widespread flooding occurred at the airport, which was shut down. Severe damage occurred especially along the reach of the Kinnickinnic River between S. 6th Street and S. 16th Street in Milwaukee. Flooding impacts occurred in other areas, including along Wilson Park Creek, located in the Kinnickinnic River watershed, and the near northwestern portion of Milwaukee along the Menomonee River and Woods Creek, where severe basement flooding occurred due to sewer backup. Impacts near the mouth of the Menomonee River are shown in Figure III-2.

Kinnickinnic River Watershed

Measured by the spatial extent of the flood damage and disruption resulting from the event, the April 1973 flood (which within the Kinnickinnic River watershed had a 1.8 percent annual probability of occurrence) was not the most serious flood experienced in the watershed. In addition, by this time, as noted above, considerable channel modifications had been completed within the Kinnickinnic River watershed on the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, and other tributaries, thereby again providing for the control of the relatively high flood flows that were experienced. Within the watershed, major damage and disruption attributed to the flood were confined to the S. 6th Street to S. 16th Street reach of the Kinnickinnic River in the City of Milwaukee, although damage also occurred at General Mitchell Field. Although major channel modifications had been completed throughout the aforementioned Kinnickinnic River reach in 1961, the modified channel in combination with the 13 stream crossings then in the reach did not have sufficient capacity to convey the 1973 flood flows within the channel banks. As a result, floodwaters overtopped the low point of the roadways of all 11 bridges then crossing the Kinnickinnic River beginning with and including S. 7th Street and extending through S. 15th Place.

Accordingly, overland flooding occurred on both sides of the River between S. 6th Street and S. 16th Street, extending as much as 700 feet, or more than one city block, away from the River. The areal extent of the effect of flooding undoubtedly extended outside the area affected by the overland flooding in the form of secondary flooding. Many residential and commercial buildings in the area of overland flooding incurred both structural damage and damage to contents as a result of basement or first-floor flooding. Extensive monetary losses occurred in the case of some individual structures, including a $16,000 (about $86,500 in 2016 dollars) loss resulting from damage to the inventory of a pharmacy located less than one-half block from the Kinnickinnic River. In addition, an isolated incident of flood damage occurred at General Mitchell Field, where a concrete box culvert beneath a taxiway in the northwestern corner of the airport suffered serious damage as a result of high stormwater flows.

Except for the serious flood damage and disruption that occurred in the S. 6th Street to S. 16th Street reach of the Kinnickinnic River, no serious flood problems were reported in the Kinnickinnic River watershed as a result of the April 1973 flood event. Significantly, the area along and near the River between S. 16th Street and S. 43rd Street, which had experienced serious flood damage and disruption during the major flood events of 1912, 1917, 1938, and 1960, did not exhibit any flood problems as the result of the April 1973 flood event, even though the flood flows generated by the earlier flood events were probably of the same order of magnitude as that of the April 1973 flood. As in the case of the September 1972 flood event, the absence of flood problems along the S. 16th Street to S. 43rd Street reach of the River in the April 1973 flood event probably reflects the effectiveness of the channel improvements made to the River in that reach between 1960 and 1965.

An August 1986 storm event centered in a one- to four-mile-wide band extending northwesterly from the City of Oak Creek through General Mitchell International Airport to the northern portion of the City of Wauwatosa near Lawrence J. Timmerman Airport resulted in a storm total rainfall of 6.84 inches in 24 hours, the single-day record at the General Mitchell International Airport recording station. The 24-hour rainfall recorded at the airport had about a 0.5 percent annual probability of occurrence. Widespread flooding occurred in the General Mitchell International Airport area and closed the airport (see Figure III-1). The overall flooding attendant to the storm event caused great damage, including severe damage along the reach of the Kinnickinnic River between S. 6th Street and S. 16th Street in the City of Milwaukee. However, the August 1986 rainfall event caused an area of inundation along this reach of the River that was substantially smaller than the area along the same reach that was inundated in the April 1973 flood event. The substantial differences in the areas of inundation may be attributed to the proper performance of significant channel improvements implemented between 1973 and 1986. A one-percent-annual-probability flood would have been contained within the limits of the improved channel. It is clear that the flood control improvements involved functioned as designed to significantly reduce flood damages in the August 1986 storm.

In the August 1986 flood event, significant flooding impacts also occurred along Wilson Park Creek, located in the Kinnickinnic River watershed. Severe basement flooding due to sewer backup was also experienced in numerous areas in the Kinnickinnic River watershed that are remote from streams.

Menomonee River Watershed

The April 1973 flood event, which illustrates the extreme sensitivity of rainfall-induced floods to antecedent moisture conditions in the Menomonee River watershed, was the most severe flood event recorded in the watershed up to that time in terms of damage and disruption. In that flood event, moderate rainfall volumes occurred over the entire watershed under very wet antecedent moisture conditions. Although the event caused flood problems throughout most of the urban area of the watershed, which at the time encompassed about 54 percent of the total area of the watershed, the damage and disruption arising from the event were most serious along Underwood Creek in the Village of Elm Grove and along the Menomonee River in the City of Wauwatosa. In addition, significant damage and disruption and/or significant overland flooding occurred in the Cities of Mequon and Wauwatosa and the Villages of Germantown and Menomonee Falls. However, the flood had little impact on the other riverine-area communities in the watershed, including the City of Milwaukee. The general absence of significant flood problems in these communities in the April 1973 flood event is primarily attributable to the presence of structural flood control works that protected riverine-area residential, commercial, and industrial development. Thus, largely as a result of channel modifications and sheet steel floodwalls completed by the City of Milwaukee Sewerage Commission and the Metropolitan Sewerage Commission between 1962 and 1968 along the 1.5-mile-reach of the Menomonee River from the Chicago, Milwaukee, St. Paul & Pacific Railroad yard in the Menomonee River industrial valley upstream to about N. 45th Street in the City of Milwaukee, the April 1973 flood there was confined to the channel area. Similarly, a sheet steel floodwall constructed along the Menomonee River by the Falk Corporation in 1962 prevented flooding at the company's location, even though the peak stage of the April 1973 flood was about two feet higher than that of the March-April 1960 flood, which caused the Falk Corporation to suffer extensive losses. It is important, however, to recognize that there were areas in the Menomonee River watershed that continued to experience localized stormwater problems.

In the August 1986 flood event, significant flooding impacts also occurred near the northwestern portion of the City of Milwaukee, including the area along the Menomonee River and Woods Creek adjacent to Milwaukee County Stadium. Severe basement flooding due to sewer backup was also experienced in numerous areas in the Menomonee River watershed that are remote from streams.

Milwaukee River Watershed

With regard to the Milwaukee River watershed, the studies performed in the preparation of the initial comprehensive plan for the watershed adopted by SEWRPC in 1972, as well as research performed under subsequent related planning efforts, indicated that up to, and including, 1971, five major flood events occurred within the watershed since its settlement by Europeans: one in March 1918, one in August 1924, one in March 1929, one in March 1959, and one in March-April 1960. Although no significant widespread damage occurred as a result of these flood events in areas then or now located within the City of Milwaukee, the historical experience with flooding in the portion of the Milwaukee River watershed located within the City includes flooding along the 3.1-mile-long reach of the River extending from the site of the North Avenue dam to the mouth of the River. The damages associated with such flooding have been relatively very minor in the reach involved, being limited to minor damage due to basement seepage in structures along the River and to the backup of sewers within the downtown area of the City. Some shallow inundation of low-lying street intersections located relatively close to the Milwaukee River reach involved has also occurred.

No historical flood damages are known to have occurred along the approximately three-mile-long reach of the Milwaukee River extending from the North Avenue dam to Estabrook Park. The riverbanks along this reach are generally high, and a considerable proportion of the stream bank area is devoted to park or other open space uses.

In the August 1924 flood event, portions of the 2.1-mile-long reach of the Milwaukee River extending from Estabrook Park to W. Silver Spring Drive experienced very high water levels, as evidenced by reported high water marks. The peak flood stage of the River at the W. Silver Spring Drive crossing of the River, located in the present-day City of Glendale, was about 11 feet above normal and only about 2.4 feet below the crown of the road over the bridge. Much of the potential damage in the reach involved was eliminated, however, by the implementation in 1937 of channel improvements between Lincoln Park and N. Port Washington Road. Basement flooding has also been experienced in the past along this reach of the River due to stormwater drainage problems not directly related to the flood stages of the Milwaukee River. Remedial measures were implemented by the City of Milwaukee to alleviate the surface drainage problems that caused this basement flooding.

Floods of moderate severity occurred on the Milwaukee River in 1959 and in 1960, with the 1959 flood having a 10-percent-annual-probability of occurrence and the 1960 flood being slightly larger. The major floods that occurred in 1918 and 1924 in the City of Milwaukee each had annual probabilities of occurrence of about 1.3 percent.
eFlooding, in various degrees, has long commonly occurred adjacent to Lincoln Creek, which is tributary to the
Flooding, in various degrees, has long commonly occurred adjacent to Lincoln Creek, which is tributary to the Milwaukee River and whose subwatershed is located largely within the City. Flooding along Lincoln Creek has increased proportionally to the conversion of land within its subwatershed from open, rural use to urban use. Subsequently, channel improvements and bridge replacements were implemented to accommodate the increased flows. During the period from 1960 through 1981, the four largest flood events of record along Lincoln Creek occurred in 1964, 1968, 1972, and 1973. The major consequences of these and other runoff events along Lincoln Creek have been flooding of roadways and underpasses, first-floor flooding of buildings, and basement flooding caused by sewer backup. Over the period from 1960 through 1975, more than 1,300 separate flooding and water-

related problems were reported to the City of Milwaukee by property owners in the Lincoln Creek area. The problems thus reported included first-floor inundation, yard flooding, and basement flooding, with the most common complaint being basement flooding. Studies and planning efforts completed subsequent to SEWRPC's preparation and adoption of its initial comprehensive plan for the Milwaukee River watershed, including a SEWRPC study undertaken to develop the detailed flood control plan for Lincoln Creek that was adopted by SEWRPC in 1983 as an amendment to the Milwaukee River watershed study, identified the Lincoln Creek subwatershed area in the City of Milwaukee as a specific problem area, with over 1,600 structures located within the flood hazard area.

In late 2001, MMSD completed a comprehensive flood control and stream rehabilitation project on Lincoln Creek which included bridge removals and conveyance modifications, in-line floodwater storage, floodplain lowering and widening, habitat enhancements, and two floodwater detention facilities. The detention facilities include the 26-acre Green Tree Detention Pond and the 11-acre Havenwoods wetland/detention facility which provide a total of 229 acre-feet of storage. The project spanned more than nine miles of stream channel and included bio-engineered stream restoration using native prairie and wetland plants. This project removed all 1,600 homes and businesses from the one-percent-annual-probability floodplain, and is reflected in the effective FEMA digital flood insurance rate map for Milwaukee County.

Oak Creek Watershed

Within the portion of the Oak Creek watershed that is located within the City of Milwaukee, historical flood damages have been limited to two areas: 1) one area along the North Branch of Oak Creek located east of S. 13th Street and north of W. College Avenue where two commercial buildings are currently located within the flood hazard area; and 2) an area in the southern portion of General Mitchell International Airport where four governmental structures are located in the flood hazard area of the Mitchell Field Drainage Ditch.

Root River Watershed

Neither any historical flood damages nor any current flood problem areas have been identified within the portions of the Root River watershed that are located within the City of Milwaukee.

Lake Michigan Direct Drainage Area

Flooding problems are reported to be relatively minimal in the portion of the Lake Michigan direct drainage area that is located within the City.

Description of Recent Flood Events

Since 1993, there have been 34 flood events reported by the NCDC affecting the City of Milwaukee and some of the watershed areas that lie partly within its boundaries, or an average of 1.4 flood events per year. Those flood events were reported to the NCDC to have caused damages totaling about $330 million in property damage. The most severe recent events occurred in 1997, 1998, 2000, 2004, 2008, 2009, and 2010. These flood events, which are significant with regard to the current flood mitigation planning effort for the City, include the following:

- The event of June 20-21, 1997, when a period of moderate rainfall followed by intense thunderstorms centered in northern Milwaukee County resulted in at least four inches of rain across the County, with much of the County receiving at least six inches of rain. More than nine inches of rain was recorded in the Village of Brown Deer. Severe localized damage occurred in Brown Deer, the City of West Allis, and the Lincoln Creek area of the City of Milwaukee. The reach of Lincoln Creek between N. 37th Street and N. 60th Street in the City experienced significant flooding and stormwater drainage problems during the flood event. Of the total of 1,510 flooding complaints received by the City in the one-week period following the flood event, about 980, or 65 percent, occurred with regard to the Lincoln Creek subwatershed. Severe, direct overland flooding also occurred in several other areas, including areas along the Menomonee River in the Cities of Milwaukee and Wauwatosa (Figure III-3). Sewer backup flooding was reported in the Kinnickinnic River watershed, but no damages resulting from overbank flooding along waterways in that watershed were reported. There were, however, numerous occurrences of stormwater drainage and sanitary sewer backup problems in communities located throughout the areas of heavy rainfall.

  Estimated flood damages during the June 1997 event were $117.7 million[15] in Milwaukee County. Assistance received by the City of Milwaukee through the FEMA and State Hazard Mitigation and Public Assistance programs administered by the Wisconsin Department of Military Affairs Division of Emergency Management associated with this event totaled about $1,122,000 under the FEMA Hazard Mitigation program and $1,412,000 under the FEMA Public Assistance program.

- The event of July 2, 1997, a "follow-up" storm to the June 20-21, 1997, storm event, involved as much as four inches of rain, but resulted in little additional property damage.

- The event of August 6, 1998, in which over six inches of rain fell in northwestern Milwaukee County and eastern Waukesha County, resulting in severe direct overland flooding for a second consecutive year along Lincoln Creek in the City of Milwaukee as well as along the Menomonee River in the City of Wauwatosa, Underwood Creek in the City of Brookfield and the Village of Elm Grove, and Southbranch Creek in the Village of Brown Deer. Significant property damage resulted from over-bank flooding along Lincoln Creek and the Menomonee River. As in the 1986 and 1997 major storm

[15]*Damages adjusted to 2016 dollars using the Consumer Price Index.*

events in the area, there were numerous occurrences of stormwater drainage and sanitary sewer backup problems in communities located throughout the areas of heavy rainfall.

Estimated flood damages during the August 1998 event were $14.4 million[16] in Milwaukee County. Assistance received by the City of Milwaukee through the FEMA and State Hazard Mitigation and Public Assistance programs associated with this event totaled about $227,000 under the FEMA Public Assistance program.

- The event of July 2, 2000, in which as much as 6.5 inches of rain fell on portions of eastern Waukesha and southern Milwaukee Counties, including 4.42 inches recorded at General Mitchell International Airport on the far south side of the City of Milwaukee. The storm associated with this event produced one tornado in southern Milwaukee County about three-fourths of a mile northwest of S. 27th Street and W. Ryan Road in the City of Franklin. The tornado moved east/northeast through the City of Oak Creek and into neighboring Racine County. In addition to damage from the tornado, significant damages due to flooding also occurred. The most severe flooding occurred in the communities south of Milwaukee, including the Cities of Franklin and Oak Creek and the Villages of Greendale and Hales Corners. In the City of Milwaukee, reported damages occurred mainly in the Kinnickinnic River and Oak Creek watersheds, with damages mostly limited to basement flooding due to either sewer backup or inoperable sump pumps caused by power outages.

  Estimated flood damages during the July 2000 event were $8.9 million[17] in Milwaukee County.

- The storms that occurred in the Region in May of 2004 occurred over relatively long periods of time and the probability of occurrence of the rainfalls at a given location generally decreased as storm duration increased. In the City of Milwaukee, widespread flood damage was not reported. The most severe five- and 10-day rainfalls in the City occurred at the City of Milwaukee gauge in the Menomonee River watershed at 8800 W. Lisbon Avenue where the annual probability of occurrence for both storm durations was estimated at 10 to 20 percent. The annual probabilities of the 15- and 20-day rainfalls at that location were in the range from 4 to 10 percent and the 25-day rainfall probability was about 2 percent. Despite the occurrence of relatively rare long-term rainfalls at the W. Lisbon Avenue gauge, the recorded peak flow on the Menomonee River at N. 70th Street in the City of Wauwatosa had a probability of only 20 to 50 percent. That flood probability is in line with the estimated five-day rainfall probability over the entire Menomonee River watershed where rainfall

[16]Ibid.

[17]Ibid.

amounts were generally less at locations other than the W. Lisbon Avenue gauge. Elsewhere, recorded peak flood flows on streams in the City of Milwaukee had annual probabilities of occurrence ranging from greater than 50 percent on the Kinnickinnic River at S. 11th Street to 10 to 20 percent on the Milwaukee River.

- The June 2008 rainfall events broke three records for Milwaukee. The 7.18 inch, 48-hour rainfall occurring on June 7 and 8 was the largest 48-hour total ever recorded and the monthly total rain of 12.27 inches set a new Milwaukee record for both June and for monthly maximum rainfall.

Many areas in the City of Milwaukee experienced stormwater drainage flash flooding as a result of the June 7th rain, including vehicles stalling and floating at intersections and in some parking lots and 28 manhole covers/sewer grates being blown off from the water pressure. Just west of downtown Milwaukee, water up to two feet deep was reported in some intersections (N. 51st Street and W. Good Hope Road, Layton Avenue, S. Howell Avenue near Edgerton Avenue and to the south, W. Fond du Lac Avenue and W. Locust Street, S. 27th Street and W. Morgan Avenue), causing damage to buildings and abandonment of cars. A section of IH 894 had to be closed for a time near S. 27th Street due to the presence of water over the freeway and ramps. General Mitchell International Airport closed at 8:00 p.m. on June 7th due to major flooding. Also, a state of emergency was declared in Milwaukee County. On June 8th more rain exacerbated flooding, with the Kilbourn Tunnel being closed due to flash flooding. Approximately 1,000 homes in the City of Milwaukee reported water in their basements and several neighborhoods reported downed trees. Two privately owned buildings on the near south side collapsed due to the weight of rain on their roofs. Flooding along the Kinnickinnic River for this event is shown in Figure III-4.

MMSD reported a 686 million gallon (MG) separate sewer overflow from June 7-9, 2008. MMSD also reported a combined sewer overflow June 7-15, 2008 of 2.9 billion gallons (BG), which was the largest combined sewer overflow since the deep tunnel opened in 1994.

In the first half of June all the rivers in the City of Milwaukee reached flood stage, with the Milwaukee gage at the Milwaukee River cresting at 7.34 feet on June 14, 2008 which is the second highest stage recorded since 1914.

On June 14th, disaster aid from FEMA was authorized under a major disaster declaration issued for the state by President Bush. Federal funding of $6 million was made available to affected individuals in 30 counties in Wisconsin including Milwaukee. Damage totals for Milwaukee County were estimated at $43 million, with $32 million for residences and $6 million to private businesses. It was estimated that 19,000 homes in Milwaukee County were damaged, with approximately 40 percent due to sump pump failures. Governor Doyle announced in September 2009 that the State still needed

$1.22 billion to cover flood damage for housing, businesses, and infrastructure to the 30 declared counties. As of June 2009, the State had received about $124 million from the US Department of Housing and Urban Development.

- The June 18-19, 2009 event was a series of thunderstorms that dropped 6.02 inches of rain on the downtown Milwaukee area and 4.15 inches at the General Mitchell International Airport (GMIA). These thunderstorms dropped very heavy rain over a relatively short period of time (as much as two inches per hour), resulting in stormwater drainage flash flooding and basement backups, and even some river flooding in the Milwaukee metropolitan area. Sewage and stormwater seeped into a storage room in the Milwaukee County medical examiner's office at N. 9th Street and W. Highland Avenue, some flash flooding and flood damage occurred at the service level of Miller Park, two feet of standing/flowing water was reported at IH 894 near GMIA, there was an estimated one foot of water over the curb at IH 894 at S. 27th Street, several cars stalled in high water near S. 6th Street and W. Canal Street, and both directions of the 3200 block of W. Capitol Drive were closed due to high water and abandoned cars. The City of Milwaukee Environmental Engineering Section reported 658 calls for basement backups, 172 calls for surface ponding, and seven sanitary sewer overflows for the June 19, 2009 event.

- The 2010 flood event in Milwaukee included two events, one event on July 14 and 15 and a more severe event on July 22. The July 14-15 event dropped more than five inches of rain in parts of the City in less than six hours, causing stormwater street flooding at 157 locations, basement backups, and sewer overflows. The City of Milwaukee received 42 reports of manhole covers being blown off. Standing water was reported at N. 35th Street and W. Capitol Drive, N. 60th Street and W. Mill Road, and W. Juneau Avenue and N. Martin Luther King Drive. Approximately 1,200 basement backup complaints were called in to the City of Milwaukee Department of Public Works (DPW). MMSD reported a 2.75 MG separate sewer overflow and a 521 MG combined sewer overflow for the July 14-15 event.

  General Mitchell International Airport reported a rainfall total of 5.61 inches for July 22nd, which is the second highest one day rain for Milwaukee for the period of record behind only the 1986 rain event of 6.81 inches. Rainfall at the MMSD rain gage at 3600 W. Fond du Lac Avenue totaled 7.52 inches for the day. Rain gages on the City of Milwaukee north side measured rainfall amounts of more than 3.7 inches in one hour, which is less frequent than the one-percent-annual-probability (100-year recurrence interval) event. For the month through July 22nd, Milwaukee received 9.49 inches of rain, nearly three times the normal amount.

The July 22 event caused stormwater drainage street and freeway ponding, basement backups, and closure of GMIA due to surface ponding. One person was injured when their vehicle was swallowed in a large sinkhole at Oakland and North Avenues (Figure III-5), and one death was reported for the driver of a car that went into Lincoln Creek. Over 6,000 homes in the City reported water filled basements. IH 43 was shut down between Atkinson Avenue and Mequon Road in Ozaukee County and USH 45 was shut down at W. Hampton Avenue. Fond du Lac Avenue was flooded from W. North Avenue to N. 107th Street, and the ramps at IH 43 and Capitol Drive were closed. Water pressure blew off manhole covers throughout Milwaukee, with one at N. 68th Street seen blowing five feet out of the manhole. Streets surrounding the Bradley Center and the US Cellular Arena were under nearly a foot of water. Rushing water moved along both sides of Downer Avenue south of E. Edgewood Avenue at the University of Wisconsin-Milwaukee campus. Water rose quickly on Downer Avenue to cover hubcaps, then license plates of parked vehicles. Localized flooding caused at least five basements to collapse in the 5000 block of N. 19th Place, adjacent to Lincoln Creek. Two homes in the 1900 block of W. Eggert Place, also adjacent to Lincoln Creek, were demolished due to destroyed foundations. Examples of damages to building foundations are shown in Figure III-6. MMSD estimated a total sewer overflow of 2.1 billion gallons (1.985 billion gallons combined sewer overflow, 171 million gallons separate sewer overflow).

For the July 2010 events the preliminary private damage estimate for the City of Milwaukee was $6.9 million[18] (5,496 residential and business properties affected, 17 with major damage and three destroyed). This estimate did not include property owned by the City and public costs. Nineteen Milwaukee homes became uninhabitable due to flood damage after inspection. Damage estimates included approximately $29.8 million in the private sector and $11.3 million in the public sector for Milwaukee County. Riverside University High School at 1615 E. Locust Street received nearly six feet of water in its lower level, causing more than $5.1 million in damage. Forty-two Milwaukee Public School properties sustained flood damage totaling $7.2 million. The Milwaukee Department of Public Works crews picked up more than 1,300 tons of flood debris. President Obama declared a Federal disaster for Milwaukee County on August 11, 2010, with $45.8 million approved for Individual Assistance to Milwaukee and Grant Counties on 31,600 total applications.

Vulnerability and Community Impacts Assessment

The floodplain areas, as well as the subwatershed boundaries, within the City of Milwaukee are shown on Map II-4 in Chapter II of this report. These areas are generally located along the major stream system throughout the

[18] *This estimate and subsequent damage estimates in the description of the July 2010 flood are given in 2016 dollars.*

City. The floodplains have been delineated for a total of about 61 miles of stream within the City. Most of the floodplain areas for which detailed studies are available have been mapped on large-scale topographic mapping prepared at a scale of one inch equals 100 feet with a contour interval of two feet. Flood flows and stages are currently readily available for about 58 miles of the total stream reaches involved, while the floodplain for about three miles of stream is delineated by approximate methods under the Federal Flood Insurance Study for the City. Under the Milwaukee County Automated Mapping and Land Information Program and its successor Milwaukee County Land Information Council, updated digital large-scale topographic maps for the entire City have been prepared, and Light Detection and Ranging (LiDAR) data were collected in 2010, enabling development of one-foot interval elevation contours for the entire County.

Kinnickinnic River Watershed

As of 2016, a total of 688 structures were identified as being located within the one-percent-annual-probability floodplain in the Kinnickinnic River watershed (Table III-9). These structures were identified using floodplain delineations completed as part of a floodplain delineation project undertaken by SEWRPC for the Milwaukee County Automated Mapping and Land Information System (MCAMLIS) Steering Committee that was completed in 2016 and by MMSD through the Kinnickinnic River watershed flood management plan, completed in 2017.[19] Table III-9 shows the distribution of these structures among subwatersheds of the watershed. Most of the structures identified as being located within the one-percent-annual probability floodplain in this watershed are located along either the mainstem of the Kinnickinnic River, Wilson Park Creek, or Lyons Park Creek. Smaller numbers of these structures are located along either the 43rd Street Ditch and Villa Mann Creek. Table III-9 also shows that average annual flood damages in the Kinnickinnic River watershed are estimated to be slightly less than $2.2 million per year (2016 dollars).

Menomonee River Watershed

As of 2016, one structure was identified as being in the floodplain along the Little Menomonee River in the City. This is a residential structure along N. Granville Road north of W. Good Hope Road. The assessed value of this property was $166,400.

Milwaukee River Watershed

Table III-10 shows that a total of three structures were identified as being located within the one-percent-annual-probability floodplain in the Milwaukee River watershed within the City of Milwaukee. These structures were identified as part of updated mapping of the floodplains along a 13.2-mile section of the mainstem of the Milwaukee River between the Milwaukee-Ozaukee County line and the upstream limit of the Milwaukee Harbor

[19]*Milwaukee Metropolitan Sewerage District,* Kinnickinnic River Watershed Flood Management Plan: Final Report, *May 4, 2017.*

estuary at the site of the former North Avenue Dam under existing channel conditions and planned 2020 land use.[20] These map updates were incorporated into the September 26, 2008 Flood Insurance Study. Table III-10 also presents flood damage estimates for these structures. It is estimated that a one-percent-annual-probability flood would result in $64,100 (2016 dollars) in damages. Average annual flood damages in the portion of the Milwaukee River watershed in the City are estimated to be $14,100 (2016 dollars).

Oak Creek Watershed

Currently, six structures are located within the flood hazard area in the portion of the City of Milwaukee that is located in the Oak Creek watershed. Two commercial buildings are located within the flood hazard area associated with the North Branch of Oak Creek in an area east of S. 13th Street and north of W. College Avenue. Four governmental structures are located in the flood hazard area associated with the Mitchell Field Drainage Ditch in the southern portion of General Mitchell International Airport.

Repetitive Loss Properties

FEMA and the NFIP define repetitive loss properties as those properties that have made two or more flood insurance claims of at least $1,000 each. FEMA has also defined a subset of those properties as severe repetitive loss properties. These are defined as NFIP-insured properties that have either: 1) experienced four or more claims over $5,000, including buildings and contents, each, or 2) experienced at least two claims with a cumulative amount exceeding the value of the building. For both of these criteria for severe repetitive loss properties, at least two of the claims must have occurred within any rolling 10-year period since 1978 and must be greater than 10 days apart. As of December 31, 2015, there were 230 repetitive loss properties located within the City of Milwaukee. These included 183 single family residences, 40 two to four family residences, three multifamily housing units, and four other nonresidential structures. None of these properties were severe repetitive loss properties.

Critical Facilities

Map III-1 shows the location of selected types of critical community facilities, including fire and police stations, hospitals, and community administration facilities within the City. None of these facilities are located within the flood hazard areas. However, because of the need for access to and from these facilities, the flood mitigation plan includes their location and shows the relationship to the flood hazard areas.

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[20] *SEWPRC Memorandum Report No. 172,* A Watercourse System Plan for the Milwaukee River in Milwaukee County upstream of the Milwaukee Harbor Estuary, *December 2010.*

Flooding of Roadways

The Milwaukee River watercourse system plan identified potential street flooding locations and estimated maximum flooding depths during a one-percent-annual-probability flood in its study area.[21] Two of the areas identified are located in the City of Milwaukee. The first is a 2,000-foot section of N. Milwaukee River Parkway that is located west of the Milwaukee River and south of W. Silver Spring Drive that could be flooded to a maximum depth of about 4.4 feet during a one-percent-annual-probability flood. This area includes a short portion of W. Lawn Avenue. The second is a section of N. Milwaukee River Parkway that is located in Lincoln Park west of the Milwaukee River and north of W. Hampton Avenue that could be flooded to a maximum depth of about 0.1 foot during a one-percent-annual-probability flood.

Basement Backwater Problems

A review of the extent and severity of flooding conditions within the City of Milwaukee indicates that there is a significant community impact primarily as a result of the damages caused by flooding of buildings, primarily basements, and disruption of the transportation system during extreme flooding events. In addition, sanitary sewer backup into basements is another important consideration. Flooding of streets and buildings, primarily basements, has been reported in the City as a result of storm events since June 20-21 and July 2, 1997.[22] From 1999 to 2010, there were a total of 14,622 reported basement backwater problems within the City of Milwaukee ranging up to 12,203 in one year as shown in Table III-11. The greatest number of reported backwater problems occurred in 2010, with all of the incidents being reported during the month of July. Although total annual precipitation during 2010 was only 1.17 inches above average annual precipitation, precipitation for July 2010 was 7.35 inches greater than average July precipitation. In addition, precipitation for the month of June 2010 was 3.37 inches greater than average June precipitation. The second greatest number of reported backwater problems occurred in 2008, when total annual precipitation was about nine inches above normal and precipitation for the month of June was 8.71 inches greater than average June precipitation. Many of these backups were associated with storms that occurred on June 7 and 8, which deposited about 7.18 inches of rainfall at General Mitchell International Airport. Since 2010, only a few backwater problems have been reported.

Several types of structure flooding have been reported from 1997 to present. One major source of basement flooding problems has been surcharging of sanitary sewers and resultant backups into basements. Another source of basement flooding was sump pump failure and clear water overflow due to electrical power outages. Clearwater overflow into the sanitary sewer basement floor drain can quickly exceed the capacity of those relatively small-diameter sewers, leading to surcharging and backup of a combination of sanitary sewage and

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[21]Ibid.

[22]Ibid.

clear water into basements. Additional sources of clear water inflow to sanitary sewers were through: 1) flooding of basements due to surface runoff, 2) excessive amounts of water collecting in streets or roadside swales and entering sanitary sewer manholes through unsealed lids and frames, and 3) sanitary sewer manhole lids which were disturbed.

In 2010, the MMSD began development of a Private Property Infiltration and Inflow (I/I) Reduction Program with input from all communities in their service area, including the City of Milwaukee. The purpose of this program was to provide a funding mechanism for local communities to reduce private property I/I to the sanitary sewer system, through investigation, design, and construction of mitigation measures. The communities prioritize their basement backup areas of concern, and then develop solutions to eliminate infiltration and inflow of clear water to their local sanitary sewer system. MMSD has a budget of $62 million for 2011-2020 for the Private Property Infiltration and Inflow Reduction Program for all 28 member communities. The City of Milwaukee has to date completed $13.6 million of work on 1,260 properties.

Given the current flood control projects that have been carried out during the past 15 years under the MMSD watercourse management program, the flooding impacts on the City's infrastructure and the need to prepare for major evacuations and other emergency actions are not considered to be a major concern given the nature and the severity of the overland flooding problems. However, the Milwaukee County emergency operations planning program does have provisions for carrying out the latter if it would be needed. Furthermore, significant flood-related impacts on the community economy and businesses are of an infrequent and short-term nature. The major impact on City operations, which are relatively frequent, involve posting and closure of selected roadway locations where floodwaters frequently overtop bridges and culverts and cause short-term roadway flooding.

Stormwater Drainage Problems

Because of the interrelationship between stormwater management and floodplain management, stormwater management actions are an important consideration of the flood vulnerability assessment. Stormwater drainage problems are known to exist throughout the urbanized portions of the City. The City has undertaken stormwater management planning programs or initial stormwater management system inventories as the first step in developing comprehensive stormwater management plans. The current status of stormwater management planning in the City of Milwaukee is described further in Chapters II and V. The intense storm events of 2008 through 2010 caused significant surface flooding problems as the local storm drainage facilities were overwhelmed. The City of Milwaukee should identify specific locations where the major stormwater management system is inadequate to handle the runoff from storms with annual probabilities of occurrence of 1 percent or greater and prepare stormwater management plans to address those deficiencies.

Potential Future Changes in Floodplain Boundaries and Problems

As described in Chapter II of this report, the City of Milwaukee and communities in the tributary areas currently have in place land use controls and planning programs to preserve nearly all of the remaining environmentally sensitive areas, including wetlands and floodplains. Furthermore, development within the City itself is approaching "buildout" conditions with new development expected to be largely limited to infilling and isolated open space parcels outside of the environmentally sensitive areas. The City has an adopted stormwater management ordinance which requires sound stormwater management practices for new development and redevelopment sites which will limit any increases in future stormwater runoff peak rates of flow. Accordingly, there is not expected to be any significant changes in the flood flows and hydrologic characteristics of the stream system resulting from future land use changes in the City. Detailed analyses conducted under the MMSD watercourse system planning program, the Southeastern Wisconsin Regional Planning Commission comprehensive watershed plans for the watersheds tributary to the City of Milwaukee, and an ongoing floodplain mapping program being conducted by SEWRPC for the MCAMLIS Steering Committee and its successor Milwaukee County Land Information Council, and MMSD have documented the potential extent of increases in future flood flows within the City of Milwaukee. As part of this floodplain mapping effort, flood flows are also being updated to reflect physical changes in the watersheds such as more current land use, more extensive stream gage information, and in some cases to reflect more recent rainfall events. For some of the City streams the change in flood flows is minimal, while in others it is more significant. The increased flood flows and updated topography used for the MCAMLIS effort had the greatest impact on the numbers of flooded structures for the Kinnickinnic River, Wilson Park Creek, and Lyons Park Creek.

The MMSD has also developed the Chapter 13 Rule, which applies to all member and contract municipalities, including the City of Milwaukee. Chapter 13 requires all new development or redevelopment beyond certain imperviousness or land disturbance thresholds to control peak rates of stormwater runoff. The Chapter 13 requirements were developed to maintain the effectiveness of MMSD flood mitigation projects in reducing flooding within the MMSD service area.

With regard to the impact of development beyond the City of Milwaukee limits, however, nearly all of the developing communities lying upstream of the City, have recently prepared, or have under preparation, detailed stormwater management plans and/or stormwater-related ordinances designed to minimize any negative downstream impacts on flood flows and stages. In addition, most of the developed and developing communities in the tributary subwatersheds are currently involved in the Wisconsin Department of Natural Resources (WDNR) stormwater permitting program as set forth under Chapter NR 216 of the *Wisconsin Administrative Code*. This program will eventually lead to the development of additional stormwater management practices.

In addition to the above and as described in Chapter II of this report, the City of Milwaukee's current floodplain zoning regulations are designed to prevent any new floodprone development, as well as to prevent any floodplain encroachment that would cause changes in the existing flood flows or stages.

If current floodplain and related land use regulations and existing and ongoing stormwater management plans and regulations are carried out and/or implemented in the future, the extent and severity of flooding problems within the City resulting from the overflow of streams would not be expected to become significantly more severe in the near term. However, given recent evidence that changes in climate may be increasing the frequency of intense rain storms, it is important that stormwater and floodplain management planning begin to consider such impacts. Discharge records at streamflow gauges show evidence that the frequency of large floods is increasing. For example, over the 36-year record for the USGS gauge along the Kinnickinnic River, six of the 10 largest flows occurred since 2000 and nine of the largest flows occurred since 1997. Similarly, over the 58-year record for the USGS gauge along the Menomonee River, six of the 10 largest flows occurred since 2000 and seven of the largest flows occurred since 1997. Future planning should utilize more reliable estimates of the magnitude of the effects of climate change on precipitation as they become available.

Changes in climate are likely to affect the potential for flooding in the City of Milwaukee during the 21st century. As previously described, model projections show Wisconsin receiving more precipitation and more frequent intense precipitation events. By the mid-21st century, the City may receive 2.5 more precipitation events of two or more inches in 24 hours per decade, roughly a 21 percent increase in the frequency of heavy precipitation events. At General Mitchell International Airport, there is currently a 99 percent probability that a 24-hour rainfall equaling or exceeding 2.35 inches will occur in a year.

This increase in the frequency of heavy rainfall events is likely to increase the frequency of high flows and high water levels and potentially increase the frequency and severity of flooding. In particular, the expected increases in the magnitude and frequency of large rainfall events will likely increase flood magnitudes in streams and rivers in Wisconsin, although the amount of increase will vary from place to place. The amount of precipitation that falls as rain during winter and early spring months is expected to significantly increase. Winter rain can create stormwater management problems as well due to icing and runoff over frozen ground which may also lead to increased risk of flooding events.

These potential climate changes may lead to several flood- and stormwater-related impacts. Increased rainfall and shifting precipitation patterns that favor more rain during winter and early spring periods of low infiltration and evapotranspiration may lead to more frequent and severe stream and river flooding. Increased precipitation during winter and spring may result in increased occurrence of inland lake flooding. Increased cold-weather precipitation and increased variability in frost conditions may cause a rise in water tables in some areas, leading to an increase in groundwater-related flooding.

The projected increase in the magnitude and frequency of heavy storms could also affect the performance of existing and planned stormwater management and flood mitigation systems. This increase could also expand flood hazard areas, such as the one-percent-annual-probability flood hazard area, beyond their existing boundaries, potentially encompassing existing development. This could lead to an increase in the risk of flood damages and a need for larger stormwater management facilities and programs. The magnitudes of potential increases in flooding are unknown, and there is a complex interrelationship between the climatological factors that will be affected by climate change and the features of watersheds that produce runoff. In some cases, climate change-induced changes in certain climatological factors may offset the changes in other factors relative to their effects on flood flows. In other cases, the effects will reinforce one another. Thus, it is very important to continue to improve methods for downscaling climatological data, to expand the climatological parameters for which downscaled data can be developed, and to apply hydrologic and hydraulic simulation models to quantify the potential effects on flooding resulting from climate change.

Multi-Jurisdictional Flooding and Stormwater Management Risk Assessment

Flooding and associated stormwater drainage problems have been identified as a significant risk in the City of Milwaukee and adjacent communities. In addition, the Milwaukee County Pre-Disaster Mitigation Plan assesses flooding as posing the greatest risk to both the population and to buildings and structures within Milwaukee County.[23] As noted earlier and summarized in the City of Milwaukee Flood Hazard Mitigation Plan, flood hazard areas have been identified throughout the City and adjacent communities. However, as noted above, nearly all of the developing communities lying upstream of the City, have recently prepared, or have under preparation, detailed stormwater management plans and/or stormwater-related ordinances designed to minimize any negative downstream impacts on flood flows and stages. In addition, most of the developed and developing communities in the tributary subwatersheds are currently involved in the Wisconsin Department of Natural Resources stormwater permitting program as set forth under Chapter NR 216 of the *Wisconsin Administrative Code*. In addition, all of the communities served by the MMSD are subject to the MMSD Chapter 13 rule, which requires that communities mitigate potential increases in peak rates of runoff from new development and re-development in a manner designated to limit increases in downstream flood flows and stages. These programs will eventually lead to the development of additional stormwater management practices.

[23] *Milwaukee County Office of Emergency Management,* op. cit.

As previously mentioned, improvements are being made as part of the MMSD's work and these efforts are reducing the overall flooding problems facing both the City and environs throughout Milwaukee County and beyond. In addition, the MMSD is currently conducting its fourth-generation wastewater facilities planning effort. This effort includes further development of its watercourse plans.

VULNERABILITY ASSESSMENT FOR THUNDERSTORMS, HIGH WINDS, HAIL, AND LIGHTNING

Thunderstorms

Compared to other natural hazards within the State of Wisconsin, thunderstorms are the most common type of severe weather event. A thunderstorm is defined as a severe and violent form of convection produced when warm, moist air is overrun by dry, cool air and as the warm air rises, thunderheads (cumulonimbus clouds) form. These thunderheads produce the strong winds, lightning, thunder, hail, and heavy rain that are associated with these storm events. The thunderheads formed may be a towering mass averaging 15 miles in diameter and reach up to 40,000 to 50,000 feet in height. These storm systems may contain as much as 1.5 million tons of water and enormous amounts of energy that often are released in one of several destructive forms, such as high winds, lightning, hail, excessive rains, and tornadoes. Thunderstorms and their related high winds, lightning, and hail hazards are covered within this section. However, excessive rains that cause flash flooding, such as occurred in the summer storm events in 1998 and 2000 when the request for Presidential disaster declaration was approved (see Vulnerability Assessment for Flooding and Associated Stormwater Drainage Problems) and tornadoes are covered separately from this hazard analysis (see Vulnerability Assessment for Tornadoes).

A thunderstorm often lasts approximately 30 minutes in a given location, because an individual thunderstorm cell frequently moves at an average velocity that ranges between 30 to 50 miles per hour (mph). However, strong frontal systems may produce more than one squall line composed of many individual thunderstorm cells. In Wisconsin, these fronts can often be tracked across the entire State from west to east.[24] Thunderstorms may occur individually, form clusters, or occur as a portion of a large line of storms. Therefore, it is possible that several thunderstorms may affect one particular area in the course of a few hours, as well as larger areas of the State or County, within a relatively short period of time.

All thunderstorms are potentially dangerous. However, only about 10 percent of all thunderstorms that occur each year nationwide are classified as severe. According to the National Weather Service, a thunderstorm is considered severe if it produces hail sizes at least one inch in diameter, generates wind speeds equal to or greater than 58

[24]*National Weather Service Forecast Office.*

miles per hour (measured or implied by tree and/or structural damage), or produces a tornado.[25] A thunderstorm with wind speeds equal to or greater than 40 miles per hour or hail at least 0.5 inch in diameter is defined as approaching severe. Severe weather event statistics in the State of Wisconsin for the period 1982-2008 indicate that about 56 percent of these severe storm events are characterized by damaging straight-line winds, 38 percent are hail events, and the remaining 6 percent are made up of tornadoes. Severe thunderstorms can cause injury or death and can also result in substantial property damage. They may cause power outages, disrupt telephone service, and severely affect radio communications, as well as impact surface and air transportation, which may seriously impair the emergency management capabilities of the impacted areas.

The National Weather Service monitors severe weather for 20 southern Wisconsin counties, including the City of Milwaukee, from its Milwaukee/Sullivan office.[26] A severe thunderstorm watch indicates that conditions are favorable for severe weather and that persons within the area for which the watches are issued should remain alert for approaching storms. A severe thunderstorm warning indicates that severe weather has been sighted in an area or indicated by weather radar and persons should seek shelter immediately. These severe thunderstorm watch and warning bulletins and advisories are disseminated over a number of telecommunication channels, including the NOAA Weather Radio, the NOAA Weather Wire and the State Law Enforcement TIME System. NOAA Weather Radio is available to any individual with a weather alert radio. This system and the other sources are routinely monitored by local media which rebroadcast the weather bulletins over public and private television and radio stations. In addition, the National Weather Service operates a 24-hour weather radio transmitter serving Milwaukee and Waukesha Counties, operating at a frequency of 162.400 megahertz (MHz), from a location in the Town of Delafield, Waukesha County. Southern portions of the Milwaukee County area, including portions of the City, are also served by a transmitter operating at a frequency of 162.450 MHz from a location at CTH KR and Wood Road in Racine County.

High Winds

High-velocity, straight-line winds that are produced by thunderstorms and widespread nonthunderstorm high winds are a destructive natural hazard in Wisconsin and are responsible for most thunderstorm wind-related damages to property. Thunderstorm winds can also be fatal. During the period from 1982 to 2016 in the State of Wisconsin, 30 fatalities and 211 injuries were attributed to wind from severe thunderstorms and non-thunderstorm high winds.[27] Although distinctly different from tornadoes, straight-line winds produced by thunderstorms can be

[25]*Prior to 2010, the National Weather Service criteria for severe thunderstorms were production of hail at least 0.75 inch in diameter, wind speeds equal to or greater than 58 miles per hour, or a tornado.*

[26]*National Weather Service, Milwaukee/Sullivan Weather Forecast Office.*

[27]*National Climatic Data Center Database.*

very powerful, are fairly common, and can cause damages similar to that of a tornado event. Depending upon their intensity, high winds can uproot trees, down power lines, and damage or destroy buildings and infrastructure (Figure III-7). Flying debris can cause serious injury and death to humans, livestock, and wildlife in their path. Boats and airplanes are also extremely vulnerable to damage from high winds.

Hail

Hailstorms are also associated with thunderstorms and are a destructive type of weather hazard. A hailstorm is a product of strong thunderstorms and unique weather conditions where atmospheric water particles form into rounded or irregular masses of ice that fall to earth. Hail normally falls near the center of the moving storm along with the heaviest rain. However, strong winds at high altitudes can blow the hailstones away from the storm center, causing unexpected hazards at places that otherwise might not appear threatened. Hailstones normally range from the size of a pea to that of a golf ball. Hailstones 1.5 inches or larger in diameter are not common in the State of Wisconsin. Hailstones form when subfreezing temperatures cause water in thunderstorm clouds to accumulate in layers around an icy core. When strong underlying updraft winds no longer can support their weight, the hailstones fall earthward. Hail tends to fall in swaths that may be 20 to 115 miles long and five to 30 miles wide and can fall continuously or sporadically in a series of hail strikes. Hail strikes are typically one-half mile wide and five miles long. They may partially overlap, but often leave completely undamaged gaps between them.

Hailstorms are considered formidable among the weather and climatic hazards to property, because they can dent vehicles and structures, break windows, and damage roofs to the point that significant losses result. Falling hailstones can also cause serious injury and loss of human life. These occurrences, however, are rarely associated with hailstorms. In addition to impact damage, thick hail combined with heavy rain can clog storm sewers and contribute to stormwater flooding. Hail sufficiently thick to cover a road will pose a traffic hazard. The peak season for hailstorms is April through August, although hail has been reported with thunderstorms in every month of the year.

Lightning

Every thunderstorm produces lightning, and lightning has been shown to kill more people within the United States each year than tornadoes.[28] Lightning is defined as a sudden and violent discharge of electricity from within a thunderstorm due to a difference in electrical charges, and represents a flow of electrical current from cloud to cloud or cloud to ground. Water and ice particles also affect the distribution of electrical charge. Lightning bolts can travel 20 miles before striking the ground. The air near a lightning bolt can be heated to 50,000 degrees

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[28]*National Oceanic and Atmospheric Administration.*

Fahrenheit (ºF), which is hotter than the surface of the sun. The rapid heating and cooling of the air near the lightning channel causes a shock wave that results in thunder.

Lightning is a significant hazard associated with any thunderstorm and can cause extensive damage to buildings, structures, electrical and electronic equipment, kill or injure people and livestock, and start forest fires and wildfires. Lightning is a major cause of damage to farm buildings and equipment, is responsible for more than 80 percent of all livestock losses, and is the number one cause of farm fires. Counties in southern Wisconsin report a higher number of lightning events compared to other parts of the State due to higher thunderstorm frequency and more thorough documentation by the local media. Statistics have also shown that 92 percent of lightning-related fatalities occur from May to September, and 73 percent of these events occur during the afternoon and early evening. National statistics indicate that approximately 30 percent of persons struck by lightning die and 74 percent of lightning strike survivors have permanent disabilities. In addition, 63 percent of lightning-associated deaths occur within one hour of injury and persons with cranial burns or leg burns from lightning are at higher risk for death than others struck by lightning.

Historical Thunderstorm, High-Wind, Hail, and Lightning Problems

Historically, the State of Wisconsin averages over 30 days each year with thunderstorms across the northern region to about 40 days per year across the southern region. However, the City of Milwaukee averages only about six days per year in which thunderstorms generate winds over 50 knots, and averages only three days per year in which damaging hail (over three-fourths of an inch in diameter) is generated.[29] These thunderstorms and related high winds, hail, and lightning hazards can occur throughout the City during any month of the year, with little or no notice. However, the highest frequency has been shown to occur during the period of May through September, and between the hours of noon and 10:00 p.m. The City of Milwaukee is subject to damage caused by thunderstorms and related hazards, which can be severe and affect large portions of the City, as well as potentially cause substantial loss of life and damage to property.

Description of Recent Thunderstorm, High-Wind, Hail, and Lightning Events

The gravity of any particular thunderstorm and related wind, hail, and lightning hazard events is measured in terms of resulting deaths, injuries, and economic losses. Despite their relatively small size when compared with winter storms, thunderstorms and their related hazard events occur frequently and are dangerous. Thunderstorms and related hazard events are fourth only to temperature extremes, tornadoes, and winter storms in regards to both total number of deaths and injuries, compared to other natural hazards that impact southeastern Wisconsin, as shown in Table III-5. In addition, thunderstorms and related hazard events are second only to damage associated with floods and stormwater as the most costly natural hazards to impact the City of Milwaukee.

[29] *National Oceanic and Atmospheric Administration,* http://www.nssl.noaa.gov/hazard/totalthreat.html.

A total of 216 thunderstorm and 239 high-wind events, have been recorded in the Milwaukee County during the 60-year period between July 1956 and December 2016. These events are documented in terms of their magnitude and impact in Table III-12 based upon data published by the NCDC. As shown in Table III-12, these storms can range from one or two events per year, up to 16 events per year, which demonstrates the high unpredictability of these events. Since 1993, in total, these thunderstorm and high-wind events have resulted in three deaths, 11 injuries, and over $52 million in property damages within Milwaukee County. Most of these damages occurred as a result of two storm events in 1998. The first was a thunderstorm and high-wind event that occurred on May 31, 1998, that resulted in over $25 million in property damage. The second event was a widespread, nonthunderstorm, high-wind event on November 10, 1998, which struck south-central and southeastern Wisconsin and caused four deaths, 14 injuries, and almost $15 million in damages to property. This storm caused nearly $700,000 in damages in the City of Milwaukee. Most recently, a severe thunderstorm impacted the City of Milwaukee on August 21, 2002, resulting in over $6.2 million in property damage.

Severe weather and flooding affected much of south-central and southeast Wisconsin on August 21, 2002, into the pre-dawn hours of August 22nd. This event was probably the most widespread and significant outbreak for the 2002 warm-season. Just about every type of weather phenomena was observed: a tornado; a funnel cloud; powerful, hurricane-force, downburst winds that uprooted trees and damaged buildings; torrential rains reducing visibilities to 100 feet; urban and small stream flooding; numerous lightning strikes—some that resulted in fire damage; and the early stages of a ground-based vortex that never made it to tornado status. Clusters and short lines of thunderstorms ahead of a cold front eventually merged into a single complex that moved west to east across southern Wisconsin. Surface dew points were in the lower 70s and maximum afternoon temperatures were in the mid to upper 80s. At least 56,000 customers in southeast Wisconsin lost electrical power due to lightning strikes, and tree damage to power lines. One of the worst lightning strikes was in Fox Point, where a lightning fire burned a home to the ground. Powerful winds associated with this storm affected Milwaukee County. An estimated wind gust of at least 70 knots (80 miles per hour or mph) ripped a 100-foot-long blimp from its mooring at Timmerman Airport, allowing the blimp to fly about six blocks and damage four homes on impact. In Cudahy an eight-car garage's roof was removed by the winds, and three stalls collapsed, based on Amateur Radio reports. A picnic shelter and several other garages and businesses on College Avenue near Lake Michigan also sustained some damage. In the City of South Milwaukee, a business's sign and fence were destroyed by the winds. This storm caused an estimated $6.2 million in property damages in Milwaukee County.

During the 6-year period between May 2010 and December 2016, 28 thunderstorm and 55 high-wind events were recorded in the Milwaukee County. In total, these thunderstorm and high-wind events resulted in over $400,000 in property damages in Milwaukee County (2016 dollars). Many of these damages occurred as a result of two storm events that impacted the City in 2013 and 2016. The first event was a thunderstorm and high-wind event that occurred on May 14, 2013. Several lines of severe thunderstorms crossed southern Wisconsin during the evening. These storms produced damaging wind gusts of 70 to 75 mph. Widespread damage was reported in swaths up to six miles in width. The damage included structural damage to homes and farm buildings, downed trees, and power lines. We Energies reported that 23,000 customers in Dodge, Jefferson, Waukesha, and Milwaukee Counties were without power at the height of the storm. The severe thunderstorms formed along a warm front that extended from northwest Wisconsin to Chicago. While wind shear and instability were marginal, evaporative cooling from rain falling into dry air produced prime conditions for downbursts. A trained spotter reported numerous downed trees and power lines along a path from two miles west of the City of Wauwatosa to east of the City of Cudahy. A downed power line caused a house fire three miles southwest of downtown Milwaukee. This event resulted in over $51,000 in property damages in Milwaukee County (2016 dollars).

Another high-wind event impacted the City of Milwaukee on February 19, 2016. A strong low pressure system moved across northern Wisconsin, sweeping an occluded front across southern Wisconsin during the late morning and afternoon hours. This was accompanied by wind gusts of 58 to 65 mph, with a maximum gust of 63 mph being reported at General Mitchell International Airport. Damages that were reported as a result of this storm include downed trees and branches, damaged homes and vehicles, and downed signs. Four semi-trucks were blown over on the interstate, blocking lanes. A shelter at a bus stop blew over and was damaged in the Riverwest neighborhood. About 26,000 customers were affected by power outages. This event resulted in $100,000 in property damages in Milwaukee County.

From 1956 to 2016, 142 major hailstorms were reported in the Milwaukee County. Several of these events coincided with thunderstorm and high wind events. From 1956 to 2016, NCDC reported $9.6 million in property damages from hailstorm events that occurred in and around the City of Milwaukee. The costliest hailstorm occurred on April 13, 2005. This event consisted of three hailstorms associated with supercell thunderstorms that pushed east-northeastward through southern Wisconsin. This storm produced hailstones up to four inches in diameter. Throughout southern Wisconsin, thousands of motor vehicles, residential homes, businesses, and farms sustained hail damage. There were no reports of injuries or deaths. Vehicle damage consisted of broken windows and dented sheet metal. Roofs, windows, and siding of buildings were damaged. This episode was the most costly recorded hailstorm in the State of Wisconsin. Based on insurance company estimates provided to the National Weather Service, over $8.6 million in damages in Milwaukee County were associated with this event. Because it is covered under most homeowner's policies, hail damage is directly reported to insurance companies and is not usually publicly reported, unless it is extensive.[30]

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[30]*Rusty Kapela, Warning Coordination Meteorologist at Milwaukee/Sullivan NWS, personal communication.*

From 1995 to December 2016, 27 lightning events were reported in Milwaukee County that resulted in significant property damage throughout southeastern Wisconsin. Most of the lightning events occurred during a thunderstorm or high wind event. In all, the NCDC has recorded about $2.8 million dollars in property damage due to lightning events in Milwaukee County, as shown in Table III-12. Most of these damages occurred as a result of two lightning events: on July 27, 1997, lightning caused a massive fire at a towing business on the south side of Milwaukee, and on August 21, 2002, a lightning fire in the Village of Fox Point burned a home to the ground. During the 2002 storm event, at least 56,000 customers in southeastern Wisconsin lost electrical power due to lightning strikes and tree damage to power lines.

Vulnerability and Community Impact Assessment

The National Weather Service can forecast and track a line of thunderstorms that may be likely to produce severe high winds, hail, lightning, and tornadoes, but where these related hazards form or touch down, and how powerful they might be, remains unpredictable.

In order to assess the vulnerability of the City of Milwaukee to thunderstorms and related storm hazards, a review of the community assets described in Chapter II indicate the potential for significant thunderstorm and related hazard impacts to: 1) a variety of residential, commercial, and other developed land uses; 2) roadway transportation system; 3) utilities; 4) critical community facilities; and 5) historic sites. In addition, the Milwaukee County Pre-Disaster Mitigation Plan concluded that thunderstorms and related hazards are one of the greatest risks to the population and infrastructure within Milwaukee County.[31] Significant impacts may also be possible to other infrastructure or utility systems, or hazardous material storage sites. On average, between 1993 and 2016 reported damages have resulted in about $124,000 per event, or about $2.2 million per year. However, very few events have been responsible for a large percentage of the total damages. Thus, this average damage cost is considered to be a very approximate measure of potential damages.

Mobile and manufactured homes can be particularly vulnerable to damage from high winds associated with severe thunderstorms. The light weight, flat-sided construction, and tenuous foundation connections of mobile and manufactured homes can make them highly vulnerable to wind damage. The U.S. Department of Housing and Urban Development (HUD) began regulating and governing their design and construction in 1974. Units manufactured before the HUD code was enforced federally in 1976 are the most vulnerable. Damage to mobile homes may be caused directly from wind or as a result of failure of the anchoring system for the home. Stronger winds can dislodge manufactured homes from their foundations or blow them over entirely if not properly anchored. Direct damage may include blown-off roof panels, loss of roof framing, loss of wall panels and framing

[31]*Milwaukee County Office of Emergency Management,* op. cit.

and broken windows. Add-ons such as carports and garages are an additional source of wind damage to mobile and manufactured homes. Most of these add-ons are not built to the HUD code, and many are not designed to be attached to manufactured homes. Damage to these structures at high wind speeds can cause a breach of the manufactured home's envelope, resulting in significant additional damage to the host structure. Debris from disintegrating add-ons can also impact other homes in the vicinity. Licensing information collected by the Wisconsin Department of Safety and Professional Services indicates that there are five mobile home parks containing a total of 655 sites for mobile homes in the City of Milwaukee.

In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion. About $20.7 billion of this total assessment is comprised of buildings and other improvements. Based on the current average estimate of $2.2 million in reported damages per year, it can be expected that approximately 0.01 percent of the value of all property, including buildings and infrastructure in the City of Milwaukee, will be damaged from these events each year. Due to the unpredictability of thunderstorm, high-wind, hail and lightning events, all buildings, infrastructure, and critical facilities within the City are considered at risk. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

Potential Future Changes in Thunderstorm, High-Wind, Hail, and Lightning Conditions

Based upon historical data, the City of Milwaukee can expect to experience an average of 10.2 thunderstorm, high-wind, hail, and/or lightning events per year. It should be noted that the historical record shows considerable variation among years in the number of events that occurred. While it would be expected that in some years the City will experience either fewer events or more events than the average number, the average annual number of events is not expected to change.

The likely effect of climate change on thunderstorm and high-wind events is not clear. While projections based upon downscaled climate model results indicate that the magnitude and frequency of heavy precipitation events are likely to increase by the middle of the 21st century, they do not address potential trends in wind, hail, or lightning conditions. Modeling studies utilizing the output of multiple climate models suggest that, between now and the end of the 21st century, there will be an increase in the number of days per year in which atmospheric environments will occur that are known to support the formation of severe thunderstorms under current climatic conditions.[32] It should also be noted that wind strengths over the Great Lakes have increased and are expected to

[32]*Noah S. Diffenbaugh, Martin Scherer, and Robert J. Trapp, "Robust Increases in Severe Thunderstorm Environments in Response to Greenhouse Forcing,"* Proceedings of the National Academy of Sciences, *Volume 110, pages 16,361-16366, 2013.*

continue increasing in the future.[33] Surface wind speeds above the Lakes are increasing by about 5 percent per decade, exceeding trends in wind speed over land.

Changes in land use can have an impact on the potential for thunderstorm and related hazards to occur. However, development within the City itself is approaching "buildout" conditions with new development expected to be limited, as documented in the adopted regional land use plan and summarized in Chapter II, and indicate a limited potential increase in risk of weather related damage and related losses in the already developed urbanized areas within the City. Because of actions taken by the City, the County, local units of government and individuals, the current vulnerability to thunderstorms and related hazards have decreased in recent years. These ongoing mitigation measures are described further in Chapter V.

VULNERABILITY ASSESSMENT FOR TORNADOES

Wisconsin lies along the northern edge of an area of the United States commonly known as "tornado alley." This area extends northeasterly along an axis extending from Oklahoma and Iowa in the west, to Michigan and Ohio in the east. This corridor is one of the most tornadoprone areas of the United States, reporting 29 violent tornadoes during the year 2001. A tornado is defined as a violently rotating column of air extending from the ground up to the thunderstorm base. It generally lasts for only a short period of time. The tornado appears as a funnel-shaped column with its lower, narrower end touching the ground and upper, broader end extending into the thunderstorm cloud system. In some cases, the visible condensation cloud may not appear to reach the ground, but meanwhile tornado-force winds may be causing severe destruction (rotating winds can be nearly invisible, except for dust and debris). Similar events not reaching the ground surface, are known as funnel clouds. A funnel cloud may be a precursor to a tornado event. In Wisconsin, tornadoes usually occur in company with thunderstorms formed by eastward-moving cold fronts striking warm moist air streaming up from the south. However, it is not possible to predict tornado activity based upon the occurrence of thunderstorms, and, occasionally, multiple outbreaks of tornadoes occur along the frontal boundaries, affecting large areas of the State at one time. Tornadoes generally occur near the trailing edge of a thunderstorm. It is not uncommon to see clear, sunlit skies behind a tornado.

Historically, tornadoes have been categorized based upon the most intense damage along their paths using the Fujita Scale. This scale is shown in Table III-13. Under this scale tornado intensities range from F0 events, representing the tornadoes doing the smallest amount of damage, to F5 events, representing the tornadoes doing the greatest amount of damage. Wind velocities necessary to produce the particular damage are often associated with ratings along the Fujita Scale, but that practice can be misleading. The wind estimates associated with the

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[33]*Ankur R. Desai, Jay A. Austin, Val Bennington, and Galen A. McKinley, "Stronger Winds Over a Large Lake in Response to Weakening Air-to-Lake Temperature Gradient,"* Nature Geoscience, *Volume 2, pages 855-858, 2009.*

Fujita Scale are intended to be based upon the expected damage to a well-built residential structure. Poorly built structures can suffer significant structural damage under lesser winds than the Fujita Scale might suggest. Other sorts of structures may or may not experience the same failures under high wind speeds that a house might. Thus the Fujita Scale is largely a residential scale, with much more care required in assessment after wind damage to other sorts of structures. Since February 2007, the Fujita Scale has been replaced by the Enhanced Fujita Scale which retains the same basic design of its predecessor with six strength categories. This scale is shown in Table III-14. The newer scale reflects more refined assessments of tornado damage surveys, more standardization, and consideration of damage over a wider range of structures. Because the National Weather Service has decided not to reclassify tornadoes that occurred prior to the implementation of the Enhanced Fujita Scale, the Fujita Scale classifications have been retained for those storms which occurred prior to February 2007.

The destructive power of the tornado results primarily from its high-wind velocities, wind-driven debris, and uplifting force. These tornado characteristics probably account for 90 percent of tornado-caused damage. Since tornadoes are generally associated with severe storm systems, hail, torrential rain, and intense lightning usually accompany tornado events. In addition, tornadoes may be accompanied by downbursts; these events are characterized by strong downdrafts initiated by a thunderstorm that manifests as straight-line winds on or near the ground. These winds can be powerful, with speeds up to 70 to 100 mph. These winds interact with tornadoes, and can affect the path of the tornado event in such a manner as to make tornadoes somewhat unpredictable. Depending on their intensity, tornadoes can uproot trees, down power lines, and damage or destroy buildings and infrastructure. Flying debris can cause serious injury and death to humans, livestock, and wildlife in their path. An approaching cloud of debris can mark the location of a tornado, even if the classic funnel cloud is not visible. Before a tornado hits, the wind may die down and the air may become very still.

The National Weather Service monitors severe weather nationwide from its Norman, Oklahoma, office. This office is the only entity that can issue a tornado watch. The National Weather Service office in Milwaukee/ Sullivan, and Milwaukee County Emergency Management, may issue tornado warnings. A tornado watch means that tornadoes are possible, and that persons within the area for which the watches are issued should remain alert for approaching storms. A tornado warning means that a tornado has been sighted in an area or it is indicated as likely to have occurred by weather radar. When tornado warnings are issued for an area, persons near and within that designated area are advised to move to a pre-designated place of safety. Tornado shelters are identified by appropriate signage in public buildings. The National Weather Service operates a 24-hour weather radio transmitter serving Milwaukee and Waukesha Counties, operating at a frequency of 162.400 megahertz (MHz), from a location in the Town of Delafield, Waukesha County. Southern portions of the Milwaukee County area, including portions of the City, are also served by a transmitter operating at a frequency of 162.450 MHz from a location at CTH KR and Wood Road in Racine County.

In addition to tornado watches and warnings, severe thunderstorm watches and warnings indicate severe weather conditions that may generate conditions in which tornadoes may occur. Such watches and warnings may be followed by tornado watches and warnings as weather conditions develop.

Historical Tornado Problems

Historically, a tornado with one of the longest tracks recorded in Wisconsin occurred on May 23, 1878.[34] This tornado tracked over 150 miles from Iowa County through Dane, Waukesha, and Milwaukee Counties, killing 19 and injuring 45 people throughout the four counties. Although such tornadoes are relatively rare natural hazards in the City of Milwaukee, they can cause substantial loss of life and damage to property.

Description of Recent Tornado Events

In the State of Wisconsin, tornado paths historically have averaged 3.5 miles in length and 50 yards in width, although tornado paths of a mile or more in width and 300 miles in length have been known to occur elsewhere in the United States. On average, tornadoes in southeastern Wisconsin move across the land surface at speeds between 25 and 45 miles per hour, although overland speeds of up to 70 mph have been reported. Tornadoes rarely last more than a few minutes over a single spot or more than 15 to 20 minutes in a 10-mile area, but, in those few minutes, significant damage may occur.

The gravity of any particular tornado event is measured in terms of resulting deaths, injuries, and economic losses. The magnitudes of the tornadoes recorded in southeastern Wisconsin have been low, primarily F0 or weak F1 events on the Fujita scale, as shown in Table III-13. Nevertheless, tornadoes are the third most costly natural hazards to impact southeastern Wisconsin.

Since 1950, a total of 18 tornadoes have been recorded in or near the City of Milwaukee, or about one tornado every 40 months. These are shown on Map III-2, and documented in terms of their magnitude and impact in Table III-15. In total, these 18 tornadoes have resulted in no deaths, 176 injuries, and over $18.3 million in property damages, with the average damage estimated at almost $1,019,000 dollars. On average, there are approximately 23 tornadoes reported each year within the State of Wisconsin.

Of the tornadoes reported in Milwaukee County since 1950, seven were categorized as F2 events on the Fujita scale. These seven tornado events collectively resulted in over $5.4 million in property damage in Milwaukee County. However, two F1 tornadoes caused the greatest number of injuries and highest damage costs recorded. On August 11, 1969, an F1 tornado caused 153 injuries and over $1.6 million in damages, and on March 8, 2000, an F1 tornado caused over $6.4 million in property damage and 16 injuries near General Mitchell International

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[34] *National Oceanic and Atmospheric Administration,* http://www.crh.noaa.gov/mkx/tortrack.htm.

Airport (Figure III-8). Of the remaining tornado events, nine were classified as F1 tornadoes and one was classified as an F0 event. No magnitude information was available for one tornado.

Vulnerability and Community Impact Assessment

In order to assess the vulnerability of the City of Milwaukee to tornado and related storm hazards, a review of the community assets described in Chapter II was made which indicates the potential for significant tornado impacts to: 1) a variety of residential, commercial, and other developed land uses; 2) roadway transportation system; 3) utilities; 4) critical community facilities; and 5) historic sites. In addition, the Milwaukee County Pre-Disaster Mitigation Plan concluded that tornadoes are a major risk to people within Milwaukee County.[35] Significant impacts may also be possible to other infrastructure or utility systems, solid waste disposal sites, or hazardous material storage sites.

Tornado prediction is not an exact science. The National Weather Service can forecast that a line of thunderstorms may be likely to produce tornadoes, but where they form or touch down, and how powerful they might be, remains unpredictable. As can be seen from the distribution of historic F1 and F2 tornado events since 1950 in the City of Milwaukee, shown on Map III-2, the locations of tornado impact points are widely scattered throughout the City and County. On average, historic tornado events have resulted in about $1,019,000 in property damages per event. However, one of the events have been responsible for over one third of the total damages. Thus, the average damages cost is considered to be only an approximate measure of potential damages. Based on a yearly average estimated from reported tornado damage between 1958 and 2016, tornadoes cause approximately $310,853 in damage each year.

During a tornado, homes, businesses, public buildings, and infrastructure may be damaged or destroyed by high winds, rain, and hail. Airborne debris carried by the tornado and associated high winds, can break windows and doors, allowing winds and rain access to interior spaces. Fixed infrastructure, such as roads and bridges, also can be damaged by exposure to high winds, although more damage appears to result from washout associated with flash flooding and debris jams as opposed to direct damage due to contact with funnel clouds. Notwithstanding, in an extreme tornado event, such as a F4 event, the force of the wind alone can cause tremendous devastation, uprooting trees, toppling power lines, and inducing the failure of weak structural elements in homes and buildings.

As discussed in the section of this chapter on thunderstorms, mobile and manufactured homes can be particularly vulnerable to some hazards such as high wind. Extreme winds can displace these homes from their sites,

[35] *Milwaukee County Office of Emergency Management*, op. cit.

especially if they are not properly attached to the site or if such attachment fails. In addition, these structures usually lack basements. As a result, they afford their occupants little shelter in the event of hazardous winds. As of May 2017, there were five mobile home parks located in the City of Milwaukee. These parks had sites for a total of 655 mobile homes. These structures and their occupants may be particularly vulnerable to impacts from tornadoes.

In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion.[36] About $20.7 billion of this total is comprised of buildings and other improvements. Based on the current average estimate of $310,853 in reported damages per year, it can be expected that approximately 0.0015 percent of the value of all property, including buildings and infrastructure in the City of Milwaukee, will be damaged from tornadoes each year. Due to the unpredictability of tornado events, all buildings, infrastructure, and critical facilities within the City are considered at risk. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

Potential Future Changes in Tornado Conditions

Based upon historical data, the City of Milwaukee can expect to experience an average of 0.31 tornado events per year or about one tornado every three years. It should be noted that the historical record shows considerable variation among years in the number of events that occurred. While it would be expected that in some years the City will experience either fewer events or more events than the average number, the average annual number of events is not expected to change.

Changes in land use can have an impact on the potential for tornado and related hazards to occur. However, development within the City itself is approaching "buildout" conditions with new development expected to be limited, as documented in the adopted regional land use plan and summarized in Chapter II, and indicate a continuing level of moderate risk of tornado damage and related losses in the City. Because of actions taken by the City, the County, and individuals, the current vulnerability to tornadoes and related hazards has decreased in recent years. Ongoing mitigation measures are described further in Chapter V.

The likely effects of climate change on tornado frequency and severity are not clear. The projections based upon downscaled climate model results do not address potential trends in tornado conditions. A recent study that examined trends in tornados rated F1 or EF1 and higher over the period 1954 through 2013 found that the frequency of outbreaks of multiple tornadoes may be changing.[37] While the study found no change in the

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[36]*Wisconsin Department of Revenue.*

[37]*James B. Elsner, Svetoslava C. Elsner, and Thomas H. Jagger, "The Increasing Efficiency of Tornado Days in the United States,"* Climate Dynamics, *Volume 45, pages 651-659, 2015.*

frequency at which tornadoes occur, it found a decrease in the number of days per year on which at least one tornado occurs. At the same time, it found an increase in the number of days per year on which multiple tornadoes occur. Increasing trends were found at several different thresholds for defining outbreaks of multiple tornadoes. Thus, the study found that the proportion of tornadoes that occur on "big tornado days" has increased. In addition, the study found that the spatial and temporal density of the tornadoes occurring has increased. The study concluded that the risk of "big tornado days" featuring clusters of densely packed tornadoes is increasing. This trend could potentially increase tornado-related damages.

VULNERABILITY ASSESSMENT FOR EXTREME TEMPERATURES

Extreme heat and cold are two of the most underrated, least understood, and deadly of all the natural hazard events that impact the City of Milwaukee. In contrast to the visible, destructive, and violent characteristics associated with floods and tornadoes, extreme high or low temperatures are "silent killers." Heat deaths occur quietly, without headline-making destruction. The Center for Disease Control and Prevention reports that on average, 688 people die each year nationwide from excessive heat, more than lightning, tornadoes, floods, and hurricanes combined.[38] Excessive heat has become the most deadly hazard in Wisconsin. According to the National Weather Service, between 1982 and 2015, 137 people have died in Wisconsin as a direct result of heat waves. During the same period excessive heat was identified as a contributing factor in 102 other deaths. This rate of mortality due to heat events during this period is over twice that of the next most deadly natural hazards, cold waves (65 deaths). Temperature data for two selected observation stations in the City of Milwaukee have been shown in Table III-16 to indicate extreme high and low temperatures and the departure from average temperatures recorded in the period from 1990 through 2016. The average high and low extreme temperatures for these two stations are 95.1ºF and -6.8ºF for General Mitchell International Airport and 97.8ºF and -8.2ºF for Mount Mary College during this period. Prolonged exposure to either of these temperatures could present a significant danger. It is worth noting that Lake Michigan may be exerting some effect on the average and the extreme cold temperature, but is not appreciably reducing the average extreme high temperature.

Heat and humidity together can inflict the most harm to human health. High humidity makes heat more dangerous because it slows the evaporation of perspiration, which is the body's natural cooling process. A measure of discomfort and the level of risk posed to people in high-risk groups is the Heat Index (HI) which is expressed in degrees Fahrenheit (ºF) and equals a relative humidity (RH) adjustment added to the actual air temperature. For example, if the air temperature is 94ºF and the RH is 55 percent, the HI would equal 106ºF (see Table III-17). Since HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values

[38]*U.S. Centers for Disease Control and Prevention, "Heat-Related Deaths—United States, 1999-2003,"* Morbidity and Mortality Weekly Reports, *Volume 55, July 28, 2008.*

by up to 15ºF. The level of risk to people in high-risk groups associated with different levels of the HI is shown in Table III-18.[39] The NWS initiates alert procedures (advisories or warnings) when the Heat Index is expected to have a significant impact on public safety. The expected severity of a heat wave determines whether advisories or warnings are issued. High temperature periods are often also accompanied by the related air quality problems related to ground-level ozone which can be harmful, especially to sensitive groups, such as active children and adults with respiratory problems. During 2001 and 2002, there were 10 and 11 days, respectively, when weather conditions were forecast in southeastern Wisconsin which could have resulted in unhealthy levels of ozone (the main component of smog).

The following definitions/criteria are for the 20 counties in south-central and southeastern Wisconsin served by the Milwaukee/Sullivan Weather Forecast Office:

- **Outlook Statement**—Issued two to seven days prior to time that minimal Heat Advisory or Excessive Heat Warning conditions are expected. Serves as a long-term "heads-up" message.

- **Excessive Heat Watch**—Issued 24 to 48 hours in advance when Excessive Heat Warning conditions are expected.

- **Heat Advisory**—Issued six to 24 hours in advance of any 24-hour period in which daytime heat indices are expected to be 100° to 104°, or 95° to 99° for four or more consecutive days, and nighttime heat indices are greater than or equal to 75°. Advisories are issued for less serious conditions that cause significant inconvenience and, if caution is not exercised, could lead to situations that may threaten life.

- **Excessive Heat Warning**—Issued six to 24 hours in advance of any 24-hour period in which daytime heat indices are expected to exceed 105° for three or more hours, and nighttime heat indices are greater than or equal to 75°. In addition if Heat Advisory conditions are expected to persist for four or more days, an Excessive Heat Warning will be issued. Warnings are issued for weather conditions posing a threat to life.

During extended periods of very high temperatures, coupled with high humidity levels, individuals can suffer a variety of ailments, including heat cramps (muscular pains and spasms due to heavy exertion). Although heat cramps are the least severe symptom, they are an early signal that the body is having trouble with the heat. Heat exhaustion typically occurs when people exercise heavily or work in a hot, humid place where body fluids are lost through heavy sweating. Blood flow to the skin increases, causing blood flow to decrease to the vital organs. This

[39]*High-risk groups include the very young, the old, and people with chronic health conditions.*

results in a form of mild shock. If not treated, the victim may suffer heat stroke. Heat stroke is life threatening and requires immediate medical attention. The victim's temperature control system, which produces sweat to cool the body, stops working. The body temperature can rise so high that brain damage and death may result if the body is not cooled quickly. Sunstroke is another term for heat stroke. In addition to posing a public health hazard, periods of excessive heat usually result in high electrical consumption for air conditioning, which can cause power outages and brown outs.

Extreme cold is also a deadly hazard. Exposure to extreme cold temperatures can cause a number of health conditions and can lead to loss of fingers and toes; or cause permanent kidney, pancreas, and liver injury; and even death. These health impacts often result from a combination of cold temperatures, winds, and precipitation. As a result, winter storms can pose substantial risks because they can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. In addition, when deaths and injuries due to cold-related vehicle accidents and fatalities, fires due to dangerous use of heaters, and other winter weather fatalities are considered, the impact of severe cold periods become even greater.

Frostbite and hypothermia are two major health risks associated with severe cold. Frostbite is injury caused by freezing of the skin and underlying tissues. Frostbite causes a loss of feeling and a white or pale appearance in extremities. Mild frostbite, frostnip, does not cause permanent skin damage and can be treated with first-aid measures. More severe frostbite can damage skin and underlying tissues and requires medical attention. Potential complications of severe frostbite include infection and nerve damage. Frostbite is most common on fingers, toes, nose, ears, face, and chin. While exposed skin in cold, windy weather is most vulnerable to frostbite, this injury can occur on skin covered by gloves or other clothing.

Hypothermia is a condition brought on when the core body temperature drops to less than 95°F. It occurs when the body loses heat more quickly than it is able to produce it. Relative to temperature extremes, this occurs due to exposure to cold or frigid environments. As with frostbite, wind or wetness can contribute to producing hypothermia. Symptoms of mild hypothermia can include shivering, dizziness, hunger, nausea, fatigue, increased heart and respiration rates, lack of coordination, and difficulty speaking. As hypothermia worsens, shivering may end. Symptoms of moderate to severe hypothermia include lack of coordination, slurred speech, confusion, drowsiness, progressive loss of consciousness, weak pulse, and shallow breathing. Hypothermia may cause lasting kidney, liver, and pancreas problems or death. Members of certain populations are particularly vulnerable to hypothermia. These include older adults, infants and very young children, the homeless, persons using alcohol or other drugs, and persons taking certain medications.

Wind chill is an index used to evaluate the risk posed by the combination of cold temperatures and wind. It is based on a combination of temperature and wind speed. Table III-19 shows the wind chill table used by the

National Weather Service. Wind chill is not the actual temperature, but rather a measure of how wind and cold feel on exposed skin. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature. This combination can strongly affect the risks associated with exposure to the temperature. For example, a wind chill of -20°F will cause frostbite on exposed skin in just 30 minutes.

The National Weather Service issues wind chill advisories when wind chill temperatures are potentially hazardous and wind chill warnings when wind chill temperatures are life threatening. A wind chill advisory is issued when wind chill values will reach -5°F to -19°F, with wind speeds around 10 mph or more. A wind chill warning is issued when wind chill values will reach -20°F or colder, with wind speeds around 10 mph or more. In addition, a wind chill watch is issued when these conditions may be met 12 to 48 hours in the future.

During the period from 1982 through 2016, 65 people died in Wisconsin due to exposure to cold. When vehicle accidents and fatalities, fires due to dangerous use of heaters, and other winter weather fatalities are also considered, it increases the severity of severe cold periods. Exposure to extreme cold temperatures can cause hypothermia and frostbite; can lead to loss of fingers and toes; or cause permanent kidney, pancreas, and liver injury, and even death. A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. Wind chill is not the actual temperature, but rather how wind and cold feel on exposed skin. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature. A wind chill of -20°F will cause frostbite in just 30 minutes. Frostbite is damage to body tissue caused by extreme cold. Frostbite causes a loss of feeling and a white or pale appearance in extremities, such as fingers, toes, ear lobes, or the tip of the nose. If symptoms are detected seek immediate medical help. Hypothermia is a condition brought on when the body temperature drops to less than 95°F. Hypothermia may cause lasting kidney, liver, and pancreas problems or death. Warning signs include uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness, and apparent exhaustion. Take the person’s temperature. If below 95°F, get medical care immediately. Infants and elderly people are most susceptible. Fifty percent of all cold-related injuries are expected to occur in people over 60 years old, more than 75 percent will happen to men, and about 20 percent will occur in the home.

What constitutes extreme cold varies in different parts of the country. In the south, near freezing temperatures are considered extreme cold. Pipes may freeze and burst in homes that are poorly insulated or without heat. In the north, extreme cold means temperatures well below zero. Winter residents in the City of Milwaukee may see heavy snow, strong winds/blizzards, extreme wind chill, lake-effect snow, and ice storms. The public can stay informed by listening to NOAA Weather Radio, commercial radio or television for the latest winter storm warnings, watches.

Historical Extreme Temperature Problems

Historically, most of the all-time maximum daily temperatures in Wisconsin were recorded during the Dust Bowl years between 1934 and 1936. The City of Milwaukee reached a record high temperature of 105ºF on July 24, 1934. The highest temperature ever recorded in Wisconsin was 114ºF, which occurred on July 13, 1936, at the Wisconsin Dells. In the City of Milwaukee, beginning on July 12, 1995, the National Weather Service issued a heat advisory, the next day that advisory was upgraded to an excessive heat warning. Temperatures reached 104ºF and the heat index peaked at 125ºF. This was the very first time that the National Weather Service in Sullivan, Wisconsin, had issued a heat advisory and an excessive heat warning. There was a period of high temperatures in 1988, but that was a dry heat and the outcome was much different. This heat wave was unusual because high temperatures were combined with high humidity, resulting in a heat index, which peaked at 125ºF. The "summer of 1995" severe heat wave affected most of Wisconsin and resulted in 154 fatalities, 82 direct and 72 indirect. In addition, approximately 400 people received medical treatment due to heat-related causes. Many of these deaths occurred in urbanized areas in southeastern Wisconsin, particularly in the City of Milwaukee. The 1995 summer heat wave holds the record as the number one weather-related killer in Wisconsin since it became a state in 1848. The July 1995 heat wave was a highly rare and, in some respects, unprecedented event in terms of both unusually high maximum and minimum temperatures and the accompanying high relative humidity.

On December 9, 1995, bitter-cold arctic air swept into Wisconsin on northwest winds of 20 to 40 mph. Temperatures dropped as much as 15ºF in 15 minutes as the strong front moved through. Wind chill values ranged from -25ºF to -50ºF. In the City of Milwaukee, two people died directly from hypothermia, while hypothermia was a secondary cause indirectly related for one death in Dane County and one death in Kenosha County. Twelve cases of frostbite were also reported in the City of Milwaukee. An episode of extreme cold, which started in late January 1996, continued through the first four days of February across south-central and southeastern Wisconsin. Wind chills were in the -35ºF to -60ºF range many times during this event that resulted in four cold-weather hypothermia deaths. In addition, there were 15 reported cases of sustained frostbite in the City of Milwaukee and a low temperature of -23ºF was recorded on February 3, 1996, in the City of Milwaukee.

Description of Recent Extreme Temperature Events

Extreme temperatures that affect the City of Milwaukee are not localized events, as they usually encompass the entire south-central and southeastern portions of the State and may continue for several days or weeks. Table III-20 lists the extreme and record high and low temperature events in southeastern Wisconsin from 1994 through 2016, which have directly resulted in 125 fatalities and 246 injuries. Extreme heat was attributed as the cause of 104 reported fatalities and 220 reported injuries and extreme cold was attributed as the cause of 11 fatalities and 26 injuries.

Extreme Heat

In the spring and summer of 2002, several brief one day heat waves were recorded with heat indices over 100ºF and as high as 110ºF. Two deaths were directly related to these events. In the summer of 2001, three rounds of excessive heat in July and August affected most of southeastern Wisconsin. Heat index temperatures reached 110ºF, six people died, and numerous people suffered from heat-related sicknesses in the City of Milwaukee.

During the last two weeks of July 1999, an oppressive heat wave enveloped the City of Milwaukee, peaking during the four days of July 28 through 31, 1999. Throughout these four days, high humidity and temperatures in the 90s and 100s produced heat index values from 110ºF to as high as 125ºF. The heat wave was directly and indirectly responsible for 20 deaths in Wisconsin, eight in the City of Milwaukee. During this time, there was record peak daily electric power demand in the Milwaukee area, and during that summer, there was a record set for the Midwest region for electrical demand.

A period of very hot and humid weather began on the evening of July 30, 2006 and continued into August 2, 2006. Overnight temperatures fell to only 70 to 75ºF on July 30 and soared into the 95 to 100 degree range during the afternoon of July 31. With dew points in the low to mid 70s, heat index values dropped to about 75 degrees overnight on July 30 and peaked in the 105 to 110 degree range across south-central and southeastern Wisconsin during the afternoon of July 31. Temperatures and heat index values remained high until the passage of a cold front on the afternoon of August 2 ended the heat wave. This heat wave resulted in two heat-related deaths in Milwaukee County. In addition, an estimated 40 people in Milwaukee County were hospitalized due to heat-related symptoms.

A dome of hot and humid air over the southern and central Plains affected Wisconsin during the period of July 17, 2011 through July 21, 2011. Temperatures in the 90s accompanied by dewpoints in the 70s generated heat index values between 100°F to 110°F. Based on news reports, it is estimated that 60 people in Milwaukee sought treatment for heat-related problems. In addition, hundreds of others called a social service agency seeking free air-conditioners. Milwaukee-area organizers and health officials took steps to address the safety of fair and festival-goers prior to and during this long-duration excessive heat event.

Beginning on June 16, 2012, gusty southwest winds brought a hot air-mass into southern Wisconsin that persisted until the afternoon of June 20. During this period, maximum daytime air temperatures reached the lower to middle 90s, resulting in heat index values of 95°F to 96°F. Heat index values during the evening and night remained in the 75°F to 80°F range. This heat wave resulted in two deaths from hyperthermia in the City of Milwaukee. The first was a 66-year-old woman found in her home's backyard. The second was a 60-year-old man found in his home.

Most heat-related deaths occur in cities. Large urban areas become “heat islands.” Brick buildings, asphalt streets, and tar roofs store heat and radiate it like a slow burning furnace. Heat builds up in a city during the day and cities are slower than rural areas to cool down at night. The amount of sunshine is an important contributing factor in urban heat waves. In addition, the stagnant atmospheric conditions associated with a heat wave trap ozone and other pollutants in urban areas. The worst heat disasters, in terms of loss of life, happen in large cities when a combination of high daytime temperatures, high humidity, warm nighttime temperatures, and an abundance of sunshine occurs for a period of several days. There are also socioeconomic problems that put some urban populations at greater risk. The elderly, disabled, and debilitated are especially susceptible to heat-related illness and death. During the 1995 nationwide heat wave, 67 percent of the fatalities occurred in the 60-year-old to 89-year-old age group (see Table III-21).

Extreme Cold

An arctic high-pressure ridge, fresh, deep snow cover, clear skies, and light winds allowed temperatures to plunge on January 5, 1999, to well below zero across south-central and southeastern Wisconsin. Several new low temperature records were set, -23ºF at Janesville (Rock County) and -20ºF in the City of Kenosha.

In the wake of a major winter storm on December 1, 2006, cold weather settled over southern Wisconsin, with daily temperature averages well below normal. December 7 was an unseasonably cold day in Milwaukee, with a high temperature of 17ºF and a low temperature of 8ºF. One death was attributed to this cold snap.

A cold weather event resulted in the death of a 64-year-old woman from hypothermia on December 3, 2014, in the City. The woman was homeless, and had been living in her vehicle at the time of her death. Temperatures were in the 20s in the early morning hours of this event, and were in the lower 30s when the woman was found.

Cold weather resulted in the death of a 58-year-old homeless man from hypothermia on January 1, 2015. The man was found deceased in an alcove near a liquor store, and the Milwaukee County Medical Examiner's office determined that intoxication significantly impacted his death. Temperatures ranged between 15°F and 30°F degrees throughout the day.

Vulnerability and Community Impact Assessment

Temperature extremes are primarily a public health concern. The poor and elderly are much more susceptible to temperature-related deaths and injury. Education, improved social awareness, and community outreach programs have likely helped to reduce the number of individuals killed or injured by extreme temperature events. Those at greatest risk are the very young, the very old, and the sick. Most deaths during a heat wave are the result of heat stroke. Large and highly urbanized cities can create an island of heat that can raise the area temperature 3ºF to 5ºF. Urban communities with substantial populations of elderly, disabled, and debilitated people could face a significant medical emergency during an extended period of excessive heat. Some residents in high crime areas, especially the elderly, may be afraid to open windows or travel to cooling shelters. As neighborhoods change, some older residents become isolated because of cultural, ethnic, and language differences.

In 2014, the Wisconsin Department of Health Services; Building Resilience Against Climate Effects (BRACE) program conducted a geo-spatial analysis of heat-related vulnerability in Milwaukee County.[40] This analysis used existing data related to population density, such as the number of people per square mile; health factors, such as the percentage of the population that visited a hospital emergency department for heat stress; demographic and socioeconomic factors, such as the percentages of young children or persons over 85 years of age and the percentage of households in poverty; and natural and built environment factors, such as surface air temperature during a heat wave, land cover, and air quality; to create a heat vulnerability index (HVI) to identify areas of greatest risk for negative health impacts due to extreme heat. The HVI was calculated for each census block in the County. Based on the HVI, each census block was placed in one of five vulnerability categories based on the level of vulnerability indicated, with each category consisting of 20 percent of the census blocks analyzed. It is important to note that the levels of vulnerability shown by the HVI indicate relative levels of risk and do not indicate absolute risks.

Map III-3 shows the HVI for census blocks in Milwaukee County. The largest areas of high and moderate high HVI values identified on the map are in the central portion of the City of Milwaukee. Areas of lower HVI values within the City occur along the Lake Michigan shoreline and in the southeastern portion of the City. It is important to note that major areas identified as having high and moderate high HVI values correspond to areas within the City that have concentrations of people living in poverty.[41]

Extreme heat can lead to high demands for electricity related to operation of air conditioners and fans. This can result in blackouts and brownouts. Loss of water pressure can result from the opening of fire hydrants in urban areas. Stagnant atmospheric conditions that occur with heat waves are also favorable for trapping ozone and other pollutants in urban areas. Pets can suffer from prolonged exposure to excessive heat.

Persons who are homeless constitute one of the most vulnerable groups of people with regards to the hazardous impacts of cold weather. Non-profit organizations and religious institutions often provide temporary shelter for homeless persons. When locations such as these are filled to capacity or are unavailable, homeless persons often seek shelter in places not intended for human habitation, such as vehicles, city streets, and bridge underpasses.

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[40] *Wisconsin Department of Health Services,* Milwaukee Heat Vulnerability Index, *P-00882A, October 2014.*

[41] *This can be shown by comparing Map III-3 to Maps H.15 and H.25 in SEWRPC Planning Report No. 55,* Vision 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin, *July 2017.*

During winter months, these types of locations provide little to no protection from the hazardous conditions of intense, cold weather. In periods of extreme low temperatures, lodging in inadequately heated or uninsulated places can put occupants at high risk of experiencing serious health problems related to extended exposure to cold weather, such as hypothermia, frostbite, loss of fingers and toes, permanent damage to internal organs, and death.

The Milwaukee Continuum of Care conducted a Point-in-Time (PIT) count of homeless persons in Milwaukee County on January 25, 2017. This survey counted 900 homeless persons. Of these people, 765, or 85 percent, were being served by homeless shelters at the time they were counted. The remaining 135 persons, or 15 percent, were not being served by shelters. Of the 900 total persons counted, 98 persons, or 11 percent of the total, were considered to be chronically homeless.

Although PIT counts provide valuable information regarding homelessness, the data from the counts do not report the absolute state of homelessness in surveyed communities. Numbers from PIT counts are considered underestimates because it is unlikely that all persons experiencing homelessness in a certain area will be counted. While the counts are conducted at a time when homeless persons are expected to enter shelters to escape cold weather conditions, not all homeless persons enter shelters. Some homeless individuals and families seek habitation elsewhere. In particular, homeless youth can be under-represented in counts because shelters in many communities have a limited number of beds dedicated to young people. In addition, young persons who are homeless tend to not reside in places that are inhabited by homeless adults. PIT counts also fail to include homeless persons who are hospitalized or are incarcerated at the time of counting. Finally, persons who are homeless are not always identifiable as homeless by sight, causing some persons to be overlooked in the count process.

A review of the community assets described in Chapter II indicates the potential for extreme temperature hazard events to impact: 1) residents, especially the poor, elderly, and sick; 2) pets; 3) municipal water and electric utilities; and 4) natural surface and groundwater reserves. In addition, the Milwaukee County Pre-Disaster Mitigation Plan also found that extreme temperature hazards pose a risk to the population within Milwaukee County.[42] No specific cost data are estimated for temperature extreme events, because the nature of such events does not readily permit direct cost analysis.

Potential Future Changes in Extreme Temperature Conditions

Based upon historical data, the City of Milwaukee can expect to experience an average of 3.6 extreme temperature events per year. On average, there are 1.6 extreme cold events and 2.0 extreme heat events per year.

[42] *Milwaukee County Office of Emergency Management,* op. cit.

It should be noted that the historical record shows considerable variation among years in the number of events that occurred. While it would be expected that in some years the City will experience fewer events or more events than the average number, the average annual number of events is not expected to change.

Extreme heat events are likely to occur more frequently and to be more severe by the middle of the century. As previously described, average summertime temperatures in the City of Milwaukee are projected to increase by 6.0 to 5.5ºF by year 2055. The number of days per year in which temperatures in southern Wisconsin exceed 90ºF is expected to double from about 12 to about 25 by 2055. Given that much of the documented increases in average temperature since 1950 have occurred through increases in night-time low temperatures, it is likely that there will be fewer night-time breaks in the heat during extreme heat events in the future. This could result in some extreme heat events persisting longer. Heat waves have direct impacts on human health, especially among sensitive populations such as young children and the elderly. In the absence of mitigative measures, the projected increase in the frequency, duration, and severity of heat waves will be likely to cause increases in fatalities and illnesses related to extreme heat.

By contrast, the frequency of extreme cold events may decrease by the middle of the century. The projected warming trends are expected to be greatest during the winter. Average winter temperatures in the City of Milwaukee are projected to increase by about 7.5ºF. This may result in a reduction of some risks associated with extreme cold.

VULNERABILITY ASSESSMENT FOR LAKE MICHIGAN COASTAL HAZARDS

The Lake Michigan coast lying within the jurisdiction of the City of Milwaukee consists of about eight miles of shoreline. The land uses along the shoreline are documented in Chapter II.

There are three types of Lake Michigan coastal hazards which potentially affect the City of Milwaukee, including:

- Erosion of coastal bluffs, beaches, and nearshore lakebeds;
- Flooding from high lake levels and storm-induced surge (temporary water level changes); and
- Damage to shoreline structures, such as residences, businesses, and public facilities, from storm waves, including wave runup.

The focus of the vulnerability assessment is on the first type of hazard noted above, erosion of bluffs, beaches, and nearshore areas as that phenomenon is a documented hazard in Milwaukee County where bluff recession rates exceeding 12 feet per year have been reported.[43] However, there is only a short length of shoreline between Edgewood Avenue and the north end of the Linnwood Avenue water treatment plant where potential shoreline erosion is an issue. In this reach, the bluffs are considered moderately stable and the rate of erosion is less than one foot per year. The second hazard, flooding from high lake levels, is being considered, along with flooding in other areas of the City. With regard to the third hazard, storm wave damage, there are hazards in the County primarily in the City of Milwaukee in areas protected by sheet piling, breakwaters, and revetments. However, the design of these shore protection structures, most notably those protecting the City sewage treatment and water plants, and the marina facilities, have been designed using standards suitable for major public and private facilities. In addition, the structures are maintained as needed. Given these conditions, Lake Michigan coastal erosion is considered to be a relatively minor hazard in the City of Milwaukee even though there are areas within Milwaukee County where this hazard is more severe.

Coastal erosion can be influenced by a number of natural factors, including the orientation of the shoreline, currents, freeze-thaw cycles, and water levels in Lake Michigan. Water levels in the Lake and changes in these levels can also have a strong influence.

Water levels in Lake Michigan vary on a number of different time scales. Short-term variations result from the impacts of tides, wind, and barometric pressure. Tides are changes in water levels caused by the gravity of sun and moon. These occur twice daily on Lake Michigan. According to the National Oceanic and Atmospheric Administration, the largest tides on the Great Lakes are less than two inches in height. These variations are generally masked by fluctuations in water levels produced by other causes.

Annual variations occur with the changing seasons. Annual high water levels on Lake Michigan usually occur during the summer and low water levels usually occur during the winter. In the 30-year period between 1988 and 2017, the average difference between the summer high water levels and winter low water levels has been about one foot.[44] During the same period this difference has varied between about 0.4 and 2.2 feet. Long-term variations depend on climatic factors such as precipitation, the presence or absence of ice cover on the Lake during the winter, and evapotranspiration.

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[43]*SEWRPC Community Assistance Planning Report No. 163,* A Lake Michigan Coastal Erosion Management Study for Milwaukee County, Wisconsin*, October 1989; and SEWRPC Technical Report No. 36,* Lake Michigan Shoreline Recession and Bluff Stability in Southeastern Wisconsin: 1995*, December 1997.*

[44]*This is calculated from average monthly water levels obtained from the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory.*

Historical Coastal Hazard Conditions

Coastal hazard problems have been most evident in the City of Milwaukee during high water periods. These have occurred in recent history on Lake Michigan in the early 1950s, the early 1970s, and the mid-1980s, with record high levels occurring in 1986, surpassing the previous record high level set in 1886. As of December 2017, Lake Michigan water levels were high. Between January 2013 and August 2017, monthly average water levels in the Lake rose over 4.5 feet. They have decreased by about 0.7 foot since then; however, this decrease most likely reflects normal seasonal variation. As of December 2017, Lake Michigan water levels were about 1.2 feet above the mean for the period 1918-2017.

Low water levels on Lake Michigan can also cause problems with shore protection structures, such as rotting of timber pilings, which are normally under water, being exposed to air, as well as significantly affecting shipping and boating and marina activity. As recently as 2011, lake levels were approximately 2.1 feet below the historical mean for the period 1918-2017, but approximately two-thirds of a foot above the historic record low levels set in 1964 and 1965. Lake Michigan low-water-level problems were discussed as an important topic during a March 2002 workshop.[45]

A 1989 Lake Michigan coastal erosion management study, prepared for Milwaukee County with assistance from the Wisconsin Coastal Management Program, identified the extent of that erosion at 638 locations along the shoreline. The study identified erosion rates of less than one foot per year over the period 1963 to 1985.[46]

Description of Recent Coastal Hazard Conditions

As described in Chapter II, a 1997 study was prepared by SEWRPC and others in cooperation with the Wisconsin Coastal Management Program to evaluate shoreline erosion and bluff stability conditions along the Lake Michigan shoreline in southeastern Wisconsin, including the City of Milwaukee.[47] That study found relatively stable bluff erosion rates of less than one foot per year over the period 1975 to 1995 in the area of concern in the City of Milwaukee. No building or infrastructure damage has been reported in association with bluff erosion.

In March 1987, 55 to 60 mile per hour northeast winds created 10-foot high waves that pounded the Lake Michigan shoreline. Significant shoreline and bluff erosion was reported all along the shore. Waves crashed over

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[45]*University of Wisconsin-Sea Grant Institute and Bay Lake Regional Planning Commission,* Living with the Lakes Workshop*, at University of Wisconsin-Green Bay, March 22, 2002.*

[46]*SEWRPC Community Assistance Planning Report No. 163,* op. cit.

[47]*SEWRPC Technical Report No. 36,* op. cit.

Lincoln Memorial Drive, leaving up to one foot of water standing in the road in some places. The MMSD Jones Island sewage treatment plant was closed due to flooding in tunnels below the plant.[48]

During a large rainfall event, a portion of a bluff along the Lake Michigan shoreline collapsed after soils became saturated with water.

Numerous improvements were made to the City of Milwaukee's lakefront as part of the creation of Lakeshore State Park and integration with Pier Wisconsin, Discovery World, and the Quadracci Pavilion addition to the Milwaukee Art Museum. The first phase of planned improvements was completed in 2007 for the 17-acre park at a cost of $17 million. Detailed coastal analyses were completed with physical models to assess water levels, wave conditions, design storm events, and water circulation. Improvements to the lakefront included reconstruction of the eastern shore of the island park and two new breakwalls. One 180 linear foot breakwater protects the Quadracci Pavilion addition from wave runup, and a 1,200 linear foot breakwater minimizes wave heights in a maritime basin just north of the state park.[49]

Vulnerability and Community Impacts Assessment

A review of the Lake Michigan lakeshore erosion conditions within the City of Milwaukee indicates that there is a very limited potential community impact as a result of the potential loss of land improvements and infrastructure in selected areas due to lakeshore erosion. With proper surveillance, the need to prepare for major evacuations and other emergency actions are not a significant concern given the isolated nature and the limited severity of the problems. Similarly, the Milwaukee County Pre-Disaster Mitigation Plan identified that several coastal communities are at risk from coastal erosion, but coastal erosion was not considered a primary concern relative to the potential damages to population and infrastructure within Milwaukee County.[50]

Potential Future Changes in Coastal Hazard Conditions

Changes in land use can have an impact on the potential for coastal erosion hazards to occur. Such changes relate to the potential future increase in development within the erosion hazard areas, particularly when not accompanied by proper shore protection measures. Because of the current zoning procedures which are in place, this situation has not occurred.

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[48]*Milwaukee Journal, "Storm Pounds Lakeshore," March 9, 1987.*

[49]*Fred Klancnik and William Brose, "Lakefront Renaissance,"* Civil Engineering—ASCE, *Volume 80, July 2010.*

[50]*Milwaukee County Office of Emergency Management,* op. cit.

As discussed in the sections above, Lake Michigan water levels have risen more than four feet since January 2013. In addition, climate change may lead to more drastic fluctuations in Lake Michigan water levels. Over the five-year period covered by this plan update, Lake Michigan water levels, which are currently higher than average, are expected to fluctuate. Potential future fluctuations in Lake Michigan water levels could lead to erosion, particularly in areas that have no shoreline protection, where shoreline protection structures are not maintained adequately, or where shoreline protection structures are not built to sufficient specifications to protect against fluctuating water levels. These fluctuations could also damage shoreline protection structures, especially where they are not adequately maintained or designed to protect against fluctuating water levels. Mitigation measures to protect areas along the Lake Michigan coast are described further in Chapter V.

Changes over the 20th century and projections based on downscaled results from climate models indicate that there will likely be changes affecting coastal conditions over the 21st century. Coastal areas have experienced, and are projected to experience, increases in air temperatures; increases in precipitation, especially during fall, winter, and spring months; and increases in the frequency of heavy precipitation events. Wind strengths have increased over the Great Lakes and are expected to continue increasing into the future.[51] In addition, wind patterns over Lake Michigan have shifted. Prevailing winds during summer months shifted from coming from the southwest during the 1980s to coming from the east after 1990.[52] These climatic changes are expected to influence Lake levels, coastal erosion, flooding, and shoreline stability, sometimes in complex ways.

For example, Lake Michigan is likely to be impacted by trends that act both to increase and to decrease water levels. Increased precipitation[53] will increase water contributions to the Lake. At the same time, increases in temperatures will lead to increases in evaporation of water from the Lake. The temperature increase will also result in reduced ice cover over the winter. This affects evaporation because ice cover on the Lake acts as a cap, reducing evaporation by preventing water vapor from escaping into the air. As a result of both of these processes, evaporation from the Lake is projected to increase. It is expected that the increases in evaporation will eventually be greater than the increases in precipitation. As a result, average water levels in Lake Michigan are expected to decrease by about 0.8 to 1.4 feet by the end of the 21st century. It should be noted that water levels in the Lake vary widely about their average, with high-water and low-water decades occurring. This variability is expected to

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[51]*Desai, Austin, Bennington, and McKinnley, 2009,* op.cit.

[52]*James T. Waples and J. Val Klump, "Biophysical Effects of a Decadal Shift in Summer Wind Direction over the Laurentian Great Lakes,"* Geophysical Research Letters, *Volume 29, pages 43-1 through 43-4, 2009.*

[53]*Wisconsin Initiative on Climate Change Impacts, 2011,* op. cit. *The WICCI report indicates there is a 75 percent probability that average annual precipitation will increase under mid-century climate change conditions.*

continue. By the end of the century it is expected that highest and lowest water levels will be slightly lower than they have been over the past 100 years.

While the hazard impacts associated with water level variations should be similar in type to those impacts currently resulting from water level variations, there may be some increase in the magnitude of these impacts. While low water levels may allow beaches and beach ridges to build and beach-anchoring vegetation to move toward the Lake, they may also adversely impact shipping, power generation, and tourism. It should be noted that long periods of low water levels may lead to erosion of the lakebed, which may allow storm-generated waves to reach farther inland when water levels rise. While high water levels may benefit communities, businesses, and industries that depend upon Great Lakes waters for commercial shipping, recreational boating, and tourism, higher water levels with increased storm frequency and intensity could increase shoreline and bank erosion. This could increase damages to lakefront property and reduce the area of beaches.

Several other elements of climate change may also act to intensify shoreline erosional processes. Increases in wind strength over the Lake and changes in prevailing wind direction are likely to lead to greater offshore wave development. This will produce higher waves along the coast. Changes in several elements of climate may affect the stability of bluffs along the lakeshore. The amount of water contained in bluff soils is an important factor determining their stability. Friction between soil particles hold them in place. As water fills the spaces between these particles the friction between soil particles decreases, causing the soil to become more fluid and less stable. Higher Lake levels and increases in 1) precipitation, 2) the frequency of heavy storms, and 3) the number of freeze-thaw cycles will all contribute to shoreline bluffs becoming less stable and more susceptible to slumping. Prolonged dry periods and droughts may also contribute to reduced stability of coastal bluffs. As bluff soils dry out, cracks in the soil can form, weakening the surface soil. During long-term droughts, these cracks can develop into deep fractures. Such fractures can allow surface water to penetrate deep into bluff soils. If heavy rainfall events occur following a drought, they may cause rapid saturation of dry, fractured bluff soils, which could cause a major slope failure.

VULNERABILITY ASSESSMENT FOR WINTER STORMS

Winter storms can vary in size and strength and include heavy snow storms, blizzards, freezing rain, sleet, ice storms, and blowing and drifting snow conditions. Extremely cold temperatures accompanied by strong winds can result in wind chills that cause bodily harm, such as frostbite and death. A variety of weather phenomena and conditions can occur during winter storms. For clarification, the following are National Weather Service approved descriptions of winter storm elements:

- **Heavy Snowfall**—The accumulation of six or more inches of snow in a 12-hour period or eight or more inches in a 24-hour period.

- **Blizzard**—An occurrence of sustained wind or frequent gusts 35 mph or higher accompanied by falling or blowing snow, and visibilities of one-quarter mile or less, for three or more hours.

- **Ice Storm**—An occurrence of rain falling from warmer upper layers of the atmosphere to the colder ground, freezing upon contact with the ground and exposed surfaces, resulting in ice accumulations of one-quarter inch or more within 12 hours or less.

- **Freezing Drizzle/Freezing Rain**—The effect of drizzle or rain freezing upon impact on objects that have a temperature of 32ºF or below.

- **Sleet**—Solid grains or pellets of ice formed by the freezing of raindrops or the refreezing of largely melted snowflakes. This ice does not cling to surfaces.

- **Wind Chill**—An apparent temperature that describes the combined effect of wind and low air temperatures on exposed skin.

Much of the snowfall in Wisconsin occurs in small amounts, between one and three inches per occurrence. Heavy snowfalls that produce at least eight to 10 inches of widespread accumulation occur, on average, only once per winter season across southern Wisconsin. In addition, a snowfall event of six to eight inches usually occurs once per winter. The northwestern portion of Wisconsin receives most of its snow during early and late season storms, while southwestern and southeastern counties receive heavy snows more often in mid-winter. Snowfall amounts in the City of Milwaukee average 47.5 inches per season.

Historic Winter Storm Problems

True blizzards are not common in Wisconsin. However, when they do occur, they tend to affect the eastern counties near Lake Michigan. Due to less frictional drag over Lake Michigan, northwest wind storms can reach higher speeds. Blizzards are more likely to occur in northwestern Wisconsin than in southern portions of the State, even though heavy snowfalls are more frequent in the southeast. Blizzard-like conditions often exist during heavy snowstorms when gusty winds cause severe blowing and drifting of snow. Heavy snow and ice storms have been a part of nearly every winter in the City of Milwaukee history (see Milwaukee County Pre-Disaster Mitigation Plan).[54] As listed in Table III-22, there have been 148 major winter storm events reported since January 1993. All of these storms contained some form of snow, sleet, freezing rain, or slippery road conditions. A heavy snowstorm may cause schools and businesses to close, delay or cancel airline flights, and create treacherous roadway travel conditions.

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[54] *Milwaukee County Office of Emergency Management,* op. cit.

In March 1976 a disastrous ice storm occurred in the southern portion of the State. This storm was of such magnitude and caused such a significant amount of damage that a Presidential Disaster Declaration was obtained. This storm affected 22 counties, resulted in extensive power outages and caused over $50 million in damage. Near-blizzard conditions occurred in January 1979 when record snowfalls were recorded in many areas of the State and winds gusted to over 30 mph. Many persons were isolated from assistance and services as roads drifted shut and highway crews were unable to keep them open. Conditions were extremely hazardous in the City of Milwaukee where a Presidential Emergency Declaration was obtained to assist in snow removal operations. The winter of 1981-1982 recorded a storm event, with extremely cold temperatures, accompanied by high winds gusting to 50 mph. Wind chill factors reached 100 degrees below zero and severely affected the health and safety of those who ventured outdoors.

Description of Recent Winter Storm Events

Generally, the winter storm season in Wisconsin occurs between October and March. Severe winter weather has occurred, however, as early as September and as late as the latter half of April and into May in some locations in the State. The average annual duration of snow cover in the City of Milwaukee is approximately 85 days. As previously noted, since 1993, there have been 148 winter storms recorded in the City of Milwaukee, or about 3.1 per year.

Ice and sleet storms can occur at any time throughout the winter season from October to April. The majority of these storms occur in west-central to east-central Wisconsin, based on data from 1982-2008. In a typical winter season there are three to five light freezing rain events. A major ice storm occurs about once every other year somewhere in the State. If one-half inch of rain freezes on trees and utility wires, extensive damage can occur, especially if accompanied by high winds that compound the effects of the added weight of the ice. There are also between three and five instances of glazing (less than one-quarter of an inch of ice) throughout the State during a normal winter.

The winter of 1998-1999 was considered mild. However, a heavy snowfall occurred January 1-3, 1999, and more than 10 inches fell in most southern counties with parts of Milwaukee, Racine, Kenosha, Ozaukee, Walworth, Washington, and Waukesha Counties receiving more than 18 inches of snow. A recent blizzard occurred December 2-4, 1990, depositing 10 or more inches of snow across the central and southern portions of the State. This excessive snowfall throughout such a large area of the State severely taxed capabilities to clear and remove snow.

December 2000 was one of the 10 coldest Decembers on record for most of the State. In addition, record or near record snow depths of 15 to 34 inches occurred in much of southern Wisconsin during December. The City of Milwaukee registered 49.5 inches in snowfall for the month of December alone and was included in a Presidential Emergency Declaration area.

Two heavy snowfalls occurred in the City of Milwaukee during January 2005. Over the period from January 4 through 6, 2005, low pressure in the southwestern United States pulled large amounts of moisture from the Gulf of Mexico and eastern Pacific Ocean over a stationary front located over Illinois, Iowa, and Missouri. Widespread heavy snow developed in northern Illinois and moved into southern Wisconsin, resulting in heavy snowfall in Milwaukee. Accumulations of snow were between eight and 10 inches in most of Milwaukee County, with a total of 12 inches reported at the University of Wisconsin-Milwaukee campus. Heavy snow also developed in south-eastern Wisconsin on the evening of January 21, 2005, and persisted into January 22. Snowfall rates overnight were in the two to three inch per hour range at times. Total snow accumulations in Milwaukee County generally ranged from 12 to 16 inches. After the storm was over, lake effect snow produced an additional three to four inches of snow across the Region for a two-day total accumulation of 10 to 16 inches. In addition to heavy snow, winds began to strengthen to 20 to 30 miles per hour, with gusts up to 45 miles per hour, by the morning of January 22. This produced considerable blowing and drifting snow and blizzard conditions at times. Although hundreds of traffic accidents were reported, the storm swept through on a Friday night and road crews had an easier time clearing roadways on Saturday without the presence of rush hour traffic.

The 2007-2008 winter season in Wisconsin was "one-for-the-ages." Numerous winter storms, including a couple blizzards and four ice storms, pounded the southern half of the State. Winter snowfall totals of 70 to 122 inches across the southern counties established new all-time winter snowfall records at many locations. Most of Milwaukee County received in excess of 90 inches of snow during this winter, and much of the City of Milwaukee received over 110 inches. These totals were roughly 200 to 240 percent of normal. The worst storm of the winter occurred on February 5 and 6, 2008, southeast of a line from Dubuque, Iowa to Madison to Sheboygan where 12 to 21 inches of snow were deposited. Two-day snowfall totals in and near the City of Milwaukee ranged from about 13 inches at General Mitchell International Airport (GMIA) to over 17 inches at the City of West Allis. On February 6, snowfall at GMIA totaled 11.6 inches, breaking the old daily record of 8.3 inches set in 1974. Several roads in southeast Wisconsin were closed by the intense snowfalls and blowing snow. Milwaukee County was included in a Presidential Emergency Declaration. The City of Milwaukee received about $939,710 in Federal funds and about $156,618 in State funds for extraordinary expenses associated with clearing roads and emergency response efforts.

A clipper-type low pressure system passing to the southwest and south of Wisconsin resulted in widespread snow across southern Wisconsin on February 9 and 10, 2010. A second low that had moved northeastward from Texas merged with the clipper system over western Ohio and deepened. This resulted in increasing northeast winds, and with a favorable fetch down Lake Michigan, produced lake enhanced snow that boosted snow totals over eastern Wisconsin. Southeastern Wisconsin received widespread eight to 14 inches. The heaviest snow of 10 to 14 inches fell along and east of a line from northwest Sheboygan County near Elkhart Lake, through Hartford in

Washington County, the City of Waukesha in Waukesha County, and Union Grove in western Racine County to Silver Lake in western Kenosha County. While the highest snow total from the storm was 15.0 inches near the Village of Belgium in Ozaukee County, slightly lower totals were reported near Milwaukee, with 13.4 inches falling in the City of West Allis in Milwaukee County. Over 250 traffic crashes, spin-outs and collisions were reported. One fatality related to the storm occurred in Milwaukee County, where a 73-year old man with a history of heart problems died shortly after shoveling snow.

During the overnight hours of February 1 and 2, 2011, a powerful low-pressure center produced blizzard conditions across much of southern Wisconsin. Prior to the blizzard, several inches of snow fell on January 31, with light lake effect snow through the day on February 1. Snow associated with the system began in the mid-afternoon hours on February 1 in far southern Wisconsin and pushed northward into the State through the evening. Very strong winds were associated with the storm for an extended period of time. Two-day snowfall totals in the City of Milwaukee ranged between 12 and 20 inches, with 16.1 inches reported at GMIA (Figure III-9). Peak wind gusts of 60 miles per hour were reported at GMIA. Snow drifts of three to 12 feet were common, with reports of some drifts reaching 12 to 15 feet in open rural areas. Drifting snow closed Interstate 94 (IH-94) from the Illinois border north to Milwaukee, and IH 43 from Beloit to Mukwonago, with many stranded motorists having to be rescued from vehicles buried in the drifting snow. In response to this, the Wisconsin Division of Emergency Management issued a Civil Danger Warning concerning the dangerous driving conditions. The storm, known as the Groundhog's Day blizzard, had several impacts. Most flights in and out of GMIA were canceled until later in the day on February 2. Milwaukee area law enforcement reported 24 vehicle accidents, with two injuries and 47 disabled vehicles. Emergency rooms across southeastern Wisconsin reported dozens of heart attacks and injuries from snow blower accidents. Three Milwaukee area men, two with heart problems, died while shoveling snow. Numerous businesses were closed. At the height of the storm, We Energies reported 5,200 customers were without power across southeast Wisconsin. Wind gusts damaged at least five metal panels, siding, and a roll-down door on a large storage pole shed at the Port of Milwaukee. The Governor issued an emergency declaration for 29 counties and ordered the mobilization of about 100 National Guardsman to rescue stranded motorists and run emergency shelters at armories.

Low pressure and lake enhanced snow brought three to six inches of powdery snow to southern Wisconsin on December 8, 2013. Hundreds of vehicle accidents occurred, especially in the Milwaukee metropolitan area. These included several pile-ups, including a 41 vehicle pile-up on IH-894 at Greenfield Avenue in the City of West Allis. The weather was cited as a contributing factor in three deaths.

On December 28, 2015, a winter storm affected southern Wisconsin as strong low pressure tracked from the Mississippi River Valley to northeast Illinois and southern Michigan. Most areas received five to 10 inches of wet snow and sleet combined, with sleet accumulations of up to two inches in some areas. East to northeast wind gusts of 30 to 45 mph occurred restricting visibility to between one-quarter and one-half mile. As a result of this storm, more than 300 accidents occurred on interstate and State highways. These occurred mostly in the Milwaukee and Madison areas. Two men collapsed and died while shoveling on the afternoon of December 29 in Milwaukee County. A golf dome was damaged by the weight of the heavy snow in Milwaukee County.

Vulnerability and Community Impact Assessment

Based on events reported from 1993 to December 2016, it is estimated that the City of Milwaukee experiences on average approximately 6.3 winter storm events each year. Winter storms present a serious threat to the health and safety of affected citizens and can result in significant damage to property. Snow and ice are the major hazards associated with winter storms and are the eighth most destructive natural hazard in Wisconsin. Snow and ice can cause traffic accidents, bring down telephone and power lines, damage trees, impede transportation, burst water pipes, and can tax the public's capabilities for snow removal during heavy storms. A major winter storm can have a serious impact on a community. Loss of heat and mobility are key complications that contribute to winter storm fatalities.

Ice storms and freezing rain are less common than snow, but produce road conditions that can make travel hazardous as shown in Table III-23. Even fog or mist on cold roads can produce a glaze of ice that makes travel slippery and dangerous. Accumulated ice can cause the structural collapse of buildings, bring down trees and power lines, causing property damage, loss of power, and isolate people from assistance or services.

A review of the community assets described in Chapter II indicates there is a potential for winter storm hazard events to impact: 1) residents at a citywide level, 2) roadway transportation system, 3) utilities, and 4) the operation of critical community facilities. In addition, the Milwaukee County Pre-Disaster Mitigation Plan concluded that winter storm hazards are one of the greatest risks to the population and infrastructure within Milwaukee County.[55]

In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion.[56] About $20.7 billion of this total is comprised of buildings and other improvements. Due to the unpredictability of winter storm events, all buildings, infrastructure, and critical facilities within the City are considered at risk. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

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[55]Ibid.

[56]*Wisconsin Department of Revenue.*

Potential Future Changes in Winter Storm Conditions

Based upon historical data, the City of Milwaukee can expect to experience an average of 6.3 winter storm events per year as documented by the National Climatic Data Center. It should be noted that the historical record shows considerable variation among years in the number of events that occurred. While it would be expected that in some years the City will experience fewer events or more events than the average number, the average annual number of events is not expected to change.

Changes over the 20th century and projections based on downscaled results from climate models indicate that there will likely be changes in winter storm conditions affecting the City of Milwaukee over the 21st century. It is projected that by 2055, the average amount of precipitation that the City receives during the winter will increase by about 0.5 to 1.0 inch, an increase of about 25 percent. Due to increasing winter temperatures, the amount of precipitation that falls as rain during the winter rather than as snow is projected to increase significantly. It is also projected that freezing rain will be more likely to occur.

It should also be noted that the likelihood of lake effect snow occurring could be affected by climate change. A lack of ice cover over Lake Michigan during the winter promotes the development of lake effect snow. Rising temperatures during the winter will reduce the frequency and extent of ice cover over the Lake. Because the increase in temperature may also result in some of this precipitation falling as rain, it is not clear whether this will lead to an increase in the frequency of lake effect snow events.

VULNERABILITY ASSESSMENT FOR CONTAMINATION OR LOSS OF WATER SUPPLY

Water supply systems are among the most important infrastructure facilities affecting the economic development and environmental quality of the City of Milwaukee. Such systems directly affect the health and welfare of the resident and transient populations of an area, and the viability of commercial and industrial activities in an area. Accordingly, the availability of an ample supply of high-quality water for domestic, commercial, and industrial use and the protection and wise use of the available sources of supply were ranked high in priority votes by the City of Milwaukee Hazard Mitigation Steering Committee.

As noted in Chapter II, Approximately 98 million gallons per day (mgd) of Lake Michigan surface water are utilized as the source of supply by all water users in the City of Milwaukee. An ample supply of clean, wholesome water is essential to urban development. Indeed, without a reliable water supply, urban areas become unhealthy places in which to live and work, subject to epidemics of such waterborne diseases as cholera, dysentery, typhoid fever, and parasitic infections, such as *Cryptosporidium*. In addition to providing safe drinking water, a reliable water supply system is also essential in other ways to good sanitation in urban areas. An adequate and reliable water supply system is essential for bathing, laundering, and other forms of cleaning and washing, and provides the basis for the water carriage system of sanitary sewage conveyance essential to a high level of quality in urban life. An adequate and reliable water supply system is essential to good fire protection, and is also essential to all types of commercial and industrial development.

As noted above, the City of Milwaukee relies almost exclusively on surface water from Lake Michigan as its main water source. As a division of the Department of Public Works, Milwaukee Water Works operates two water treatment plants with the capability of processing 275 million gallons per day. The City's water treatment plants have been upgraded over the past 25 years, including the installation of a state-of-the-art disinfection system. The plants are considered to be well maintained and have recently installed substantial plant security facilities and programs.

Water Supply Issues

Water Main Breaks

Breaks in water mains can interrupt water supply. Depending on the size and location of the main, the effects of a break can either be local or have a large effect on a portion of the distribution system. The Milwaukee Water Works reported experiencing an average of 571 water main breaks per year over the period from 2008 through 2017.

Because of the intense cold associated with a polar vortex, the Milwaukee Water Works experienced an exceptionally high number of breaks in water mains during the winter of 2013-2014. During the months of January through March 2014, the utility had at least 553 breaks. This is about 2.3 times the 10-year average for this three-month period.

Lead Service Lines and Plumbing Fixtures

Lead is a toxic metal that is commonly found throughout the environment in lead-based paint, air, soil, food, and water. Lead in drinking water at high enough levels can pose a significant health risk, especially in young children and pregnant women. Children that are exposed to high levels of lead may experience stunted mental and physical development. Lead exposure has also been linked to deficits in attention span and learning abilities. Excessive levels of lead in adults can damage the nervous system, brain, kidneys, red blood cells, and reproductive system. Most drinking water sources in the State of Wisconsin, both groundwater and surface water, have little or no measurable lead levels. However, prior to passage of a State law in 1984, lead solder was used extensively in the construction of many household plumbing systems in the State. Some drinking water fixtures were manufactured with lead until 1996. Plumbing materials such as lead pipes, lead based solder used to join copper pipes, faucets, and lead service lines connecting the home to the water main are common in older homes. Water within plumbing systems will continuously dissolve the lead that it contacts. The rate at which lead dissolves can vary greatly depending on the age of the plumbing system and corrosive characteristics of the water. When water stands in pipes for an extended period of time, lead concentrations in the water can increase substantially.

Municipal water utilities are required by the WDNR to regularly test their water supply for lead. Under Section NR 809.54(3) of the Wisconsin Administrative Code, the lead action level is exceeded if the concentration of lead in more than ten percent of tap water samples collected during any monitoring period is greater than 15 µg/l. Thus, if the 90th percentile lead concentration is greater than 15 µg/l, the utility would be out of compliance with the WDNR lead standards.

Most homes built before 1951 in the City of Milwaukee have lead service lines. Properties served by about 75,000 service lines in the City receive water through active lead service lines.[57] This constitutes about 44 percent of the service lines served by the Milwaukee Water Works. To reduce lead release from pipes and plumbing fixtures, the Milwaukee Water Works adds anticorrosion agents to municipal water as part of its treatment process.

In addition, there are other potential sources of lead in potable water. Plumbing fixtures in many buildings contain lead solder. For example, although none of the Milwaukee Public Schools (MPS) have lead service lines, some faucets and drinking fountains at these schools contain lead solder and have corroded plumbing. This can result in elevated concentrations of lead in drinking water. MPS tests samples from plumbing fixtures for concentrations of lead. When water samples are found to exceed regulatory levels for lead, the MPS takes the source fixtures out of service for repair or replacement.

Medical professionals warn that any level of lead in drinking water can pose serious health risks to vulnerable persons. Lead exposure has been linked to severe and permanent brain damage in children, and is associated with miscarriages among pregnant women. The dangers of lead in drinking water have been shown in Flint, Michigan, where corrosive characteristics from a new water supply caused lead levels in the drinking water to increase substantially. The increase in lead levels caused the rate of lead poisoning among children in Flint to double, going from 2.4 percent to 4.9 percent in 2015. Research conducted on lead service lines in Flint confirmed that lead leached into the water system because the water was not treated to prevent the corrosion of the toxic metal. State and Federal officials declared a state of emergency in the Flint region due to the alarming rise of lead levels in drinking water and children's blood.

Cross-connections

Cross-connections are actual or potential connections between potable water supplies and a source of contamination. The most common form of cross-connection is a garden hose, which is easily connected to the public water supply system and can be used to apply a variety of potentially dangerous substances, including chemicals and fertilizer. Other common potential cross-connections include dishwashers, toilets, pressure

[57] *Jennifer Gonda, "Lead Service Lines and the Challenges of Aging Water Infrastructure," presentation at* Navigating the Future of Water Conference, *October 19, 2017, Milwaukee, Wisconsin.*

washers, boilers, pools, and lawn sprinkler systems. Water normally flows in only one direction in a plumbing system; however, under certain conditions, such as backsiphonage or backpressure, water can flow backwards, contaminating potable water supplies within a building or within a water distribution system. Backsiphonage may occur due to a loss of pressure in a water utility distribution system. Such a pressure loss can occur due to a water main break, a repair to the distribution system, or a firefighting emergency. This can create a siphon in a plumbing system which can draw water out of a sink or bucket back into a building's water system and into the municipal system. Back pressure may be created when a source of pressure such as a boiler or a pump creates pressure greater than pressure supplied through the public water system. This may cause contaminated water to be pushed into a building's water system and into the municipal system. State plumbing codes require that approved backflow prevention methods be installed at every point of potable water connection and use.

Vulnerability and Community Impact Assessment

The potential for water supplies to be interrupted could be due to the following factors:

- Contamination of the Lake Michigan surface water source in the vicinity of the water supply intakes used; and
- Major facility malfunction or shutdown.

In addition, water supplies could be locally interrupted due to water main breaks. The impact of such a break would depend upon the size and location of the affected water main. Local contamination could result from backflow due to cross-connections or release of lead from service lines. While contamination from an individual service line would most likely be restricted to the building or buildings served, the fact that a substantial portion of the service lines in the City are composed of lead suggests that this could have a large impact on drinking water quality experienced by residents of the City.

Lake Michigan has historically been a source of safe drinking water. However, no one can guarantee that an accident will not happen, and a mishap can have serious consequences. In 1993, the City of Milwaukee's public water supply became contaminated with *Cryptosporidium*, a parasite found in animal wastes. Nearly half of the 850,000 consumers were infected, 4,400 people were hospitalized, and at least 69 people died, making this the largest documented waterborne outbreak in U.S. history (Wisconsin Division of Health, 1996). Although the exact source of the *Cryptosporidium* that caused this outbreak is still uncertain, the total cost of the outbreak associated illness was estimated at about $37 million in medical costs and $77 million in productivity losses.[58] As

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[58]*Phaedra S. Corso, Michael H. Kramer, Kathleen A. Blair, David G. Addiss, Jeffrey P. Davis, and Anne C. Haddix,* Cost of Illness in the 1992 Waterborne Cryptosporidium Outbreak, Milwaukee, Wisconsin*, Emerging Infectious Diseases, Volume 9, No. 4, April 2003. Costs and losses adjusted to 2010 dollars.*

previously noted, the City of Milwaukee has, over the past 15 years, upgraded its treatment and monitoring water quality systems that include the installation of a state-of-the-art disinfection equipment. This upgrading and related actions are considered to be a sound basis for mitigating potential water quality problems, and based on current and ongoing safety measures, the probability of future events is negligible.

Typically, water supply facilities have a history of safe operation with minimal malfunctions or shutdowns. The industry has been known for providing continuous service due to the use of high-quality and redundancy in equipment. However, the facilities are always subject to the potential for an unanticipated event which could interrupt services. During the last several years, water utilities, including the City of Milwaukee Water Works and related organizations, such as the American Water Works Association and the Wisconsin Department of Natural Resources, have increased efforts to evaluate vulnerability of water supply facilities to a wide range of hazards, including acts of terrorism. The focus of these efforts has been directed toward preparation of vulnerability assessments and emergency response and mitigation plans for each facility.

VULNERABILITY ASSESSMENT FOR HAZARDOUS MATERIALS INCIDENTS

This type of hazard occurs with the uncontrolled release or threatened release of hazardous materials or substances from a fixed site or during transport that may adversely impact public health and safety and/or the environment.

Understanding the potential health effects associated with exposure to a hazardous material contaminant can be complicated and involves determining who may be exposed, how they may be exposed, and how long the exposures may last. Individuals are also known to react differently to chemical exposures depending upon their age and health. In addition, different effects may occur depending on whether a chemical is ingested versus being inhaled and the duration of exposure. There are several ways in which chemicals may enter the human body and cause detrimental health effects as summarized below:

- Inhalation-breathing the chemical into the lungs;
- Ingestion-swallowing contaminated food, water, or medication, or other chemicals;
- Absorption-assimilation through direct contact with the skin, lungs, and eyes, or indirect contact with clothing or other contaminated items; and
- Injections-penetration through the skin, much less common than other modes of exposure, but can possibly occur due to an explosion or some other type of accident.

In dealing with chemical contaminants, there are two types of exposure, namely, acute and chronic exposure. Acute exposure is defined as short-term, high-level exposure and the effects are usually immediate, whereas chronic exposure is defined as long-term, level exposure and the effects may take years to appear. Both are dangerous and have immediate and long-term health implications. General symptoms of toxic exposure can include, but are not limited to, dry and red skin upon contact, irritation of the eyes or lungs, headache, nausea, drowsiness, dizziness, insomnia, confusion, and tremors. Nonetheless, this report is only dealing with acute exposure.

In some instances, contamination can occur from legacy sources. As described in Chapter II of this report, there is one remediated Superfund site in the City of Milwaukee, the Moss-American site along the Little Menomonee River. The U.S. Environmental Protection Agency (USEPA) completed remediation activities at this site in 2009. Two additional sites in the City are being addressed through the Superfund: the Burnham Canal-Miller Compressing Company site and the Solvay Coke and Gas site. Neither are on the National Priorities List. Both of these sites are described in Chapter II.

Fixed Facilities

Over the past several decades, the use of chemicals has increased in nearly every sector of the economy. As a result, hazardous materials are present in quantities of concern in business and industry, agriculture, universities, hospitals, utilities, and other facilities in the State. There are no areas of the State that are exempt from a possible hazardous material incident. Despite extensive precautions taken to ensure careful handling during manufacture, transport, storage, use, and disposal, accidents and inadvertent releases are bound to occur. The potential impacts of such releases include short and/or long-term health hazards to those exposed, explosions, fires, and environmental contamination. An incident may also necessitate short- or long-term evacuation, which disrupts the social and economic aspects of the affected area.

The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 also known as SARA Title III, brings industry, government, and the general public together to address emergency preparedness for accidental chemical releases. The EPCRA program requires communities to prepare for hazardous chemical releases through emergency planning. This plan provides essential information for emergency responders and creates a database of hazardous chemical storage information for the community. The community right-to-know aspect increases public awareness of chemical hazards in their community and allows the public and local governments to obtain information about these chemical hazards.

In Wisconsin, facilities that use, store, or produce chemicals at or above the threshold quantities are required to submit a Tier II Reporting Form to the State Emergency Response Board (SERB), Local Emergency Planning

Committee (LEPC), and the local fire department.[59] This form is usually a one or two page document, depending on the number of chemicals being reported. Basic information asked for includes the facility name and address, emergency contact person and phone number, chemical names and quantities. The SERB sends the forms out by mid-January each year and they are due back by March 1st of that same year. Failure to receive a form does not absolve a facility from their reporting obligations. A facility can be a factory, school, gas station, community center, or hospital. Farm co-ops are exempt from reporting fertilizers and retailers are exempt from reporting goods packaged for resale. Although there are some exemptions, mainly for retailers, a facility that uses, stores, or produces hazardous chemicals may have to report the chemicals stored. However, it should also be noted that the Federal government no longer requires retail gas stations to report.

Under EPCRA, a hazardous material is defined as any chemical that is a physical hazard or health hazard for which the Occupational Safety and Health Administration (OSHA) requires a facility to maintain a Material Safety Data Sheet (MSDS). Under EPCRA there is no specific list of hazardous materials, but some of the most common hazardous chemicals include propane, kerosene, fuel oil, motor oil, and gasoline. If a facility stores 10,000 pounds or more of these products the owners are required to file a report. Under the law, there are two categories of regulated chemicals: hazardous substances and extremely hazardous substances (EHS). EHS chemicals are found on an Environmental Protection Agency list of approximately 366 substances. Common EHS chemicals include chlorine, sulfuric acid, anhydrous ammonia, and nitric acid. Unlike the more common hazardous substances, the minimum reporting quantities will vary depending on the chemical.

Transportation

The list of hazardous materials is extensive. However, the bulk of products being transported are petroleum products (gasoline, diesel fuel, jet fuel, fuel oil, asphalt, creosote, and propane), chemicals used for industrial or manufacturing processes (anhydrous ammonia, sulfuric acid, and chlorine) and waste products (industrial waste, food waste, medical waste, and animal waste). There are numerous other hazardous materials routinely transported in smaller quantities, such as pesticides, herbicides, and specialized industrial chemicals. The majority of releases are the result of transportation accidents. However, many minor releases are the result of illegal dumping of waste materials.

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[59]*Wisconsin Emergency Management, Emergency Planning and Community Right-to-Know Act Section, Planning Threshold: Facility has an extremely hazardous substance present at any one time in an amount equal or exceeding the chemical-specific threshold planning quantity (TPQ). Reporting Threshold: Facility has 10,000 pounds of a hazardous substance or either 500 pounds or the threshold planning quantity of an extremely hazardous substance present at any one time and is not exempt from reporting requirements.*

Demand for established and new chemical substances in all walks of life has resulted in extensive hazardous materials shipments within and through Wisconsin communities daily. The major overland modes of transportation are highways, railroads, and pipelines.

Highways

Trucks are the most common way of transporting hazardous materials, accounting for more than 90 percent of all hazardous materials shipments nationwide according to the U.S. Department of Transportation. Various fuels are the most common cargo that are classified as hazardous. Every roadway in Wisconsin is a potential route for hazardous material transport. IH 94 spans the eastern portion of the City of Milwaukee between the densely populated Milwaukee-Chicago corridor. Large tankers conducting inter- and intra-state transportation of hazardous materials and substances use this highway extensively.

Rail

There are four railroad companies that operate in the City of Milwaukee, as shown on Map II-6 in Chapter II. Rail is used for the transport of hazardous materials because of large-load capabilities. Rail transport routes pass through the areas east of IH 94, the Menomonee River Valley, and other portions of the City.

It should be noted that the shipment of crude oil by rail has increased as domestic oil production has increased. The typical train carrying crude oil is over a mile long and consists of 100 or more cars. Each of these cars typically carry 30,000 gallons of crude oil. Much of the increased domestic crude oil production consists of Bakken crude oil. This oil comes from a rock formation located in the States of North Dakota and Montana and the Canadian Provinces of Manitoba and Saskatchewan. Derailments and incidents involving trains carrying crude oil may pose challenges for responding organizations. Such an incident could potentially involve the release and/or ignition of thousands of gallons crude oil. Crude oil is not a uniform substance and its physical and chemical properties can vary based upon where it was produced. Crude oil often contains flammable gases, whose presence can reduce the effectiveness of traditional firefighting techniques. Responses to crude oil incidents may require specialized outside resources that will take time to arrive to the site of the incident.

On May 1, 2015, the U.S. Department of Transportation issued rules related to enhanced tank car standards and operational controls for high-hazard flammable trains.[60] Key provisions include enhanced braking systems for trains considered high-hazard flammable trains (HHFT), enhanced design standards for new tank cars, retrofitting of existing tank cars, and operating speeds of HHFTs being limited to 50 mph in most areas and 40 mph in high-threat urban areas.

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[60] *49* Code of Federal Regulations, *Parts 171, 172, 173, 174, and 179.*

Pipeline
Natural gas service is provided for the entire City of Milwaukee by the We Energies-Gas Operations. We Energies is the primary distributor of natural gas. In the City of Milwaukee the main gas supply is primarily provided for by ANR Pipeline Company which owns main and branch gas pipelines in the City of Milwaukee and the surrounding area. In addition, the We Energies natural gas system is connected to other major gas pipelines outside of, but in the vicinity of, the City of Milwaukee.

It should be noted that natural gas service and selected other hazards could be vulnerable to events, such as earthquake or an act of terrorism. Such possibilities should be considered as facility and system redundancy is carried out.

An incident involving any one of the above modes of hazardous material transport could result in a local emergency, with the potential to affect large numbers of people. The potential effects include health hazards to those exposed to the hazardous materials, explosions, major fires, and environmental contamination. An incident may necessitate short- or long-term evacuation that would disrupt the affected area. Accidents on major transport arteries can disrupt or stop traffic for extended periods of time. In the State of Wisconsin there were 10,632 transportation-related hazardous material incidents reported over the period 1971 through 2014.[61] These incidents resulted in 11 deaths and 308 injuries. In about 75 percent of these incidents, there was no damage to property. Property damages in those incidents that had damages ranged up to about $6.9 million (2016 dollars). The total damages reported as resulting from these incidents were about $62.5 million and the average amount of reported damages per incident was about $5,880.

Port of Milwaukee
As described in Chapter II, the Port of Milwaukee is a regional transportation and distribution center which handles a diverse mix of general cargos. Because of its cargo mix and current safety precautions and measures, it is generally considered to be at low risk in regard to potential hazardous materials or terrorism incidents. Nevertheless, the Port is an important facility which requires substantial consideration with regard to law enforcement, fire suppression, and rescue and emergency operations. The City of Milwaukee Police and Fire Departments and the U.S. Coast Guard are involved directly in providing protection services to the Port of Milwaukee. In addition, the Port of Milwaukee is subject to certain Federal regulations, including the Maritime Transportation Security Act, Public Law 107-295. In accordance with these regulations, and related guidelines, all major ports have developed an Area Maritime Security Plan and established an Area Maritime Security Committee. This plan and committee are intended to address security issues at the Port facilities. In addition, in

[61] *U.S. Department of Transportation Pipeline and Hazardous Material Safety Administration Incident Report Database, accessed on December 20, 2016.*

2017 the U.S. Coast Guard in cooperation with the U.S. Environmental Protection Agency updated their Area Contingency Plan for the Lake Michigan Shoreline.[62] This plan is a tool used to assist and coordinate a response to an oil or hazardous material spill or release into or near the Lake. Thus, the ongoing actions at the Port of Milwaukee related to security are considered to be a component of this hazard mitigation plan.

Description of Recent Hazardous Materials Incident Events

Between 2014 and 2015, the City of Milwaukee averaged 90 hazardous material spills or releases per year. Almost all of these spills and releases were minor incidents. The majority of these incidents involved gasoline, diesel fuel, engine waste oil, mineral oil, or other petrochemical substances.

Over the period 1971 through 2016, 1,715 transportation-related hazardous materials incidents were reported in the City of Milwaukee.[63] Most were relatively minor. One of these incidents resulted in two deaths and another resulted in one death. Forty-five of these incidents resulted in a total of 114 injuries, although four of the incidents required hospitalization. Property damage was reported in 293 incidents, with the total damages reported being $3.06 million in 2016 dollars. While most of these incidents occurred on roadways, 34 occurred on railways and 70 were air travel-related.

A total of 35 pipeline incidents have been recorded in the City of Milwaukee during a 46-year period between 1971 through 2016.[64] These events and the resulting fatalities, injuries, and damages are listed in Table III-24, based upon data published by the Federal Department of Transportation, Office of Pipeline Safety. As shown in Table III-24, the long gap in events between 1992 and 2005 demonstrates that there is a very low probability of occurrence for these events within the City of Milwaukee. In total, these pipeline incidences have resulted in no deaths, 30 injuries, and more than $17 million in property damages within the City of Milwaukee. These data indicate that hazardous material incidents are relatively rare, but can cause considerable property damage and have a relatively low risk in terms of loss of human life or injury.

On January 23, 2012, an aviation jet fuel release occurred from a Shell Pipeline Company pipeline at General Mitchell International Airport. The first indication of this release was the presence of aviation fuel in a storm sewer near Wilson Park Creek. The cause of the release was the failure of a fuel pipeline located under a taxiway at the airport. As a result of this failure, aviation fuel entered a drainage ditch, the public storm sewer, and the

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[62] *U.S. Coast Guard,* Sector Lake Michigan Area Contingency Plan, *February 15, 2017.*

[63] *U.S. Department of Transportation Pipeline and Hazardous Materials Safety Incident Report Database, accessed November 8, 2017*.

[64] Ibid.

Creek. While no fatalities or injuries were reported, an estimated 9,000 gallons of fuel were released. This caused damage to asphalt at the airport. The pipeline's owner spent an estimated $19.3 million on cleanup operations.

Vulnerability, Community Impact, and Multi-Jurisdictional Assessment

There are several factors that should be considered when attempting to identify the scope, magnitude and vulnerability in terms of transportation-related hazardous materials incidents within specific areas of the City of Milwaukee. One factor is the density of traffic and development. Certain pipeline sections, major highway segments, rail lines, or pipelines may handle more hazardous material traffic than others. Therefore, the northern and central portions of the City of Milwaukee are more vulnerable than the other areas, due to the presence of major highways, rail lines, and pipelines. The condition of the transport routes and seasonal weather effects should also be considered, as well as predominant wind patterns within the County. Developing communication between planning agencies and storage site and transportation system owner/operators can be beneficial in determining the possible risks associated with transporting hazardous materials into or through a particular community. Based on past events, it is likely that there would be averages of about 90 hazardous material releases or spills per year, about 38.1 transportation-related hazardous material incidents per year, and about 0.8 pipeline incidents per year. It should be noted that the historical record shows considerable variation among years in the number of events that occurred. While it would be expected that in some years the City will experience fewer events or more events than the average number, the average annual number of events is not expected to change. On average, these incidents have resulted in reported damages of about $447,000 per year. However, very few events have been responsible for a large percentage of the total damages. Thus, this average damage cost is considered to be a very approximate measure of potential damages. In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion. About $20.7 billion of this total assessment is comprised of buildings and other improvements. Based on the current average estimate of $447,000 in reported damages per year, it can be expected that less than 0.02 percent of the value of all property, including buildings and infrastructure in the City of Milwaukee, will be damaged from these events each year. Due to the unpredictability of hazardous material incidents all buildings, infrastructure, and critical facilities within the City are considered at risk. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

Milwaukee County Emergency Management maintains records on all planning and reporting facilities within the City of Milwaukee and all reported incidents that have occurred at storage and transportation sites, and during acts of transport.

Potential Future Changes in Hazardous Materials Incident Conditions

Although significant hazardous materials incidents are not expected to change in the future, changes in land use can have an influence on the potential magnitude of any particular hazardous materials incidents that occurs. However, development within the City itself is approaching "buildout" conditions with new development expected to be limited, as documented in the adopted regional land use plan and summarized in Chapter II, and indicate a small potential increased risk of potential exposure to hazardous materials incidents, damage, and related losses in the expanding urbanized areas within the County.

VULNERABILITY ASSESSMENT FOR MEDICAL/HEALTH RISKS

This type of hazard is a composite of both potential epidemics and the spread of disease from natural disasters or human-induced hazard-related events. The Center for Disease Control and Prevention (CDC) has developed a list of emerging infections priority issues which include; antimicrobial resistance, food and water safety, vectors and animal health, blood safety, infections that cause chronic diseases, opportunistic infections, maternal and child health, health of travelers and refugees, and vaccines. The potential for natural and human-induced hazardous incidents exists almost everywhere. While these incidents can be relatively infrequent, they are capable of endangering the health of the individuals involved and the emergency personnel directed to assist them.

Historical Public Health Emergencies

The “Spanish” influenza pandemic of 1918-1920 was a world-wide disaster. This virus infected an estimated 500 million persons.[65] Estimates of the total number of deaths caused by this pandemic range between 50 million and 100 million.[66] About 675,000 people in the United States died from this disease outbreak. This strain of influenza was unusual in several ways. Influenza cases caused by this strain had a very rapid onset, and this virus was more virulent than typical influenza strains. In about 20 percent of cases, infection with this strain led to the development of pneumonia. While the fatalities caused by most strains of influenza occur among juvenile, elderly, or weakened patients, this strain predominantly killed healthy young adults. The pandemic struck the United States in three waves. The first erupted as a wave of mild influenza during late spring and early summer of 1918. The second wave struck as severe influenza during fall 1918 and the third wave struck during spring 1919. At least 103,000 Wisconsin residents developed “Spanish” influenza during the second wave of the outbreak and it caused about 8,460 deaths in the State. An estimated 1,295 deaths from this disease occurred in Milwaukee County—most of these in the City of Milwaukee. Based upon a recommendation from the U.S. Surgeon General, the Wisconsin State Health Officer ordered all public institutions in the State closed. This order included schools, churches, theaters, and other places of amusement and public gathering. Almost every local government in the State put this order into effect.[67]

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[65] *F. Burnet and E. Clark,* Influenza: A Survey of the Last 50 Years in the Light of Modern Work on the Virus of Epidemic Influenza, *MacMillan, 1942.*

[66] *Naill P.A.S. Johnson and Juergen Mueller, “Updating the Accounts: Global Mortality of the 1918-1920 ‘Spanish’ Influenza Pandemic,”* Bulletin of the History of Medicine, *Volume 76, Pages 105-115, 2002.*

[67] *Steven Burg, “Wisconsin and the Great Spanish Flu Epidemic of 1918,”* Wisconsin Magazine of History, *Pages 37-56, Autumn, 2000.*

Two other world-wide influenza pandemics occurred during the twentieth century. The “Asian flu” pandemic of 1957-1958 was responsible for an estimated two million deaths world-wide and an estimated 69,800 deaths in the United States. The “Hong Kong flu” pandemic of 1968-1969 caused an estimated one million deaths world-wide and an estimated 34,000 deaths in the United States.

The Hong Kong flu pandemic struck the City of Milwaukee during the winter of 1968-1969. During the eight-week period between November 10, 1968 and January 11, 1969, an estimated 333,680 residents of the City, representing about 43 percent of the City’s population, were clinically ill with influenza from this strain. Newspaper reports indicated that employers reported that high levels of absenteeism were associated with this epidemic. During December 1968, many schools were closed. Supplies of antibiotics and other drugs ran low, and the resources of the health, police, and fire departments were greatly strained. Hospital services were seriously reduced, and in some hospitals emergency care facilities were temporarily closed. The highest rates of infection were seen among working-age adults and older children. By contrast, preschool age children and adults over the age of 60 were less affected by this epidemic.[68]

Poliomyelitis is an infectious viral disease cause by the poliovirus. In most people, infection with poliovirus does not produce symptoms; however, in about 0.1 to 0.5 percent of cases infection results in muscle weakness that can cause paralysis. The weakness most often affects the legs, but may involve the muscles of the head and neck or the diaphragm. Poliovirus is transmitted from person to person through infected feces entering the mouth. Small, localized epidemics of paralytic poliomyelitis began to appear in the United States around 1900.[69] Outbreaks reached pandemic levels in the early twentieth century. Major outbreaks occurred in 1916, 1949, and 1952. The 1952 outbreak was the worst one reported in the United States. About 58,000 cases were reported in that year, resulting in 3,145 deaths and 21,269 persons left with mild to disabling paralysis. Beginning in the 1950s, the widespread availability of vaccines for the poliovirus reduced the annual number of cases. Through the use of vaccines, poliomyelitis was eradicated from the Americas by 1994.

In 1993, there was an outbreak of cryptosporidiosis in Milwaukee related to contamination of the City’s water supply that affected approximately 400,000 people. This incident was previously described in the section on contamination or loss of water supply.

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[68]*Frank F. Piraino, Edwin M. Brown, and Edward R. Krumbiegel, “Outbreak of Hong Kong Influenza in Milwaukee, Winter of 1968-1969,”* Public Health Reports, *Volume 85, 1970.*

[69]*Barry, Trevelyan, Matthew Smallman-Raynor, and Andrew D. Cliff, “The Spatial Dynamics of Poliomyelitis in the United States: From Epidemic Emergence to Vaccine-Induced Retreat, 1910-1971,”* Annals of the Association of American Geographers, *Volume 95, pages 269-293, 2005.*

Description of Recent Public Health Emergencies

In the year 2014 there were more than 12,700 reported incidents of infectious diseases within the City of Milwaukee as outlined in Table III-25, based upon data published by the Wisconsin Department of Health Services' Office of Health Informatics. The majority of these diseases were sexually transmitted diseases which comprised almost 11,000 of the reported cases (see Table III-25). These vital statistics also demonstrate that almost 90 percent of children in grades kindergarten through 12 have received all of the appropriate immunizations. Nonetheless, more than 11,000 children are noncompliant in terms of obtaining immunizations and pose a potential significant health risk within the City of Milwaukee. In addition, seasonal shortages of influenza vaccinations can also pose significant risk to both the elderly and young children within the City of Milwaukee

During the spring and summer of 2009, there was an outbreak of a novel type-A influenza virus (H1N1) in Wisconsin. Between April 15 and August 12, about 6,350 confirmed and probable cases were reported in the State. The majority of these cases occurred in the Southeastern Wisconsin Region, mostly in Milwaukee County. The number of reported cases peaked in mid-June and decreased to low levels by mid-July, although this may partially reflect changes in reporting by the Centers for Disease Control. As of August 12, 2009, 4,056 confirmed and probable cases had been reported in Milwaukee County, representing an infection rate of about 427 cases per 100,000 individuals. A second wave of H1N1 infection occurred during the fall 2009-winter 2010 influenza season. In early September, the Wisconsin State Division of Public Health reported that there were high levels of influenza-like illness in the Southeastern Wisconsin Region and lab reports indicated increased levels of H1N1.[70] This second wave peaked in early December 2009. By early January 2010, low levels of influenza-like illness were being reported in southeastern Wisconsin. Between September 1, 2009 and February 22, 2010, 1,077 hospitalizations for H1N1 had been reported in the State of Wisconsin, with 220 of these occurring in Milwaukee County. The combined number of deaths in Wisconsin attributed to H1N1 influenza in both waves was 56, with nine of these occurring in Milwaukee County.[71]

In 2011 and 2012, the United States experienced an outbreak of pertussis, which is also known as whooping cough. Pertussis is a bacterial disease of the respiratory tract that is transmitted through coughing by infected individuals. The symptoms and impacts are generally most severe in infants and young children. Wisconsin had the highest incidence of pertussis in the nation during this outbreak, with an incidence of 130.7 cases per 100,000

[70]*City of Milwaukee Health Department, "Novel Influenza A (H1N1) Situation Awareness Report No. 2," September 10, 2009.*

[71]*City of Milwaukee Health Department, "Novel Influenza A (H1N1) Situation Awareness Report No. 20," February 22, 2010.*

population. The outbreak began in July 2011. From July 1, 2011 through December 31, 2012, there were 5,322 confirmed cases and 2,132 probable cases reported in the State. While the highest number of cases occurred in southeastern Wisconsin, northern portions of the State had the largest percentage of their population affected. During the July 2011 through December 2012 outbreak, about 688 cases were reported in Milwaukee County.

In the year 2014, there were more than 4,200 deaths due to selected diseases within the City of Milwaukee, as shown in Table III-26. The majority of these mortalities were due to heart- and cancer-related illnesses. Pneumonia and influenza accounted for 68 deaths and a calculated death rate of about 11 persons per 100,000 population. Other infectious diseases and parasitic illnesses accounted for 116 deaths in the year 2014. Table III-26 also demonstrates that 68 deaths in 2014 were associated with alcohol and drug abuse within the City, which is the same number as deaths related to pneumonia and influenza.

Foodborne illness is a common and costly public health problem. An estimated one in six people in the United States gets sick from foodborne illness each year by consuming contaminated foods or beverages. There are more than 250 different disease causing pathogens that can contaminate foods. In addition to pathogens, poisonous chemicals and other harmful toxins can cause foodborne diseases when present in food. According to the CDC Foodborne Outbreak Online Database, there were 473 multi-state foodborne illness outbreaks that affected the State of Wisconsin during the period 1998 through 2014. These outbreaks caused almost 22,000 illnesses, 2,400 hospitalizations, and 71 deaths in the states affected. In 2014, the most recent year that data was available, 30 foodborne illness outbreaks were reported in the State of Wisconsin causing 594 illnesses, 79 hospitalizations, and 7 deaths. The most common pathogens that led to outbreaks in 2014 were Norovirus, *Salmonella enterica*, and *Escherichia coli*, typically originating from meats, fruits, or vegetables.

Vulnerability and Community Impact Assessment

The location of disease outbreaks is dictated by the proximity that residents have to infected people or to infected disease vectors.

The severity of a communicable disease outbreak can be evaluated from the perspective of the individual who has been infected or from the perspective of how many complications and deaths the disease causes in the population. Several factors can determine the severity of a disease outbreak. For example, the severity of a pandemic influenza outbreak can be influenced by:

- Properties of the virus: The inherent virulence and contagiousness of the virus influences the severity of a pandemic's impact. Pandemics can have a concentrated adverse impact within specific age groups. Concentrated illnesses and deaths in young, economically productive age groups may be more disruptive to societies and economies than when the very young or very old are most severely affected;

- Subsequent waves of virus spread: Cases of illness in a pandemic often occur in waves. These waves may last for six to twelve weeks and recur over a period of a year or longer. For example, the "Spanish" influenza pandemic occurred in three waves in the United States throughout 1918 and 1919. Following the initial wave, virus mutation and the emergence of more virulent strains can influence the severity of subsequent waves;

- Vulnerability of the population: In many communicable disease outbreaks, specific populations may be at greater risk than the general population. Examples of this include people with underlying health conditions or weakened immune systems and the very young or old. Nutritional factors also play a role and may influence the severity of a disease outbreak; and

- Community capacity to respond: The quality of the health services available to a community influences the impact of any pandemic. A virus that causes only mild symptoms in communities with strong health systems may be devastating to other communities where health systems are weaker. Vaccine shortages and problems with the distribution of medicines and vaccines can also impact the ability to respond to a disease outbreak.

In general, the frequencies of disease outbreaks are difficult to predict. This is due in part to the fact that communicable diseases differ from one another in their infectivity, virulence, and mode of transmission. For many diseases, these properties can be related to changes in the disease agent. For example, influenza pandemics have been related to genetic changes in the influenza virus.[72] While seasonal outbreaks of influenza occur annually, influenza pandemics are relatively rare events. A total of four influenza pandemics have occurred in the last 100 years, resulting in a rough average of one influenza pandemic every 25 years. The frequency of other diseases may be different from this. For example, cases of Lyme disease, a vector-borne disease, are detected in Milwaukee County almost every year.

The duration of individual disease outbreaks can be similarly difficult to predict. Based on the history of previous influenza pandemics, it is likely that a pandemic wave could last for about three to four months, with community outbreaks lasting about six to eight weeks. The duration of other diseases outbreaks may be different and can depend on the mode of transmission of the disease.

Different diseases also show different patterns of seasonality. While seasonal influenza viruses can be detected year-round in the United States, these viruses are most common during the fall and winter. The exact timing and

[72]*Edwin D. Kilbourne, "Influenza Pandemics of the 20th Century,"* Emerging Infectious Diseases, *Volume 12, pages 9-14, 2006.*

duration of flu seasons can vary, but influenza activity often begins to increase in October. Most of the time flu activity peaks between December and February, although activity can last as late as May. Vector-borne pathogens, on the other hand, are most prevalent during the spring through fall when disease carrying agents such as mosquitoes and ticks are most active. Transmission of vector-borne diseases is likely to occur during these seasons. Foodborne pathogens, on the other hand, can occur throughout the year.

The economic impact of a communicable disease outbreak is likely to be dependent upon the particular disease and disease strain. For some diseases, the impacts could be major. A pandemic influenza event, for example, could have severe economic repercussions, with significant costs associated with hospitalization and care for those afflicted. Broader economic impacts associated with absenteeism and lost productivity and wages could also be expected.

While anyone can be affected by a communicable disease outbreak, some individuals may be at greater risk than others. Young persons and the elderly can be more sensitive to or suffer greater impacts from some diseases than other members of the population. The Wisconsin Department of Health Services estimated that in 2013 about 30.5 percent of the City of Milwaukee's population was 19 years of age or younger and about 9.3 percent of the City's population was 65 years of age or older. Thus, about 40 percent of the City's population consists of members of these more sensitive age groups. Persons with some chronic medical conditions or who are immunosuppressed may also be more sensitive to some communicable diseases. Finally, for those diseases for which vaccines are available, persons who are not immunized are at greater risk than those who are immunized. For some communicable diseases and segments of the population, the rates of immunization in the City of Milwaukee are high. The data in Table III-25 indicates that the vast majority of school children in the City are compliant with the required immunizations. For other diseases for which vaccines are available, immunization rates in the City are likely to be much lower. Based on survey data, the CDC estimated that only about 44 percent of the persons older than six months old in the State of Wisconsin received the seasonal influenza vaccine for the 2014-2015 influenza season.[73]

While a public health emergency will not directly impact critical facilities and infrastructure, it could severely impact local health care services. In addition, communicable diseases can often spread faster in locations where many people congregate such as schools, day care centers, and nursing homes.

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[73] *U.S. Centers for Disease Control and Prevention, "Influenza Vaccination Coverage Estimates by State, HHS Region, and the United States, National Immunization Survey—Flu (NIS-Flu) and Behavioral Risk Factor Surveillance System (BRFSS), 2014-2015 Influenza Season: Wisconsin," http://www.cdc.gov/flu/fluvaxview/reportshtml/reporti1415/reportii/index.html, accessed January 19, 2016.*

Potential Future Changes in Public Health Emergency Conditions

Based upon historical national trends of infectious diseases, as well as the continuing threat of bio-terrorism, there is a potential for continued risk of communicable disease outbreaks to occur within the City of Milwaukee. For the five-year term of this plan, the probability of a communicable disease outbreak occurring is unknown. One reason for this is that numerous viruses, bacteria, protozoa, and fungi can cause communicable diseases. Each of these disease agents has its own specific characteristics, such as source, infectivity, and mode of transmission. In addition, for some disease agents such as pandemic influenza, changes in the property of the disease agent contribute to the development of major outbreaks.

As the twenty-first century proceeds, changes in climate may affect the incidence of communicable diseases in the City of Milwaukee in a number of ways.

Heavy rainfalls have been shown to be associated with outbreaks of waterborne diseases. This can happen through several pathways. Runoff resulting from heavy rains can become contaminated with animal wastes from agricultural activities and/or human wastes from improperly maintained or failing septic systems or from decaying sewers or sewer laterals. This runoff can carry disease agents into surface waters. In addition as rain infiltrates into soil, it can carry contaminants into groundwater. Depending on the disease agents that are present in the wastes, this can lead to a variety of gastrointestinal and respiratory illnesses. The projected increase in the frequency of heavy rainfall events could lead to an increase in these sorts of disease outbreaks.

The projected increase in heavy rain events could also affect the likelihood of disease outbreaks resulting from the use of recreational waters. Increases in water temperatures resulting from climate change and runoff from intense storms may create environments that deposit and support pathogens on beaches. At the same time, the projected increases in air and water temperatures are likely to lengthen the period of the year that is suitable for water-based recreational activities such as swimming. A longer swimming season is likely to increase the amount of exposure to any waterborne pathogens that are present. Thus, between now and the middle of the twenty-first century, the projected change in climate could increase the incidence of waterborne diseases among recreational water users. This would be likely to lead to more frequent closures of Great Lakes and inland beaches in order to protect human health.

The projected changes in climate could also affect the risk posed by vector-borne diseases. The dynamics of many of these diseases are sensitive to fluctuations in climate. For example, outbreaks of West Nile virus to humans are associated with prolonged periods of hot, dry weather that are followed by a significant rain event.[74] Changes in

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[74]*Paul R. Epstein, "West Nile Virus and the Climate,"* Journal of Urban Health, *Volume 78, pages 367-371, 2001.*

temperature and moisture may also change the geographic ranges of animals that vector diseases. Wisconsin is currently not within the range of the mosquito *Aedes aegypti,* which is the vector for several disease-causing viruses, including the Zika virus and those that cause chikungunya, dengue fever, and yellow fever. This mosquito is a tropical species and exposure to temperatures below 32°F kill it. As a result, the distribution of this species is currently restricted to southern portions of the United States. The increases in winter temperatures that are projected to occur over the twenty-first century could allow this range of this mosquito to expand northward,[75] creating the potential for the transmission of the diseases that it carries to occur in areas, such as Wisconsin, where these diseases rarely occur today. While an effective vaccine exists for yellow fever, the current lack of available vaccines for chikungunya, dengue fever, and Zika suggests that there may be some potential for outbreaks to develop in Wisconsin later in the twenty-first century.

It should also be noted that changes in the ranges of disease vectors resulting from climate change could also reduce the risks posed by some vector-borne diseases. For example, preliminary results suggest that climate change may be causing the range of the deer tick that transmits Lyme disease to shift northward. This may result in the range of the tick moving out of Wisconsin and into Minnesota and Canada by the end of the twenty-first century.[76]

VULNERABILITY ASSESSMENT FOR TERRORISM

Terrorism can be defined as acts that are violent or dangerous to human life that violate Federal or state law and that appear intended to intimidate or coerce a civilian population; influence the policy of a government by intimidation or coercion; or affect the conduct of a government by mass destruction, assassination, or kidnapping.[77] The Federal Bureau of Investigation categorizes two types of terrorism in the United States: domestic terrorism that involves groups or individuals whose activities are directed at elements of our government or population without foreign direction; and international terrorism that involves groups or individuals who are foreign based and/or directed by countries or groups outside the United States, or whose activities transcend national boundaries. Additionally, some acts conducted by gangs, people involved in civil unrest, radical splinter groups or activists, and people involved in illegal drug trade could also be described as terrorism.

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[75] *César Caphinha, Jorge Rocha, and Carla A. Sousa, "Macroclimate Determines the Global Range Limit of* Aedes aegypti,*"* EcoHealth, *Volume 11, pages 420-428, 2014.*

[76] *Wisconsin Initiative on Climate Change Impacts, 2011,* op. cit.

[77] *Title 19 Section 2331 of the* United States Code.

An act of terrorism can take several forms, depending on the technological means available to the terrorist, the nature of the political issue motivating the act, and the points of weakness of the terrorism target. Based on guidelines provided by the U.S. Department of Homeland Security, terrorism refers to the use of Weapons of Mass Destruction (WMD), including biological, chemical, nuclear, and radiological weapons; arson, incendiary, explosive, and armed attacks; industrial sabotage and intentional hazardous materials releases; and "cyber-terrorism."[78] Several terrorist action possibilities are listed and briefly described below.

Terrorist Action Possibilities
Incendiary Devices and Arson
Most terrorist incidents in the United States have involved bombs or incendiary devices, including arson, detonated and undetonated explosive devices, tear gas, pipe and firebombs, and rocket attacks. Often the capacity existed for large-scale damage and/or mass casualties. An example of this would be the bombing of the Alfred Murrah Federal Building in Oklahoma City in April 1995. The type of materials and method of delivery utilized in the bombing of the Murrah Federal Building are readily accessible to a potential terrorist. Because of the ready availability of such materials, the potential for mass damage and casualties and experiences to date in the nation, it is anticipated that of the various types of Weapons of Mass Destruction (WMD) and explosive weapons have a high potential for use in the United States.

FEMA defines arson and incendiary attack as the initiation of fire or of explosion on or near a target either through direct contact or remotely by other means. Generally, the extent of damage can be determined by type or quantity of accelerant and the materials present at or near the target. Arson can further be defined as any willful or malicious burning or attempt to burn, with or without intent to defraud, a dwelling, public building, motor vehicle, or other property. Fires of suspicious or unknown origins are not classified as arson. Nationally, arson resulted in 310 civilian deaths and was responsible for $473 million in property losses in 2016.[79] The number of reported arsons in the City of Milwaukee rose in the 1990s as shown in Figure III-10, as new techniques and equipment increased the identification of arson as the cause of suspicious fires. Over the period 2000 through 2009, the average number of arson fires in the City of Milwaukee was about 346 arson fires per year. Over the period 2010 through 2015, the average number of arson fires in the City was lower, about 288 per year. These fires resulted in an average of about $1.10 million in property damages per year.

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[78] *FEMA, State and Local Mitigation Planning How-to Guide, Integrating Manmade Hazards Into Mitigation Planning, Version 2.0, September 2003.*

[79] *Hilton J.G. Haynes*, "Fire Loss in the United States During 2016," *National Fire Protection Association, September 2017; available at https://www.nfpa.org/~/media/FD0144A044C84FC5BAF90C05C04890B7.ashx Accessed January 5, 2018.*

Nationwide, an estimated 20,000 intentionally set structure fires occurred in 2016, a decrease of about 13 percent from 2015.[80] In 2015, 181 fires were caused by arson within the City of Milwaukee, resulting in over $1,955,000 in damages. As shown in Table III-27, residential property accounted for the largest dollar loss due to arson, but only accounted for 48 of these fires. Arson loss for residential properties averaged $34,358 per fire. Damages to mobile property, such as vehicles, trailers, and boats, resulting from intentional set fires averaged $7,245 per fire. The majority of intentionally set fires in 2015 did not affect residential or mobile property, and damages resulting from these fires averaged about $800 per fire.

Airline Attack

After the events of September 11, 2001, questions were raised regarding the effectiveness of airport and airline security at the time. Since the September 11 attacks, security at airports and onboard airliners has been escalated. Specific changes include the oversight and supervision of passenger and baggage screening by the Transportation Security Administration, access to airplane boarding areas being restricted to passengers, restrictions being set on articles that can be taken onboard airliners, deployment of additional Federal air marshals on airliners, and improvements to cockpit security. Despite these efforts, it is possible that incidents may occur. Such incidents could include airplane bombing, sabotage or hijacking, airport bombings or shootings, or the tampering with air navigation and control systems, resulting in plane crashes or collisions.

Weapons of Mass Destruction—Chemical/Biological/Nuclear/Radiological Attack

Terrorists can use chemical and biological agents or weapons to either extort or deliberately try to kill in order to further political goals. Toxins, or even some radiological materials, such as water-soluble plutonium chloride, could become a credible threat to municipal water supplies. An example of this would be the sarin gas attack on the Tokyo subway system that occurred in March 1995.

Hostage Taking

The taking of hostages can provide terrorist groups publicity for their political or social objectives, and allow negotiation for furtherance of their aims or result in events which are designed to invoke sympathy for their causes. The main goal of response agencies is to end the incident, with the absolute minimum loss of innocent lives. The common belief that most response agencies are willing to agree to any demand to prevent endangering the safety of hostages is not a true statement in all cases.

Infrastructure Attack

An individual or group of terrorists could coordinate an attack against utilities and other public services, such as the water supply, electric power generation and transmission, or telephone service. Another form of infrastructure

[80]Ibid.

attack is against computer resources, such as networks, databanks and software by infiltrating computer networks and altering, stealing or destroying programs and data. As society becomes more dependent on computers, this form of cyber-terrorism is a legitimate concern.

Response to Terrorism Incidents

The emergency management community in the United States must accept that national security and intelligence organizations may not always be successful in preventing terrorist incidents. It is up to State and local emergency management personnel and services to respond should these attacks occur. The ramifications of responding to a terrorist incident may not be the same as traditional large-scale emergencies. The safety of emergency service providers must be an early, primary consideration. The media will take an active interest in this type of incident. The public has high expectations for emergency managers and service providers in a terrorist situation and extraordinary efforts are demanded. Federal and State government agencies depend directly on local managers and emergency response personnel and their initial and follow-on actions during any terrorist incident.

Historical Terrorism Problems

Historically, the worst case of domestic terrorism in the City of Milwaukee to date occurred on November 24, 1917. A bomb suspected to have been planted by anarchists was discovered by children and brought to a police station in the Third Ward. It detonated in the police station, killing nine police officers.

In 1970, there was a series of five pipe bombings and fire bombings in the City of Milwaukee that were attributed to suspected leftist revolutionaries. Targets included two industrial research laboratories, a building containing Federal offices, a military reserve headquarters, and a fuel line at a petroleum terminal in the harbor. While some of these incidents caused property damage, there were no fatalities or injuries reported. There were also two attempted bombings in the City in 1979. In one incident, a bomb was placed in a telephone booth. No damages or casualties resulted from this incident. In the other incident, a bomb exploded outside of a parochial elementary school, injuring a police officer who was attempting to dismantle it. No property damage resulted from this incident.[81]

Description of Recent Terrorism Events

Since 2000, there has been one terrorism incident documented in the City of Milwaukee. In July 2000, a former Air National Guard pilot broke into the 128th Air Refueling Wing airbase at General Mitchell International Airport, placing a bomb, as well as scrawling graffiti calling for an end to U.S. intervention in Kosovo. The bomb failed to explode and the perpetrator was arrested. There were no injuries or fatalities, and only minor property

[81] *National Consortium for the Study of Terrorism, Global Terrorism Database,* http://www.start.umd.edu/gtd/, *accessed January 5, 2018*.

damage was reported.[82] The National Consortium for the Study of Terrorism database includes two incidents of terrorism that occurred in the State of Wisconsin between 2009 and 2017.[83] On April 1, 2012, an assailant set fire to a Planned Parenthood clinic in the Town of Grand Chute in Outagamie County. There were no casualties. The clinic suffered minor damage to an examination room. On August 5, 2012, a member of a white supremacist group attacked a Sikh temple in the City of Oak Creek. The assailant killed six people and wounded four others before being shot by a responding police officer. The assailant subsequently died from a self-inflicted gunshot wound. The National Consortium for the Study of Terrorism database lists 12 incidents of terrorism that occured in Wisconsin since 1989.

Vulnerability and Community Impact Assessment

The groups that have conducted terrorism, the issues that they are concerned with, and their objectives are widely varied. The groups and individuals responsible for or participating in terrorist incidents in Wisconsin between 1970 and 2017 have cited a variety of issues for their actions including antiwar activism, extreme left wing revolutionary activities, extreme right wing revolutionary activities, antiabortion activities, animal rights activities, and white supremacist activities. Because the objectives of these groups and individuals are so widely varied, there are numerous potential targets for terrorist activity. Any public facility, utility, element of infrastructure, or gathering place could be a potential target for terrorist activity. In addition, certain types of businesses and governmental institutions may be more prone to terrorist activities due to the specific nature of their business or size. For example, businesses such as banks, financial institutions, health care facilities, or businesses engaged in controversial activities are likely to be at risk. Local, State, and Federal government facilities; public schools; and colleges and universities are also potential terrorist targets.

A review of the community assets described in Chapter II indicate a limited potential for terrorism-related hazard impacts to: 1) a variety of residential, commercial, and other developed land uses; 2) roadway transportation system; 3) utilities; 4) critical community facilities; and 5) historic sites in the vicinity of the incident. It is safe to assume that any type of facility on which a terrorist attack could generate desired publicity or further terrorism objectives could be classified as a potential target for terrorist activity, including large-scale public events, such as a sporting or entertainment event. Based on past events, however, the probability of a terrorist attack occurring in the City of Milwaukee is assumed to be very low.

[82]Ibid.

[83]Ibid.

In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion.[84] About $20.7 billion of this total is comprised of buildings and other improvements. Due to the unpredictability and lack of precedent concerning terrorism events in the City of Milwaukee, all buildings, infrastructure, and critical facilities within the City are considered at risk. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

VULNERABILITY ASSESSMENT FOR MAJOR FIRE AND EMERGENCY MEDICAL INCIDENTS

Major structure fire or emergency medical incident is an important type of hazardous event that can potentially cause significant serious injuries, fatalities, and property damages. Local authorities and the City of Milwaukee Fire Department (MFD) maintain their own services to those affected by fire incidents, coordinate with various organizations which support emergency services, and have established lines of communication with neighboring fire departments, inclusive of areas outside of the City of Milwaukee. In addition, the City of Milwaukee Fire Department, like all emergency management programs, is required to conduct disaster preparedness exercises. Disaster exercises are valuable from a variety of standpoints, because they test emergency management plans and procedures, bring together people from various emergency response departments who must work together when disaster strikes, help break down barriers and foster communication between departments, allow simulation of emergency incidents, and provide valuable training.

The Milwaukee Fire Department houses 12 Emergency Medical Services (EMS) paramedic units located throughout the City (see Appendix B Table B-2). The Milwaukee Fire Department (MFD) has been a part of Milwaukee County's Emergency Medical System (EMS) since 1977. Milwaukee County provides each fire department in the County with medical oversight and training. The system allows paramedics from any participating fire department within the County to respond to emergencies in neighboring municipalities when needed. For example, MFD Med No. 15 routinely responds into St. Francis as their paramedic unit. Wauwatosa's Med 51 responds to emergencies in the "finger area" on the west side of Milwaukee. This is significant in the event of a major fire or emergency medical incident. This enables individual departments to supplement their own personnel, apparatus, and equipment with that from other departments in response to emergencies. Importantly, the agreement allows individual departments to access equipment, such as tankers, aerial trucks, and extrication equipment, which they themselves do not possess and which they may only need infrequently.

The majority of EMS responses required Basic Life Support (BLS), which includes patient evaluation, monitoring of pulse, blood pressure, and breathing, bandaging wounds and splinting fractures, and the performance of

[84] *Wisconsin Department of Revenue.*

Cardio-Pulmonary Resuscitation (CPR) and cardiac defibrillation. All Fire Department vehicles are equipped with defibrillators, a life-saving device used to control irregular heart activity. A Basic Life Support alarm usually results in the dispatch of a single BLS unit, which may be an engine, ladder truck, or fire squad staffed by Firefighter-Emergency Medical Technicians (EMTs). Almost all members of the Milwaukee Fire Department are trained as EMT, and many have received additional training to qualify them as Paramedics.

In addition to traditional fire-fighting and EMS functions, the Milwaukee Fire Department has several specially trained units which perform extra duties. The Dive Rescue Team and fireboat respond to water incidents. The Hazardous Materials Team responds to incidents involving the unintentional release of hazardous materials. The Heavy Urban Rescue Team (HURT) responds to building collapses, construction site incidents, confined space emergencies, and similar situations, including rescue of trapped firefighters. Special team responses, while infrequent, may require extensive Fire Department time on scene, as well as advance readiness in the form of specialized training and equipment. Table III-28 indicates recent activity of each of these special teams.

Historical Major Fires and Emergency Medical Incidents

Historically, Milwaukee's greatest fire to date occurred in 1892 in what was known as the Irish 3rd Ward**.** The fire originated at what is now 232 North Water Street. More than 440 buildings throughout 16 city blocks were completely destroyed. Calculated in terms of an 1892 appraisal, the loss was in excess of $4.5 million or over $100 million in today's terms. Two firemen and five other people died, and more than 1,800 people were made homeless.

Description of Recent Major Fires and Emergency Medical Incidents

In 2015, the Milwaukee Fire Department responded to 13,999 fire, service, and rescue alarms and 70,504 Emergency Medical Service (EMS) calls. Table III-28 illustrates the number of fire and emergency medical service responses between 2000 and 2015. Fire alarms include any dangerous situation which is not classified as medical, including gas leaks, oil spills, water leaks, electrical problems or malfunctioning appliances, extrications from vehicles involved in accidents, and a wide variety of other situations in addition to fires. Of the fire alarms in 2015, 1,039 were for residential and building fires in which structural damage and loss of contents totaled $25.5 million. Ten of these fires resulted in ten fatalities.

For a fire or hazard alarm, the minimum MFD response is a pumping engine and a ladder truck. More typically, the response would include three pumping engines, two ladder trucks, a fire squad, and two battalion chiefs. "Greater alarm" fires are incidents requiring additional equipment and personnel to respond. In 2009, 18 "greater alarms" or major incidents requiring additional equipment and personnel to respond occurred. No estimates are available on the loss or damage to property and value of contents resulting from these fires. Over the period 2000 through 2004, the last period for which data are available, annual damages to property and value of contents resulting from "greater alarm" incidents ranged between $2.2 million and $8.6 million with an annual average of

$5.1 million.[85] In December 2003, a fire broke out on the 14th floor at 111 East Wisconsin Avenue (also known as the Bank One building) in downtown Milwaukee. It is believed that welding sparks from building renovation on the 17th floor traveled down a pipe shaft, igniting paper on the 14th floor. This fire caused more than $1.3 million in damage and injured three people. On December 6, 2006, a gas explosion related to a gas leak occurred at Falk Corporation in the Menomonee Valley. This explosion killed three persons and injured 47. Debris from the explosion landed several blocks away. The incident was classified as a five-alarm fire.

On January 18, 2010, a four-alarm fire broke out at a building at the corner of E. North Avenue and Oakland Avenue. Over 150 firefighters responded to this blaze. The fire destroyed a restaurant, three other businesses, and 10 apartments. Damages resulting from the fire were estimated at $3.3 million.

On June 20, 2012 a five-alarm fire occurred at a grocery store at N. 12th Street and W. Vliet Street. According to news reports, over 150 firefighters responded to this fire. The building was destroyed when its roof and three exterior walls collapsed. One firefighter sustained minor injuries fighting this blaze.

On July 17, 2012, a five-alarm fire broke out in a building housing and automobile repair shop, artist studios and galleries and apartments on E. Center Street. Over 100 firefighters responded. During the fire, portions of the 25,000-square foot building and roof collapsed. According to news reports, two firefighters were treated for heat exhaustion.

Vulnerability and Community Impact Assessment

Table III-28 shows the number of fire deaths, fires and other hazard incidents, and medical responses, and the rate of fires per 1,000 people. EMS responses account for about three-quarters of Fire Department dispatches. Like fire alarms, the number of emergency medical alarms is usually highest in the summer. Fire and emergency medical incidents are not evenly distributed throughout the City. Densely populated areas may be more at risk for major fire and fire fatalities and injuries than more sparsely populated areas. Children and the elderly are most at risk for fatality or injury due to fire.

Generally, most fire injuries and fatalities occur in home and residential fires. In 2016, about 81 percent of all fire fatalities nationwide occurred in the home.[86] Figure III-11 shows the number of fatal fires that occurred between 1990 and 2015 in the City of Milwaukee, and that the number of adults and children that have died in fires has significantly declined over this time period. In addition, fires caused by children playing with matches or other

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[85]*Damages were adjusted to 2016 dollars using the Consumer Price Index.*

[86]*Hylton J.G. Haynes, "Fire Loss in the United States during 2016,"* op. cit.

incendiary devices significantly declined during this time period as shown in Figure III-12. In 1992, over 110 nonfatal fires were started by children playing with matches, lighters, or other heat sources. The Milwaukee Fire Department reported that in 2003, 38 nonfatal fires were caused by children playing with incendiary devices. In 2015, Milwaukee Fire Department reported that only 25 fires were caused by ignition related to matches, lighters, and similar incendiary devices. Similar declines were seen in fires started by careless smoking: in 1991, over 80 nonfatal fires were reported to have been caused by careless smoking. This number decreased to a low in 2005, with six fires caused by ignition related to smoking materials. While the number of fires caused by ignition related to smoking materials has increased slightly since then, it remains substantially lower than it was in the early 1990s.

Based on fire incidents reported between 2000 and 2015, it is likely that the City of Milwaukee will continue to average approximately 960 fires per year, and over the next few years, an estimated 7.6 fires could result in 8.9 fatalities each year.

In 2016, the total equalized assessed property value in the City of Milwaukee was estimated at over $25.1 billion.[87] Slightly over $20.7 billion of this total is comprised of buildings and other improvements. Based on data from 2000-2015, total property damages due to fire are approximately $21.9 million per year, or less than 0.1 percent of the total assessed property value in the City of Milwaukee. All buildings, infrastructure, and critical facilities within the City are considered at risk for fire. Based on availability, the 2016 assessed values of the identified critical facilities are provided in Appendix B.

Potential Future Changes in Major Fire and Emergency Response Conditions

Several fire safety programs were implemented in the early 1990s and results indicate that the number of fatal fires and fatalities have decreased (further details of these programs are included in Chapter V of this report).[88] In 1991, the Milwaukee Fire Department instituted the FOCUS program (Firefighters Out Creating Urban Safety) to educate the public. In FOCUS, firefighters go door-to-door in targeted areas to install smoke detectors, explain their maintenance and replace batteries, provide fire safety tips, and answer questions. In 1992, Milwaukee Fire Education Center's Survive Alive House officially opened. Over 13,000 Milwaukee children visit each year to learn to survive in the event of an actual fire in the home. The house is available to public and private schools located in the City of Milwaukee. Child fatalities have greatly decreased since this program has been implemented. In 1997, the Fire Department also began providing fire inspection services for public buildings. The Fire Department also works with building managers to identify any potential fire hazards.

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[87] *Wisconsin Department of Revenue.*

[88] *Milwaukee Fire Department community relations programs are described on the department website at* http://city.milwaukee.gov/CommunityRelations.htm.

As the Milwaukee Fire Department continues to teach the public fire safety techniques and further outreach efforts to provide smoke detectors, the City of Milwaukee may continue to see decline in the number of fatalities and injuries associated with fires.

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SEWRPC Community Assistance Planning Report No. 282-3ED

CITY OF MILWAUKEE ALL HAZARDS MITIGATION PLAN UPDATE

Chapter III

ANALYSIS OF HAZARD CONDITIONS

TABLES

[Blue highlighting indicates additions or revisions to the previous edition of the plan.]

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Table III-1

HAZARD IDENTIFICATION SUMMARY FOR THE 2005 PLAN BASED UPON CITY OF MILWAUKEE HAZARD MITIGATION STEERING COMMITTEE INPUT

Number of Points Assigned to Hazards Identified by the Steering Committee[a]	Hazards Required by FEMA[b]	Hazard Types Considered
- -	- -	A. Natural Hazards
15	✓	Flooding
7	✓	Thunderstorms, high wind, hail, lightning
7	✓	Winter storms
3	✓	Tornadoes
0	✓	Temperature extremes
0	✓	Coastal erosion
0	✓	Drought
0	✓	Earthquake
- -	- -	B. Other Hazards Human Induced/Technical Hazards
0	- -	Transportation accidents
0	- -	Arterial street and roadway
0	- -	Railroad
0	- -	Airport
0	- -	Milwaukee harbor boating/shipping
1	- -	Contamination or loss of water supply
- -[c]	- -	Hazardous materials incident
- -[c]	- -	Medical/health risks
0	- -	Fixed facility (storage/distribution centers)
3	- -	Terrorism incident
- -[c]	- -	Major fire and emergency incidents
0	- -	Power outage incident/energy grid incident
- -[c]	- -	Basement backups (to be considered in conjunction with flooding)

[a]*Points represent the number assigned by the Steering Committee at its August 10th, 2004 meeting during a nominal group hazard ranking process.*

[b]*U.S. Federal Emergency Management Agency Federal Code of Federal Regulations 44 CFR Parts 201 and 206 Hazard Mitigation Planning and Hazard Mitigation Grant Program; Interim Final Rule, February 26, 2002.*

[c]*Hazards identified to be included in the mitigation plan by the City of Milwaukee Hazard Mitigation Steering Committee meetings on August 10, and September 21, 2004.*

Source: City of Milwaukee Hazard Mitigation Steering Committee.

Table III-2

PERCEIVED RISKS OF HAZARDS AS DETERMINED BY HAZARD AND VULNERABILITY ASSESSMENT TOOL: 2011

Event	Minimum (percent)[a]	Maximum (percent)[a]	Average (percent)[a]	Interquartile Range (percent)[b]	Rank
A1. Riverine flooding	13.9	75.0	42.9	35.4	6.5
A2. Stormwater flooding	33.3	91.7	67.2	14.3	1
A3. Tornado or high straight-line wind event	25.0	91.7	45.5	26.4	4
A4. Earthquake	0.0	33.3	12.1	20.8	39
A5. Lake Michigan coastal erosion	8.3	50.0	21.7	16.7	34.5
A6. Snow storm	33.3	58.3	42.9	16.7	6.5
A7. Blizzard or extreme snowfall	33.3	75.0	47.7	27.8	2
A8. Ice storm	33.3	83.3	46.2	19.5	3
A9. Extreme heat	11.1	50.0	28.0	25.0	23
A10. Extreme cold	13.9	34.6	23.6	21.5	28
A11. Lightning	13.9	83.3	34.9	22.9	14
A12. Thunderstorm	27.8	83.3	43.4	15.6	5
A13. Hail	5.6	44.4	31.6	21.5	19
A14. Fog	0.0	50.0	33.1	28.5	16
A15. Drought	0.0	50.0	21.7	23.6	34.5
A16. Dust storm	0.0	41.7	14.7	18.8	38
B1. Contamination or loss of water supply	13.9	44.4	23.5	4.9	29
B2. Loss of sewerage system	0.0	44.4	20.7	5.6	36
B3. Loss of telecommunication	13.9	44.4	27.8	22.2	24.5
B4. Electrical system outage	13.9	66.7	38.1	40.2	11
B5. Computer system incident/cyber attack	0.0	66.7	30.3	33.3	20
C1. Hazardous materials railroad incident	13.9	61.1	30.1	23.6	21
C2. Hazardous materials roadway incident	13.9	91.7	36.6	25.0	13
C3. Hazardous materials pipeline incident	0.0	61.1	22.2	7.6	32
C4. Hazardous materials fixed facility incident	16.7	55.6	32.1	27.1	18
D1. Aircraft transportation accidents	16.7	50.0	27.8	10.4	24.5
D2. Roadway transportation accidents	13.9	66.7	38.8	12.2	10
D3. Railway transportation accidents	11.1	66.7	28.3	19.4	22
E1. Correctional center incident	0.0	33.3	18.2	10.4	37
E2. Civil unrest	0.0	30.6	23.0	5.6	30
E3. Terrorism incident	19.4	50.0	27.5	4.9	26
E4. Biological contaminants (anthrax, smallpox, etc.)	13.9	25.0	22.0	4.9	33
E5. Workplace violence	13.9	75.0	28.9	37.5	9
E6. School violence	13.9	66.7	36.9	22.2	12
F1. Communicable disease outbreak or epidemic	13.9	75.0	32.3	25.7	17
G1. Major fire	16.7	66.7	41.2	31.9	8
G2. Explosion	11.1	50.0	34.6	26.4	15
G3. Mass casualty incident	13.9	50.0	24.2	7.6	27
G4. Building collapse or cave-in	11.1	44.4	22.5	14.6	31

[a]*Perceived threat increases with percentage.*

[b]*Interquartile range acts as a measure of agreement upon the perceived level of threat with a smaller interquartile range indicating stronger agreement and a larger interquartile range indicating weaker agreement.*

Source: SEWRPC.

Table III-3

PERCEIVED RISKS OF HAZARDS AS DETERMINED BY HAZARD AND VULNERABILITY ASSESSMENT TOOL: 2016

Event	Minimum (percent)[a]	Maximum (percent)[a]	Average (percent)[a]	Interquartile Range (percent)[b]	Rank
A1. Riverine flooding	19.4	91.7	51.7	31.3	7
A2. Stormwater flooding	33.3	91.7	66.9	29.1	1
A3. Tornado or high straight-line wind event	0.0	61.1	37.5	33.4	25
A4. Earthquake	0.0	33.3	9.0	22.2	39
A5. Lake Michigan coastal erosion	16.7	58.3	35.0	19.4	28
A6. Snow storm	41.7	83.3	52.1	16.6	6
A7. Blizzard or extreme snowfall	27.8	83.3	55.3	26.4	4
A8. Ice storm	16.7	75.0	51.4	22.2	9
A9. Extreme heat	27.8	66.7	45.8	25.0	16
A10. Extreme cold	33.3	75.0	50.2	19.4	11
A11. Lightning	25.0	75.0	43.5	12.5	19
A12. Thunderstorm	8.3	75.0	43.8	33.3	18
A13. Hail	5.6	66.7	38.4	15.3	23
A14. Fog	8.3	50.0	35.4	12.5	27
A15. Drought	0.0	38.9	17.6	13.9	37
A16. Dust storm	0.0	25.0	10.6	20.8	38
B1. Contamination or loss of water supply	8.3	66.7	31.0	25.0	33
B2. Loss of sewerage system	5.6	61.1	29.4	13.9	34
B3. Loss of telecommunication	11.1	75.0	32.5	20.9	29
B4. Electrical system outage	19.4	66.7	39.1	32.0	21
B5. Computer system incident/cyber attack	16.7	91.7	55.3	57.0	3
C1. Hazardous materials railroad incidents	19.4	100.0	50.2	27.7	10
C2. Hazardous materials roadway incidents	16.7	83.3	45.8	29.1	15
C3. Hazardous materials pipeline incidents	0.0	66.7	21.8	11.1	36
C4. Hazardous materials fixed facility incidents	13.9	66.7	38.9	38.9	22
D1. Aircraft transportation accidents	19.4	75.0	32.2	9.7	31
D2. Roadway transportation accidents	27.8	75.0	53.5	26.4	5
D3. Railway transportation accidents	11.1	75.0	31.9	18.1	32
E1. Correctional center incident	11.1	55.6	22.2	15.3	35
E2. Civil unrest	16.7	100.0	66.2	45.8	2
E3. Terrorism incident	13.9	91.7	45.7	33.3	17
E4. Biological contaminants (anthrax, smallpox, etc.)	8.3	83.3	38.0	31.3	24
E5. Workplace violence	19.4	75.0	51.4	27.8	8
E6. School violence	16.7	91.7	48.8	38.9	13
F1. Communicable disease outbreak or epidemic	8.3	83.3	43.4	32.7	20
G1. Major fire	22.2	83.3	49.5	30.6	12
G2. Explosion	16.7	83.3	48.1	30.5	14
G3. Mass casualty incident	8.3	83.3	36.5	23.6	26
G4. Building collapse or cave-in	13.9	55.6	32.4	13.9	30

[a]*Perceived threat increases with percentage.*

[b]*Interquartile range acts as a measure of agreement upon the perceived level of threat with a smaller interquartile range indicating stronger agreement and a larger interquartile range indicating weaker agreement.*

Source: SEWRPC.

Table III-4

SUMMARY OF ESTIMATED DISASTER DAMAGES THAT AFFECTED THE CITY OF MILWAUKEE FOR FEDERALLY DECLARED DISASTERS AND EMERGENCIES: 1969-2016

Date	Event	Affected Area	Reported Damages	
			Fatalities	Property Damages (in dollars)[a]
July 1969 (DR-264)	Severe storms, flooding	Milwaukee County		
April 1973 (DR-376)	Flooding	Milwaukee County	0	- -
March 1976 (DR-496)	Ice storm	Milwaukee County	- -	- -
December 1978-January 1979 (EM-3069)	Snow emergency	Milwaukee County	0	- -
August 1986 (DR-770)	Flooding	Milwaukee County	2	29,841,628
September 1986 (DR-775)	Flooding	Milwaukee County	0	8,900,150
June 1993 (DR-994)	Flooding and wind damage	Milwaukee County	0	- -
August 1996	Flooding, severe storms	Milwaukee County	0	- -
July-June 1997 (DR-1180)	Flooding	Milwaukee County	0	114,523,762
August 12, 1998 (DR-1238)	Flooding and high winds	Milwaukee County	0	15,967,854
May-July 2000 (DR-1332)	Flooding, severe storms	City of Milwaukee and surrounding municipalities	0	9,292,770
December 2000-January 2001 (EM-3163)	Snow emergency	Milwaukee County	0	- -
May 2004 (DR-1526)	Flooding, severe storms	Milwaukee County	2	1,274,941[b]
February 2008 (EM-3285)	Snow emergency	Milwaukee County	0	- -
June-July 2008 (DR-1768)	Severe storms, tornadoes, and flooding	Milwaukee County	0	88,002,396
July 2010 (DR-1933)	Severe storms, tornadoes, and flooding	Milwaukee County	1	38,336,170
January-February 2011 (DR-1966)	Severe Winter storm and snowstorm	Milwaukee County	0	11,385
Total	- -	- -	5	306,151,056

[a]*Dollar values are adjusted to year 2016 by using the annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

[b]*As of July 30, 2004, FEMA had received over 2,800 applications for assistance and had approved 668 grants related to the May flooding event. As of this date, FEMA had approved over $1.05 million in housing assistance, and over $0.5 million in other needs assistance for Milwaukee County (FEMA Disaster Summary, July 30, 2004).*

Source: Milwaukee County Pre-Disaster Mitigation Plan, National Climate Data Center, Wisconsin Emergency Management, Federal Emergency Management Agency, and SEWRPC.

Table III-5

WEATHER HAZARD EVENTS RECORDED IN MILWAUKEE COUNTY, WISCONSIN FROM 1950 TO DECEMBER 2016 (SORTED BY NUMBER OF EVENTS)

Event	Total	Reported Damages		
		Fatalities[a]	Injuries[a]	Property Damage[b] (dollars)
Dust Storms	0	0	0	$ 0
Wild Fires/Forest Fires	0	0	0	0
Tornadoes and Waterspouts	18	0	176	18,340,303
Lightning	27	0	2	2,760,414
Flood	51	1	1	329,286,411
Fog	62	0	0	0
Temperature Extremes	83	125	246	23,150
Hail	136	0	0	9,634,013
Winter Storms	152	32	9	122,505
Thunderstorms/High Winds	239	3	9	39,912,418
Total	763	160	443	400,079,214

[a]*Deaths and injuries reported were, in some cases, based upon a geographic area impacted by the hazard event which affected Milwaukee County and had a larger area of impact than the City itself.*

[b]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: Milwaukee County Pre-Disaster Mitigation Plan, the National Climatic Data Center (NCDC) a part of the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and the National Environmental Satellite, Data and Information Service (NESDIS).

Table III-6

MILWAUKEE COUNTY SEVERE WEATHER HISTORY: 1982-2014

Year	Severe Thunderstorm		Tornado	
	Watch	Warning	Watch	Warning
1982	1	1	0	0
1983	5	3	1	0
1984	6	6	7	2
1985	5	1	6	1
1986	7	3	6	0
1987	5	8	2	2
1988	0	4	2	0
1989	10	6	2	1
1990	5	5	4	0
1991	10	4	2	0
1992	3	2	3	0
1993	10	5	4	0
1994	9	7	3	2
1995	10	6	1	0
1996	5	7	9	0
1997	9	5	2	0
1998	11	5	2	0
1999	8	7	0	0
2000	7	14	3	2
2001	10	4	1	1
2002	7	5	1	0
2003	7	4	3	0
2004	15	9	5	0
2005	11	9	0	0
2006	17	16	2	0
2007	3	9	3	0
2008	8	14	4	3
2009	6	3	1	2
2010	6	8	7	3
2011	12	11	1	0
2012	7	12	0	0
2013	5	7	2	2
2014	8	10	1	0
Total	248	220	90	21

Source: National Weather Service Forecast Office.

Table III-7

TECHNOLOGICAL HAZARD EVENTS RECORDED IN THE CITY OF MILWAUKEE, WISCONSIN FROM 1971 TO DECEMBER 2016 (SORTED BY NUMBER OF EVENTS)

Event	Total	Reported Damages		
		Fatalities	Injuries	Property Damage[a] (dollars)
Pipeline Hazardous Material Incidents	35	0	30	17,058,763
Transportation Hazardous Material Incidents	1,715	3	117	3,061,651
Total	1,750	3	147	20,120,414

[a]Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.

Source: U.S. Department of Transportation, Office of Pipeline Safety; and SEWRPC.

Table III-8

SUMMARY OF HAZARDS TO BE CONSIDERED IN THE CITY OF MILWAUKEE HAZARD MITIGATION PLAN

Hazard	Risk of Occurrence (high, medium, or low)	Warning Time (short, medium, or long)	Damage to Property (high, moderate, or low)	Threat to Life Safety (high, medium, or low)	Duration of Impact (long, moderate, or short)	Size of Affected Area (large, medium, or small)
Natural Hazards						
Flooding	High	Medium	High	Low	Moderate	Large
Thunderstorm, High Wind, Hail, Lightning	High	Short	High	High	Long	Large
Winter storms	Medium	Medium	Low	Medium	Moderate	Large
Tornadoes	Low	Short	High	Medium	Short	Small
Temperature Extremes	Medium	Long	Low	High	Long	Large
Coastal Erosion	Low	Long	Medium	Low	Long	Small
Other Hazards						
Contamination or Loss of Water Supply	Low	Short	Moderate	Medium	Moderate	Medium to large
Hazardous Materials Incident	High	Short	Low	Medium	Moderate	Small
Medical/Health Risks	Low	Short	Low	High	Moderate to long	Small to large
Terrorism Incident	Low	Short	Moderate to high	High	Short	Small to medium
Major Fire and Emergency Incident	Low	Short	Low	High	Moderate to long	Small to large

Source: City of Milwaukee Hazard Mitigation Local Planning Team and SEWRPC.

Table III-9

STRUCTURES AT RISK OF FLOODING AND ESTIMATED AVERAGE ANNUAL FLOOD DAMAGES IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Structures at Risk of Flooding at Annual Probabilities of Flooding (percent)					Estimated Average Annual Flood Damages (dollars)
	10	4	2	1	0.2	
Kinnickinnic River Mainstem	114	184	232	330	389	1,376,441
43rd Street Ditch	0	0	4	9	26	16,011
Lyons Park Creek	13	47	58	66	71	198,824
Villa Mann Creek	0	6	6	9	9	31,813
Wilson Park Creek	0	87	177	274	325	541,643
Watershed Total	127	324	477	688	820	2,164,192

[a]*Damage estimates are given in 2016 dollars.*

Source: Milwaukee Metropolitan Sewerage District, Kinnickinnic River Watershed Flood Management Plan: Final Report, *May 4, 2017.*

Table III-10

INVENTORY OF BUILDINGS WITHIN THE 10- THROUGH 0.2-PERCENT-ANNUAL-PROBABILITY FLOODPLAINS AND ESTIMATED TOTAL FLOOD DAMAGES FOR THE PORTION OF THE MILWAUKEE RIVER WATERSHED LOCATED IN THE CITY OF MILWAUKEE

Annual Flood Probability Floodplain	Structure Type			Estimated Total Flood Damages (dollars)[a]
	Commercial	Recreational	Residential	
10-percent	0	0	0	0
Two-percent	0	0	0	0
One-percent	0	0	3	64,100
0.2-percent	0	0	69	2,333,240

[a]*Damages have been converted to 2016 dollars using the Engineering News Record Construction Cost Index.*

Source: SEWRPC.

Table III-11

REPORTED BASEMENT SANITARY SEWER BACKWATER PROBLEMS[a] AND ANNUAL PRECIPITATION SUMMARIES WITHIN THE CITY OF MILWAUKEE: 1999-2016

Year	Backwater Complaints (number)	Annual Precipitation Departures from Normal (inches)	Number of Days with Precipitation			
			Greater than 0.01 to 0.1 Inch	Greater than 0.1 to 0.5 Inch	Greater than 0.5 to 1.0 Inch	Greater than 1.0 Inch
1999	187	+4.95	42	43	16	8
2000	112	+11.44	61	38	16	9
2001	2	+3.80	38	35	22	9
2002	60	-8.12	45	38	11	5
2003	0	-12.51	52	34	11	2
2004	86-400[b]	-1.87	45	48	14	6
2005	0	-8.89	43	50	9	3
2006	0	+3.12	42	46	18	9
2007	0	-1.75	47	46	14	6
2008	1,000	+8.71	44	50	13	11
2009	658	+1.00	36	49	14	7
2010	12,203	+1.17	50	31	17	6
2011	0	-2.22	40	45	18	7
2012	0	-5.52	33	43	15	3
2013	1	+5.21	48	37	15	11
2014	18	-2.70	59	40	16	6
2015	0	- -	29	50	16	4
2016	1	-0.41	50	38	11	7

[a]*These are meant to illustrate rain-related basement backwater problems reported and does not include any backups that occurred due to clogged sewers or a problem in the building sewer.*

[b]*86 backwater complaints were reported by property owners during two community meetings held after the May 2004 rainfall period and are considered to be related to specific sanitary sewer problems. Newspaper reports indicate that over 400 basement backup complaints of various types were filed during the May 2004 rainfall events. There also were likely to have been more homes that were affected but not reported.*

Source: City of Milwaukee Department of Public Works, National Weather Service Milwaukee/Sullivan Weather Forecast Office, and SEWRPC.

Table III-12

THUNDERSTORM, HIGH-WIND, HAIL, AND LIGHTNING EVENTS REPORTED IN MILWAUKEE COUNTY FROM 1956 to SEPTEMBER 2016[a]

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
July 11, 1956	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
August 7, 1958	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 28, 1960	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
July 22, 1960	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 22, 1960	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 4, 1961	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 17, 1962	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
July 22, 1962	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
September 13, 1962	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
March 19, 1963	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
March 19, 1963	City of Milwaukee	- -	- -	X	- -	1.5 inch	- -	- -	- -
June 8, 1963	City of Milwaukee	X	X	X	- -	63 knots/2.0 inch	- -	- -	- -
June 9, 1963	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
July 31, 1963	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
August 1, 1963	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
April 6, 1964	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 19, 1964	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 19, 1964	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
July 22, 1964	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
July 22, 1964	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
September 3, 1964	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
May 8, 1965	City of Milwaukee	X	X	- -	- -	65 knots	- -	- -	- -
June 27, 1965	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 13, 1965	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 26, 1967	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
June 11, 1968	City of Milwaukee	X	X	- -	- -	63 knots	- -	- -	- -
June 18, 1968	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 29, 1968	City of Milwaukee	- -	- -	X	- -	0 Knots/0.75 inch	- -	- -	- -
June 30, 1968	City of Milwaukee	X	X	- -	- -	53 knots	- -	- -	- -
April 17, 1969	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 29, 1969	City of Milwaukee	X	X	- -	- -	61 knots	- -	- -	- -
August 11, 1969	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
June 19, 1971	City of Milwaukee	X	X	- -	- -	66 knots	- -	- -	- -
September 16, 1972	City of Milwaukee	X	X	- -	- -	51 knots	- -	- -	- -
September 18, 1972	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	- -

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
June 16, 1973	City of Milwaukee	X	X	- -	- -	60 knots	- -	- -	- -
August 9, 1973	City of Milwaukee	X	X	- -	- -	70 knots	- -	- -	- -
May 21, 1974	City of Milwaukee	X	X	- -	- -	65 knots	- -	- -	- -
July 3, 1974	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 11, 1974	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
January 10, 1975	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 13, 1975	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 13, 1975	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
November 9 ,1975	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 13, 1976	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 30, 1976	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
July 30, 1976	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 24, 1977	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 6, 1977	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 6, 1977	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
August 4, 1977	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
September 4, 1977	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 7, 1978	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 17, 1978	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
May 18, 1979	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 20, 1979	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 5, 1980	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
June 5, 1980	City of Milwaukee	X	X	X	- -	0 knots/1.0 inch	- -	- -	- -
June 7, 1980	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
July 15, 1980	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 4, 1980	City of Milwaukee	X	X	X	- -	0 knots/1.75 inch	- -	- -	- -
August 4, 1980	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
September 9, 1980	City of Milwaukee	X	X	- -	- -	54 knots	- -	- -	- -
July 12, 1981	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 20, 1981	City of Milwaukee	X	X	- -	- -	51 knots	- -	- -	- -
July 6, 1982	City of Milwaukee	X	X	- -	- -	60 knots	- -	- -	- -
August 3, 1982	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 19, 1983	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
July 19, 1983	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 16, 1983	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 17, 1984	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 10, 1984	City of Milwaukee	X	X	- -	- -	70 knots	- -	- -	- -
July 10, 1984	City of Milwaukee	X	X	- -	- -	70 knots	- -	- -	- -
July 23, 1984	City of Milwaukee	X	X	- -	- -	53 knots	- -	- -	- -
August 9, 1984	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
August 9, 1984	City of Milwaukee	- -	- -	X	- -	1.25 inch	- -	- -	- -
October 16, 1984	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
August 12, 1985	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
July 6, 1986	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
July 19, 1986	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 27, 1986	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 27, 1986	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 27, 1986	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
September 28, 1986	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
May 11, 1987	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
May 21, 1987	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
May 21, 1987	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 6, 1987	City of Milwaukee	- -	- -	X	- -	2.0 inch	- -	- -	- -
July 6, 1987	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 12, 1987	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 29 ,1987	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 15, 1987	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 16, 1987	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 16, 1987	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 21, 1987	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
May 8, 1988	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 4, 1988	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 4, 1988	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
August 8 ,1988	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
June 26, 1989	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 27, 1989	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 27, 1989	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
August 4, 1989	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	- -
March 13, 1990	City of Milwaukee	- -	- -	X	- -	1.75 inch	- -	- -	- -
June 29, 1990	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
September 10, 1990	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
March 27, 1991	City of Milwaukee	X	X	- -	- -	77 knots	- -	- -	- -
March 27, 1991	City of Milwaukee	X	X	- -	- -	67 knots	- -	- -	- -
April 8, 1991	City of Milwaukee	- -	- -	X	- -	0.88 inch	- -	- -	- -
July 7, 1991	City of Milwaukee	X	X	- -	- -	63 knots	- -	- -	- -
July 22, 1991	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
September 9, 1991	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
September 9, 1991	City of Milwaukee	- -	- -	X	- -	2.0 inch	- -	- -	- -
June 17, 1992	City of Milwaukee	X	X	X	- -	59 knots/1.0 inch	- -	- -	- -
June 17, 1992	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
August 30, 1993	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	83,334
July 4, 1994	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	8,125
July 4, 1994	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
July 4, 1994	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	8,125

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
July 4, 1994	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	8,125
July 4, 1994	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	8,125
July 11, 1994	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	- -
April 18, 1995	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
April 18, 1995	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
May 13, 1995	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
June 6, 1995	Milwaukee County	X	- -	- -	X	N/A	- -	- -	12,642
June 7, 1995	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 15, 1995	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	- -
July 15, 1995	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	- -
July 15, 1995	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 15, 1995	Milwaukee County	X	- -	- -	X	N/A	- -	- -	- -
July 15, 1995	Milwaukee County	X	- -	- -	X	N/A	- -	- -	- -
July 27, 1995	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	- -
August 28, 1995	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	- -
August 28, 1995	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	4,741
June 2, 1996	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	18,419
July 18, 1996	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	18,356
August 19, 1996	North Milwaukee County	X	X	- -	- -	0 knots	- -	- -	16,884
October 29, 1996	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
April 6, 1997	Milwaukee County	- -	X	- -	- -	0 knots	- -	- -	450,175
May 5, 1997	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	8,703
June 24, 1997	Milwaukee County	X	X	- -	- -	52 knots	- -	2	7,503
June 24, 1997	City of Milwaukee	X	X	- -	- -	50 knots	- -	- -	- -
June 30, 1997	Milwaukee County	X	- -	- -	X	N/A	- -	- -	30,012
July 2, 1997	Milwaukee County	X	- -	- -	X	N/A	- -	- -	37,515
July 16, 1997	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	1,501
July 21, 1997	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	1,500,584
July 26, 1997	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	1,501
September 29, 1997	Milwaukee County	- -	X	- -	- -	0 knots	- -	- -	1,501
March 8, 1998	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	28,811
May 28, 1998	Milwaukee County	X	X	- -	- -	61 knots	- -	- -	5,910
May 28, 1998	Milwaukee County	X	X	- -	- -	0 knots	- -	- -	1,477
May 31, 1998	Milwaukee County	X	X	- -	- -	87 knots	- -	- -	28,367,417
June 18, 1998	City of Milwaukee	X	X	- -	- -	55 knots	- -	- -	- -
June 18, 1998	Milwaukee County	X	- -	- -	X	N/A	- -	- -	4,432
June 28, 1998	Milwaukee County	X	- -	- -	X	N/A	- -	- -	29,549
July 20, 1998	City of Milwaukee	X	X	- -	- -	0 knots	- -	1	1,477
November 10, 1998	Southeastern Wisconsin	- -	X	- -	- -	53 knots	1	1	1,472,400
February 11, 1999	City of Milwaukee	X	X	- -	- -	61 knots	- -	3	36,139
May 16, 1999	Milwaukee County	X	X	- -	- -	54 knots	- -	- -	1,446
May 16, 1999	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	5,782
May 16, 1999	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	5,782

Date	Affected Area	Event Type: Thunderstorm	High Winds	Hail	Lightning	Magnitude	Reported Damages[a]: Fatalities	Injuries	Property Damage (dollars)[b]
May 17, 1999	Milwaukee County	X	- -	- -	X	N/A	- -	- -	72,277
June 6, 1999	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	289,110
July 20, 1999	Milwaukee County	X	- -	- -	X	N/A	- -	- -	108,416
July 23, 1999	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	43,366
August 10, 1999	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
March 8, 2000	Milwaukee County	- -	- -	X	- -	1.25 inch	- -	- -	- -
March 8, 2000	City of Milwaukee	X	X	X	- -	58 knots/1.0 inch	- -	- -	- -
May 8, 2000	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
May 8, 2000	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	6,993
May 11, 2000	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	1,399
May 11, 2000	City of Milwaukee	X	X	- -	- -	65 knots	- -	- -	69,927
May 18, 2000	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
May 18, 2000	Milwaukee County	- -	- -	X	- -	1.75 inch	- -	- -	27,971
May 18, 2000	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
May 24, 2000	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	4,196
June 1, 2000	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 2, 2000	Milwaukee County	X	- -	- -	X	N/A	- -	- -	20,978
July 2, 2000	Milwaukee County	X	- -	- -	X	N/A	- -	- -	13,985
August 26, 2000	Milwaukee County	X	- -	- -	X	N/A	- -	- -	69,927
September 11, 2000	City of Milwaukee	X	X	- -	- -	0 knots	- -	- -	2,797
September 11, 2000	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	41,956
February 25, 2001	Milwaukee County	- -	X	- -	- -	0 knots	- -	- -	55,757
April 7, 2001	Southeastern Wisconsin	- -	X	- -	- -	57 knots	- -	- -	- -
May 14, 2001	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 11, 2001	Milwaukee County	X	X	- -	- -	61 knots	- -	- -	67,996
June 11, 2001	Milwaukee County	X	- -	- -	X	N/A	- -	- -	33,998
June 18, 2001	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
August 9, 2001	Milwaukee County	X	X	- -	- -	52 knots	- -	1	101,994
September 19, 2001	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	- -
October 25, 2001	Southeastern Wisconsin	- -	X	- -	- -	56 knots	- -	- -	- -
December 5, 2001	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	135,991
April 18, 2002	Milwaukee County	X	X	- -	- -	53 knots	- -	- -	- -
June 10, 2002	Milwaukee County	X	X	X	- -	56 knots/0.75 inch	- -	- -	- -
June 15, 2002	City of Milwaukee, Timmerman Airport	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 15, 2002	City of Milwaukee, General Mitchell Airport	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 15, 2002	City of Milwaukee, General Mitchell Airport	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 15, 2002	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 8, 2002	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
August 21, 2002	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	66,934
August 21, 2002	City of Milwaukee, Timmerman Airport	X	X	- -	- -	70 knots	- -	- -	6,827,224

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
August 21, 2002	Milwaukee County	X	X	- -	- -	65 knots	- -	- -	133,867
August 21, 2002	Milwaukee County	X	- -	- -	X	N/A	- -	- -	669,336
August 21, 2002	Milwaukee County	X	- -	- -	X	N/A	- -	- -	1,339
May 11, 2003	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	39,265
July 4, 2003	City of Milwaukee, Timmerman Airport	X	X	- -	- -	60 knots	- -	- -	- -
July 4, 2003	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	3,927
August 1, 2003	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	- -
August 3, 2003	Milwaukee County	- -	- -	- -	X	N/A	- -	- -	13,088
November 12, 2003	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	68,060
March 7, 2004	Southeastern Wisconsin	- -	X	- -	- -	0 knots	- -	- -	42,073
March 14, 2004	Southeastern Wisconsin	- -	X	- -	- -	43 knots	- -	- -	66,297
April 18, 2004	Southeastern Wisconsin	- -	X	- -	- -	49 knots	- -	- -	356,983
May 10, 2004	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
May 23, 2004	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
May 23, 2004	Milwaukee County	- -	- -	X	- -	1.5 inch	- -	- -	- -
June 23, 2004	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
June 23, 2004	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 16, 2004	City of Milwaukee, General Mitchell Airport	X	X	- -	- -	50 knots	- -	- -	- -
March 30, 2005	City of Milwaukee, General Mitchell Airport	X	X	- -	- -	50 knots	- -	- -	- -
March 30, 2005	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
March 30, 2005	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
March 30, 2005	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
March 30, 2005	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 4, 2005	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
June 7, 2005	City of Milwaukee, General Mitchell Airport	- -	- -	X	- -	1.5 inch	- -	- -	- -
June 7, 2005	City of Milwaukee, General Mitchell Airport	- -	- -	X	- -	0.88 inch	- -	- -	- -
June 7, 2005	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	24,662
June 7, 2005	Milwaukee County	- -	- -	X	- -	2.0 inch	- -	- -	24,662
June 30, 2005	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	- -
June 30, 2005	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
June 30, 2005	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	- -
August 4, 2005	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	24,662
September 13, 2005	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
September 13, 2005	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
November 13, 2005	Southeastern Wisconsin	- -	X	- -	- -	55 knots	- -	- -	26,358
March 13, 2006	Southeastern Wisconsin	- -	X	- -	- -	56 knots	- -	- -	- -
April 13, 2006	Milwaukee County	- -	- -	X	- -	2.0 inch	- -	- -	2,389,179
April 13, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	2,389,179
April 13, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	2,389,179

		Event Type					Reported Damages[a]		
Date	Affected Area	Thunderstorm	High Winds	Hail	Lightning	Magnitude	Fatalities	Injuries	Property Damage (dollars)[b]
April 13, 2006	City of Milwaukee	- -	- -	X	- -	0.88 inch	- -	- -	- -
April 13, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	2,389,179
April 13, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
April 13, 2006	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
June 21, 2006	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
June 21, 2006	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	11,946
June 21, 2006	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	11,946
June 21, 2006	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	City of Milwaukee	X	X	- -	- -	56 knots	- -	- -	23,892
June 21, 2006	City of Milwaukee	X	X	- -	- -	52 knots	- -	- -	- -
July 9, 2006	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	- -
July 9, 2006	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	5,973
July 9, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 9, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	City of Milwaukee	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 9, 2006	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
July 20, 2006	City of Milwaukee	X	- -	- -	X	N/A	- -	- -	17,919
July 22, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 30, 2006	City of Milwaukee	X	X	- -	- -	61 knots	- -	- -	59,729
August 2, 2006	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
August 23, 2006	City of Milwaukee	- -	- -	X	- -	0.75 inch	- -	- -	- -
October 2, 2006	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	- -
October 2, 2006	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
October 2, 2006	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
October 4, 2006	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
October 4, 2006	Downtown Milwaukee	- -	- -	X	- -	0.88 inch	- -	- -	- -
March 21, 2007	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
March 21, 2007	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
March 21, 2007	City of Milwaukee/Timmerman Airport	- -	- -	X	- -	0.75 inch	- -	- -	- -
April 3, 2007	Milwaukee County	X	- -	- -	X	N/A	- -	- -	29,039
April 4, 2007	Milwaukee County	- -	X	- -	- -	39 knots	- -	- -	5,788
June 7, 2007	Downtown Milwaukee	X	X	- -	- -	56 knots	- -	- -	11,616
June 7, 2007	Downtown Milwaukee	X	X	- -	- -	59 knots	- -	- -	11,616
June 7, 2007	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	11,616
June 18, 2007	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	11,616

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
August 22, 2007	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	29,039
August 22, 2007	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	17,424
August 22, 2007	City of Milwaukee/Timmerman Airport	X	X	- -	- -	68 knots	- -	- -	29,039
August 22, 2007	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	17,424
September 27, 2007	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
September 27, 2007	Milwaukee County	- -	- -	X	- -	0.88 inch	- -	- -	- -
September 27, 2007	Milwaukee County	- -	- -	X	- -	0.75 inch	- -	- -	- -
September 27, 2007	City of Milwaukee/Timmerman Airport	- -	- -	X	- -	0.75 inch	- -	- -	- -
December 23, 2007	Southeastern Wisconsin	- -	X	- -	- -	50 knots	- -	- -	2,323
June 6, 2008	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	27,966
June 7, 2008	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	- -
June 8, 2008	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
June 14, 2008	Milwaukee County	X	- -	- -	X	N/A	- -	- -	22,373
July 2, 2008	City of Milwaukee/Timmerman Airport	X	X	- -	- -	56 knots	- -	- -	11,186
July 7, 2008	Downtown Milwaukee	X	X	- -	- -	56 knots	- -	- -	11,186
July 16, 2008	Downtown Milwaukee	X	X	- -	- -	56 knots	- -	- -	11,186
August 4, 2008	Milwaukee County	X	- -	- -	X	N/A	- -	- -	11,186
August 8, 2009	Milwaukee County	X	X	- -	- -	39 knots	- -	1	- -
August 9, 2009	Milwaukee County	X	X	- -	- -	60 knots	- -	- -	16,839
August 9, 2009	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
May 5, 2010	Southeastern Wisconsin	- -	X	- -	- -	39 knots	- -	- -	11,007
June 18, 2010	City of Milwaukee/General Mitchell Airport	X	X	- -	- -	57 knots	- -	- -	- -
June 21, 2010	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
June 21, 2010	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
July 22, 2010	Milwaukee County	X	X	- -	- -	53 knots	- -	- -	- -
July 22, 2010	Milwaukee County	- -	- -	- -	X	N/A	- -	2	- -
July 22, 2010	Milwaukee County	X	X	- -	- -	65 knots	- -	- -	2,201
August 9, 2010	City of Milwaukee/Timmerman Airport	X	X	- -	- -	54 knots	- -	- -	- -
September 6, 2010	Downtown Milwaukee	- -	- -	X	- -	0.88 inch	- -	- -	- -
September 6, 2010	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
September 6, 2010	Milwaukee County	- -	- -	- -	X	N/A	- -	- -	3,302
September 7, 2010	Milwaukee County	- -	X	- -	- -	42 knots	1	- -	5,504
September 21, 2010	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
September 24, 2010	Milwaukee County	- -	X	- -	- -	47 knots	- -	- -	5,504
September 24, 2010	Southeastern Wisconsin	- -	X	- -	- -	42 knots	- -	- -	1,101
October 26, 2010	Milwaukee County	- -	X	- -	- -	53 knots	- -	- -	55,035
January 1, 2011	Milwaukee County	- -	X	- -	- -	43 knots	- -	- -	4,268
February 18, 2011	Milwaukee County	- -	X	- -	- -	39 knots	- -	- -	2,134
April 10, 2011	City of Milwaukee/General Mitchell Airport	X	X	- -	- -	57 knots	- -	- -	- -
April 10, 2011	Milwaukee County	X	X	- -	- -	61 knots	- -	- -	- -

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
April 15, 2011	Milwaukee County	- -	X	- -	- -	39 knots	- -	- -	5,335
May 15, 2011	Milwaukee County	- -	X	- -	- -	41 knots	- -	- -	5,335
May 22, 2011	City of Milwaukee/General Mitchell Airport	X	X	- -	- -	53 knots	- -	- -	- -
June 8, 2011	Milwaukee County	- -	- -	X	- -	1.0 inch	- -	- -	- -
June 8, 2011	Milwaukee County	X	X	- -	- -	57 knots	- -	- -	- -
June 8, 2011	Milwaukee County	X	X	- -	- -	56 knots	- -	- -	- -
June 30, 2011	Milwaukee County	X	X	- -	- -	55 knots	- -	- -	42,680
September 3, 2011	City of Milwaukee/Timmerman Airport	X	X	- -	- -	56 knots	- -	- -	- -
September 29, 2011	Milwaukee County	- -	X	- -	- -	39 knots	1	- -	2,134
October 19, 2011	Milwaukee County	- -	X	- -	- -	50 knots	- -	- -	16,005
November 13, 2011	Southeastern Wisconsin	- -	X	- -	- -	39 knots	- -	- -	1,067
November 29, 2011	Milwaukee County	- -	X	- -	- -	49 knots	- -	- -	1,067
January 1, 2012	Milwaukee County	- -	X	- -	- -	39 knots	- -	- -	3,136
March 10, 2012	Milwaukee County	- -	X	- -	- -	29 knots	- -	- -	2,091
April 15, 2012	Milwaukee County	- -	X	- -	- -	40 knots	- -	- -	1,045
April 16, 2012	Milwaukee County	- -	X	- -	- -	26 knots	- -	- -	1,045
April 16, 2012	Milwaukee County	- -	X	- -	- -	43 knots	- -	- -	1,045
April 16, 2012	Milwaukee County	- -	X	- -	- -	39 knots	- -	- -	1,045
May 1, 2012	Southeastern Wisconsin	X	X	- -	- -	57 knots	- -	- -	2,091
June 18, 2012	Southeastern Wisconsin	- -	X	- -	- -	39 knots	- -	- -	15,681
September 17, 2012	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
November 11, 2012	Milwaukee County	- -	X	- -	- -	43 knots	- -	- -	5,227
January 18, 2013	Milwaukee County	- -	X	- -	- -	43 knots	- -	- -	8,242
January 19, 2013	Milwaukee County	- -	X	- -	- -	42 knots	- -	- -	5,152
April 11, 2013	Milwaukee County	- -	X	- -	- -	42 knots	- -	- -	12,364
May 14, 2013	Milwaukee County	X	X	- -	- -	61 knots	- -	- -	51,515
June 27, 2013	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
November 17, 2013	City of Milwaukee/General Mitchell Airport	- -	- -	X	- -	1.0 inch	- -	- -	- -
November 17, 2013	Milwaukee County	- -	- -	X	- -	1.5 inches	- -	- -	- -
November 17, 2013	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
April 12, 2014	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
April 12, 2014	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
April 12, 2014	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
May 7, 2014	Downtown Milwaukee	- -	- -	X	- -	.88 inches	- -	- -	- -

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
May 12, 2014	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
May 12, 2014	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	- -
May 12, 2014	Milwaukee County	- -	- -	X	- -	2 inches	- -	- -	- -
May 12, 2014	Milwaukee County								
May 12, 2014	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
June 17, 2014	Milwaukee County	X	X	- -	- -	65 knots	- -	- -	30,414
June 17, 2014	Downtown Milwaukee	- -	- -	X	- -	1.25 inches	- -	- -	- -
June 17, 2014	Milwaukee County	- -	- -	X	- -	0.88 inches	- -	- -	- -
June 17, 2014	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
June 18, 2014	City of Milwaukee/Timmerman Airport	- -	- -	X	- -	1 inch	- -	- -	- -
June 18, 2014	Milwaukee County	- -	- -	X	- -	0.88 inches	- -	- -	- -
June 28, 2014	Milwaukee County	X	X	- -	- -	55 knots	- -	- -	2,028
June 30, 2014	Milwaukee County	X	X	- -	- -	53 knots	- -	- -	5,069
June 30, 2014	City of Milwaukee/ General Mitchell Airport	X	X	- -	- -	51 knots	- -	- -	7,097
August 1, 2014	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
August 1, 2014	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 1, 2014	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
June 22, 2015	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	1,013
June 22, 2015	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	1,013
June 22, 2015	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	506
July 18, 2015	Milwaukee County	X	X	- -	- -	55 knots	- -	- -	1,013
August 2, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1.25 inches	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	1.25 inches	- -	- -	- -
August 2, 2015	Milwaukee County	- -	- -	X	- -	3 inches	- -	- -	- -
August 10, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
August 14, 2015	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
December 23, 2015	Milwaukee County	- -	X	- -	- -	49 knots	- -	- -	2,025
February 19, 2016	Milwaukee County	- -	X	- -	- -	55 knots	- -	- -	100,000
March 16, 2016	Milwaukee County	- -	X	- -	- -	50 knots	- -	- -	30,000
April 25, 2016	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -

Date	Affected Area	Event Type				Magnitude	Reported Damages[a]		
		Thunderstorm	High Winds	Hail	Lightning		Fatalities	Injuries	Property Damage (dollars)[b]
April 25, 2016	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
April 25, 2016	Milwaukee County	- -	- -	X	- -	0.75 inches	- -	- -	- -
April 25, 2016	City of Milwaukee/ Timmerman Airport	- -	- -	X	- -	0.75 inches	- -	- -	- -
April 25, 2016	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
June 5, 2016	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	1,000
August 3, 2016	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	5,000
August 3, 2016	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	5,000
September 7, 2016	Milwaukee County	X	X	- -	- -	50 knots	- -	- -	3,000
September 7, 2016	Milwaukee County	X	X	- -	- -	52 knots	- -	- -	1,000
September 21, 2016	Milwaukee County	- -	- -	X	- -	1 inch	- -	- -	- -
Total	- -	216	239	142	27	- -	3	11	52,308,845

NOTE: N/A indicates data not available.

[a]*Fatalities, injuries, and property damages reported were based upon a geographic area impacted by the hazard event, which affected the City of Milwaukee and, in some cases, a larger area of impact than Milwaukee County itself, generally within the southeast regional area of Wisconsin.*

[b]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: The National Climatic Data Center (NCDC) a part of the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and the National Environmental Satellite, Data and Information Service (NESDIS).

Table III-13

FUJITA SCALE CHARACTERISTICS

F-Scale	Wind Speed (miles per hour)	Character of Damage	Relative Frequency (percent)
F0 (weak)	40-72	Light damage	29
F1 (weak)	73-112	Moderate damage	40
F2 (strong)	113-157	Considerable damage	24
F3 (strong)	158-206	Severe damage	6
F4 (violent)	207-260	Devastating damage	2
F5 (violent)	261-318	Incredible damage (rare)	<1

Source: National Oceanic Atmospheric Administration.

Table III-14

ENHANCED FUJITA SCALE CHARACTERISTICS

EF-Scale	Wind Speed (miles per hour)[a]	Character of Damage	Relative Frequency (percent)
EF0 (weak)	65-85	Light damage	53
EF1 (weak)	86-110	Moderate damage	32
EF2 (strong)	111-135	Considerable damage	11
EF3 (strong)	136-165	Severe damage	3
EF4 (violent)	166-200	Devastating damage	1
EF5 (violent)	>200	Incredible damage (rare)	<1

[a]*Equivalent wind speeds associated with the Enhanced Fujita Scale represent a three-second gust of wind.*

Source: National Oceanic Atmospheric Administration.

Table III-15

TORNADO EVENTS REPORTED IN MILWAUKEE COUNTY: 1958- 2016

Number on Map III-2	Date	Affected Area	Magnitude (Fujita)	Length (miles)	Width (yards)	Fatalities	Injuries	Property Damage (dollars)[a]
1	August 7, 1958	City of Milwaukee	F2	1	100	- -	4	208,363
2	September 26, 1959	Milwaukee County	F2	2	33	- -	3	2,069,095
3	July 22, 1962	City of Milwaukee	F2	- -	33	- -	- -	199,337
4	October 4, 1962	Milwaukee County	F1	1	33	- -	- -	199,337
- -	August 22, 1964	Milwaukee County	F1	2	400	- -	- -	1,993,698
5	September 3, 1964	City of Milwaukee	F2	- -	100	- -	- -	1,993,698
6	August 11, 1969	Milwaukee County	F1	- -	100	- -	153	1,640,593
7	August 25, 1975	City of Milwaukee	F1	- -	10	- -	- -	11,227
8	August 25, 1975	City of Milwaukee	F2	- -	20	- -	- -	111,941
9	April 2, 1977	Milwaukee County	F2	1	33	- -	- -	99,393
10	August 4, 1977	City of Milwaukee	F1	- -	- -	- -	- -	- -
11	August 4, 1980	City of Milwaukee	F2		20	- -	- -	730,645
- -	July 20, 1981	City of Milwaukee	F1	1	20	- -	- -	66,262
12	August 17, 1985	City of Milwaukee	F1	2	50	- -	- -	- -
13	May 24, 1989	City of Milwaukee	F0	- -	23	- -	- -	485,519
- -	August 30, 1993	Milwaukee County	N/A	- -	- -	- -	- -	- -
14	March 8, 2000	City of Milwaukee	F1	2	75	- -	16	6,433,371
- -	July 2, 2000	Milwaukee County	F1	7	100	- -	- -	2,097,824
Total	- -	- -	- -	- -	- -	0	176	18,340,303

NOTE: N/A indicates data not available.

[a]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: National Climatic Data Center and SEWRPC.

Table III-16

EXTREME AND DEPARTURE FROM AVERAGE TEMPERATURE CHARACTERISTICS WITHIN THE CITY OF MILWAUKEE: 1990-2016

Year	General Mitchell International Airport				Mount Mary College			
	High Temperature (ºF)	Low Temperature (ºF)	Average Annual Temperature (ºF)	Departure from Average Temperature (ºF)	High Temperature (ºF)	Low Temperature (ºF)	Average Annual Temperature (ºF)	Departure from Average Temperature (ºF)
1990	98	-7	49.9	3.8	98	-8	51.2	3.7
1991	97	-3	50.0	3.9	98	-6	50.6	3.1
1992	90	-5	47.5	1.4	93	-6	48.4	0.9
1993	95	-2	47.8	1.7	95	-5	48.3	0.1
1994	100	-21	49.4	3.3	100	-24	49.3	1.1
1995	103	-5	48.5	2.4	108	-6	49.1	0.8
1996	95	-26	46.0	-0.2	97	-25	46.8	-1.4
1997	92	-8	46.4	0.2	98	-10	48.2	-0.1
1998	95	-4	50.9	4.8	N/A	-5	N/A	N/A
1999	99	-15	48.3	3.1	104	-13	50.5	2.2
2000	89	-8	47.9	1.8	94	-8	48.9	0.7
2001	95	1	48.2	2.9	102	-6	50.5	2.3
2002	98	-6	49.2	1.7	103	-5	49.7	1.5
2003	96	-5	46.2	-0.1	98	-6	48.1	-0.1
2004	91	-10	47.7	0.2	94	-12	48.5	0.3
2005	97	-1	49.2	1.3	99	-3	49.5	1.3
2006	98	12	50.1	2.6	100	14	50.2	2.0
2007	94	-11	48.9	1.4	97	-14	49.3	1.1
2008	89	-6	47.0	-0.5	95	-8	46.8	-1.4
2009	94	-12	47.3	-0.3	95	-14	47.0	-1.2
2010	92	2	50.3	2.8	95	0	50.1	1.9
2011	98	-7	48.6	1.1	100	-9	48.5	0.3
2012	103	-1	51.9	4.4	105	-3	51.9	3.7
2013	95	-5	46.7	-0.8	96	-8	46.3	-1.9
2014	89	-14	45.0	-2.5	90	-15	44.7	-3.5
2015	93	-9	48.5	N/A	94	-10	48.4	-0.1
2016	94	-7	50.8	N/A	95	-7	52.3	3.8
Average	95.1	-6.8	48.5	1.6	97.8	-8.2	49.0	0.8

NOTE: N/A indicates data not available.

Source: National Oceanic and Atmospheric Administration and SEWRPC.

Table III-17

HEAT INDEX CHART

Temperature (°F)	Relative Humidity (percent)												
	100	95	90	85	80	75	70	65	60	55	50	45	40
	Heat Index (°F)												
80	87.2	86.4	85.6	84.9	84.2	83.6	83.0	82.4	81.8	81.3	80.8	80.3	79.9
82	94.5	93.0	91.5	90.1	88.8	87.6	86.4	85.4	84.4	83.6	82.8	82.5	81.5
84	102.7	100.3	98.0	95.9	94.0	92.2	90.5	88.9	87.5	86.3	85.1	84.1	83.3
86	111.5	108.3	105.3	102.5	99.8	97.3	95.1	93.0	91.1	89.4	87.9	86.6	85.4
88	121.2	117.1	113.2	109.6	106.3	103.1	100.2	97.6	95.1	93.0	91.0	89.4	87.4
90	131.6	126.6	121.9	117.5	113.3	109.5	105.9	102.7	99.7	97.0	94.6	92.5	90.7
92	142.8	136.9	131.3	126.0	121.0	116.4	112.2	108.3	104.7	101.4	98.5	96.0	93.8
94	154.8	147.9	141.3	135.2	129.4	124.0	119.0	114.4	110.2	106.3	102.9	99.8	97.2
96	167.5	159.6	152.1	145.0	138.3	132.1	126.4	121.0	116.1	111.7	107.6	104.0	100.9
98	181.0	172.0	163.5	155.5	147.9	140.9	134.3	128.2	122.6	117.4	112.8	108.6	104.9
100	195.3	185.2	175.7	166.7	158.2	150.2	142.8	135.9	129.5	123.6	118.3	113.5	109.3
102	210.4	199.2	188.5	178.5	169.0	160.1	151.8	144.1	136.9	130.3	124.3	118.8	113.9
104	226.2	213.8	202.1	191.0	180.5	170.7	161.4	152.8	144.8	137.4	130.6	124.4	118.9
106	242.7	229.2	216.4	204.2	192.6	181.8	171.6	162.0	153.1	144.9	137.3	130.4	124.2
108	260.1	245.4	231.3	218.0	205.4	193.5	182.3	171.1	161.9	152.8	144.4	136.7	129.8
110	278.2	262.2	247.0	232.5	218.8	205.8	193.5	182.0	171.2	161.2	152.0	143.4	135.7

Source: National Weather Service.

Table III-18

LEVEL OF RISK FOR PERSONS IN HIGH RISK GROUPS ASSOCIATED WITH THE HEAT INDEX

Heat Index (degrees Fahrenheit)	Category	Possible Heat Disorders for Persons in High Risk Groups
80-90	Caution	Fatigue possible with prolonged exposure and/or physical activity
90-105	Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity
105-129	Danger	Sunstroke, muscle cramps and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity
130 or Above	Extreme Danger	Heat stroke or sunstroke likely

Source: National Weather Service.

Table III-19

WIND CHILL TEMPERATURES[a]

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

[a]Wind Chill (^oF) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$, where T = air temperature (^oF) and V = wind speed (mph). The wind chill temperature is only defined for temperatures at or below 50^oF and wind speeds above 3 mph. Bright sunshine may increase wind chill temperature by 10^oF to 18^oF.

Frostbite times associated with wind chills:
30 minutes
10 minutes
5 minutes

Source: National Weather Service.

Table III-20

EXTREME TEMPERATURE EVENTS IN SOUTHEASTERN WISCONSIN: 1994 TO 2016

Beginning Date	Ending Date	Type	Fatalities	Injuries	Property Damages (dollars)
January 13, 1994	January 20, 1994	Extreme cold	0	0	- -
June 14, 1994	June 23, 1994	Heat Wave	0	0	- -
July 13, 1995	July 15, 1995	Excessive heat	85	0	- -
October 12, 1995	October 12, 1995	Record warmth	0	0	- -
November 7, 1995	November 7, 1995	Extreme cold	1	0	- -
December 9, 1995	December 9, 1995	Extreme cold	2	0	- -
January 30, 1996	January 30, 1996	Cold and wind chill	0	0	- -
January 31, 1996	January 31, 1996	Cold and wind chill	0	7	- -
February 1, 1996	February 4, 1996	Cold and wind chill	4	15	- -
June 29, 1996	June 29, 1996	Heat	0	70	- -
January 17, 1997	January 17, 1997	Cold and wind chill	0	3	- -
July 16, 1997	July 16, 1997	Heat	1	0	- -
October 3, 1997	October 8, 1997	Heat	0	0	- -
October 12, 1997	October 12, 1997	Heat	0	0	- -
November 30, 1997	November 30, 1997	Cold and wind chill	1	0	- -
January 2, 1998	January 4, 1998	Heat	0	0	- -
March 26, 1998	March 26, 1998	Heat	0	0	- -
June 25, 1998	June 25, 1998	Heat	0	21	- -
September 27, 1998	September 28, 1998	Heat	0	0	- -
November 28, 1998	November 30, 1998	Heat	0	0	- -
December 1, 1998	December 6, 1998	Heat	0	0	- -
January 5, 1999	January 5, 1999	Cold and wind chill	0	0	- -
February 11, 1999	February 11, 1999	Heat	0	0	- -
July 4, 1999	July 5, 1999	Heat	0	0	- -
July 23, 1999	July 24, 1999	Heat	0	0	- -
July 29, 1999	July 31, 1999	Heat	4	0	- -
January 2, 2000	January 2, 2000	Excessive heat	0	0	- -
February 23, 2000	February 29, 2000	Excessive heat	0	0	- -
March 4, 2000	March 8, 2000	Excessive heat	0	0	- -
May 6, 2000	May 6, 2000	Excessive heat	0	0	- -
July 21, 2001	July 22, 2001	Heat	2	0	- -
August 6, 2001	August 9, 2001	Heat	2	0	- -
April 15, 2002	April 18, 2002	Heat	1	0	- -
June 20, 2002	June 20, 2002	Heat	1	0	- -
June 22, 2002	June 25, 2002	Heat	1	0	- -
June 30, 2002	June 30, 2002	Heat	0	0	- -
July 1, 2002	July 3, 2002	Heat	0	0	- -
July 8, 2002	July 8, 2002	Heat	0	0	- -
July 21, 2002	July 21, 2002	Heat	0	0	- -
July 26, 2002	July 26, 2002	Heat	0	0	- -
July 24, 2005	July 24, 2005	Heat	0	0	- -
December 18, 2005	December 19, 2005	Cold and wind chill	0	0	- -
February 17, 2006	February 18, 2006	Cold and wind chill	0	0	- -
February 18, 2006	February 19, 2006	Cold and wind chill	0	0	- -
July 16, 2006	July 17, 2006	Heat	0	0	- -
July 30, 2006	July 31, 2006	Heat	0	40	- -
August 1, 2006	August 2, 2006	Heat	2	0	- -
December 7, 2006	December 7, 2006	Cold and wind chill	1	0	- -
February 3, 2007	February 6, 2007	Cold and wind chill	0	0	23,150
January 19, 2008	January 20, 2008	Cold and wind chill	1	0	- -
January 30, 2008	January 30, 2008	Cold and wind chill	0	0	- -

Beginning Date	Ending Date	Type	Fatalities	Injuries	Property Damages (dollars)
February 10, 2008	February 10, 2008	Extreme cold and wind chill	0	0	- -
December 15, 2008	December 15, 2008	Cold and wind chill	0	0	- -
December 21, 2008	December 22, 2008	Cold and wind chill	0	1	- -
January 14, 2009	January 16, 2009	Cold and wind chill	0	0	- -
January 21, 2011	January 21, 2011	Cold and wind chill	0	0	- -
July 20, 2011	July 21, 2011	Heat	0	60	- -
June 18, 2012	June 20, 2012	Heat	2	0	- -
June 28, 2012	June 28, 2012	Heat	0	0	- -
July 3, 2012	July 6, 2012	Excessive heat	2	0	- -
July 16, 2012	July 17, 2012	Heat	0	0	- -
July 23, 2012	July 23, 2012	Heat	0	0	- -
July 25, 2012	July 25, 2012	Heat	0	0	- -
January 21, 2013	January 22, 2013	Cold and wind chill	0	0	- -
July 16, 2013	July 19, 2013	Excessive heat	0	0	- -
August 30, 2013	August 30, 2013	Heat	0	0	- -
January 3, 2014	January 3, 2014	Cold and wind chill	1	0	- -
January 6, 2014	January 7, 2014	Extreme cold and wind chill	0	0	- -
January 27, 2014	January 29, 2014	Cold and wind chill	1	0	- -
February 5, 2014	February 5, 2014	Cold and wind chill	1	0	- -
March 16, 2014	March 16, 2014	Cold and wind chill	1	0	- -
December 3, 2014	December 3, 2014	Cold and wind chill	1	0	- -
December 5, 2014	December 5, 2014	Cold and wind chill	1	0	- -
January 1, 2015	January 1, 2015	Cold and wind chill	1	0	- -
January 7, 2015	January 8, 2015	Cold and wind chill	0	0	- -
January 9, 2015	January 10, 2015	Cold and wind chill	0	0	- -
January 8, 2016	January 8, 2016	Cold and wind chill	1	0	- -
January 17, 2016	January 17, 2016	Cold and wind chill	1	0	- -
July 21, 2016	July 24, 2016	Heat	0	29	- -
January 27, 2016	January 27, 2016	Heat	1	0	- -
December 10, 2016	December 10, 2016	Cold and wind chill	1	0	- -
December 14, 2016	December 15, 2016	Cold and wind chill	0	0	- -
December 18, 2016	December 19, 2016	Cold and wind chill	1	0	- -
Total	- -	- -	125	246	23,150

Source: Milwaukee County Pre-Disaster Mitigation Plan, National Weather Service, and the National Climatic Data Center.

Table III-21

1995 NATIONWIDE HEAT-RELATED FATALITIES BY AGE AND GENDER

Age Group	Female	Male	Total	Percent of Total
0 to 9 Years Old	6	6	12	1
10 to 19 Years Old	0	2	2	<1
20 to 29 Years Old	2	3	5	<1
30 to 39 Years Old	7	27	34	3
40 to 49 Years Old	15	64	79	8
50 to 59 Years Old	22	73	95	9
60 to 69 Years Old	50	129	179	18
70 to 79 Years Old	131	122	253	25
80 to 89 Years Old	145	96	241	24
90 Years Old and Older	51	10	61	6
Unknown	6	54	60	6
Total	425	586	1,021	100
Percent	43	57	100	- -

Source: National Weather Service.

Table III-22

WINTER STORM AND ICE STORM EVENTS IN THE CITY OF MILWAUKEE: 1924-2016

Beginning Date	Ending Date	Affected Area	Event	Reported Damages: Fatalities	Reported Damages: Injuries	Reported Damages: Property Damages (dollars)[a]
February 1924	- -	Milwaukee County	Blizzard	3	- -	- -
January 1947	- -	Milwaukee County	Blizzard	0	- -	- -
April 1973	- -	Milwaukee County	Blizzard	0	- -	- -
March 1976	- -	Milwaukee County	Ice storm[b]	0	- -	- -
December 1978	January 1979	Milwaukee County	Snow emergency[b]	0	- -	- -
December 1987	- -	City of Milwaukee	Blizzard	10	0	- -
January 13, 1993	January 14, 1993	Statewide	Heavy snow	0	0	- -
November 8, 1993	- -	Milwaukee County	Heavy snow	0	0	- -
November 28, 1993	- -	City of Milwaukee	Heavy Snow	0	0	- -
January 5, 1994	January 6, 1994	Central and southern Wisconsin	Heavy snow	0	0	- -
January 26, 1994	January 28, 1994	All but far northwest Wisconsin	Heavy snow/Ice storm	0	0	- -
February 7, 1994	February 9, 1994	Southern and eastern Wisconsin	Heavy snow	0	0	- -
February 12, 1994	- -	Southeast Wisconsin	Heavy snow	0	0	- -
February 22, 1994	February 23, 1994	Southern Wisconsin	Heavy snow	0	0	- -
February 25, 1994	- -	Southern Wisconsin	Heavy snow	0	0	- -
December 5, 1994	December 7, 1994	Southern Wisconsin	Heavy snow	0	0	- -
January 19, 1995	January 20, 1995	Southeast Wisconsin	Heavy snow	0	0	- -
November 26, 1995	November 27, 1995	Central and southern Wisconsin	Heavy snow	0	1	- -
December 13, 1995	December 14, 1995	Southern Wisconsin	Glaze	0	0	- -
January 5, 1996	January 6, 1996	Southeast Wisconsin	Heavy snow	0	0	- -
January 16, 1996	January 16, 1996	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 23, 1996	January 23, 1996	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 29, 1996	January 29, 1996	Southeast and south-central Wisconsin	Blizzard	0	0	- -
January 16, 1997	January 16, 1997	Southeast and south-central Wisconsin	Blizzard	0	0	- -
January 8, 1998	January 9, 1998	Eastern Wisconsin	Winter storm	0	0	- -
January 2, 1999	January 2, 1999	Southeast and south-central Wisconsin	Blizzard	0	5	2,881
March 9, 1999	March 9, 1999	Southeast and south-central Wisconsin	Winter storm	0	0	- -

Beginning Date	Ending Date	Affected Area	Event	Reported Damages		
				Fatalities	Injuries	Property Damages (dollars)[a]
April 7, 2000	April 7, 2000	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 11, 2000	December 12, 2000	Southeast Wisconsin	Heavy snow	0	0	- -
December 18, 2000	December 19, 2000	Southeast and south-central Wisconsin	Heavy Snow	0	0	- -
December 2000	January 2001	Milwaukee County	Snow emergency[b]	0	0	- -
March 2, 2002	March 2, 2002	South-central and southeast Wisconsin	Heavy snow	0	0	- -
February 3, 2003	February 3, 2003	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 11, 2003	February 11, 2003	Southeast and south-central Wisconsin	Winter storm	0	0	- -
March 4, 2003	March 5, 2003	Southeast Wisconsin	Heavy snow	0	0	- -
April 4, 2003	April 4, 2003	Milwaukee County	Winter weather	0	0	- -
April 7, 2003	April 7, 2003	Southern Wisconsin	Winter weather	0	0	- -
January 4, 2004	January 5, 2004	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 16, 2004	January 17, 2004	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 26, 2004	January 27, 2004	Southeast Wisconsin	Heavy snow	0	0	- -
February 8, 2004	February 9, 2004	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 18, 2004	December 18, 2004	Milwaukee County	Winter weather	0	0	- -
January 1, 2005	January 1, 2005	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 6, 2005	January 6, 2005	Southeast and south-central Wisconsin	Winter storm	0	0	- -
January 22, 2005	January 23, 2005	Milwaukee County	Winter storm	0	0	- -
January 27, 2005	January 27, 2005	Milwaukee County	Heavy snow	0	0	- -
February 16, 2006	February 16, 2006	Southeast and south-central Wisconsin	Winter storm	0	0	- -
November 10, 2006	November 10, 2006	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 1, 2006	December 1, 2006	Milwaukee County	Blizzard	0	0	- -
January 12, 2007	January 12, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 14, 2007	January 15, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 21, 2007	January 21, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 13, 2007	February 14, 2007	Milwaukee County	Winter weather	0	0	- -
February 23, 2007	February 24, 2007	Southeast and south-central Wisconsin	Winter storm	0	0	- -

Beginning Date	Ending Date	Affected Area	Event	Reported Damages		
				Fatalities	Injuries	Property Damages (dollars)[a]
February 24, 2007	February 25, 2007	Milwaukee County	Blizzard	0	0	86,813
February 25, 2007	February 25, 2007	Milwaukee County	Winter storm	0	0	- -
March 2, 2007	March 2, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
April 11, 2007	April 11, 2007	Southeast and south-central Wisconsin	Winter storm	0	0	11,575
November 21, 2007	November 21, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 1, 2007	December 2, 2007	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 11, 2007	December 11, 2007	Southeast and south-central Wisconsin	Ice storm	0	0	- -
December 15, 2007	December 16, 2007	Southeast Wisconsin	Winter weather	0	0	- -
December 28, 2007	December 28, 2007	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 21, 2008	January 22, 2008	Southeast Wisconsin	Heavy snow	0	0	- -
January 29, 2008	January 30, 2008	Southeast and south-central Wisconsin	Winter storm	0	0	- -
January 31, 2008	January 31, 2008	Southeast Wisconsin	Winter storm	0	0	- -
February 5, 2008	February 6, 2008	Southern Wisconsin	Winter storm[b]	0	0	- -
February 9, 2008	February 10, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 11, 2008	February 12, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 17, 2008	February 17, 2008	Southeast Wisconsin	Winter weather	0	0	- -
March 21, 2008	March 22, 2008	Southeast and south-central Wisconsin	Winter storm	0	0	- -
November 24, 2008	November 24, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
November 30, 2008	November 30, 2008	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 1, 2008	December 1, 2008	Southeast and south-central Wisconsin	Winter storm	1	0	- -
December 3, 2008	December 3, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 16, 2008	December 17, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 18, 2008	December 19, 2008	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 21, 2008	December 21, 2008	Southeast and south-central Wisconsin	Winter storm	1	0	- -
December 23, 2008	December 23, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 24, 2008	December 24, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -

Beginning Date	Ending Date	Affected Area	Event	Reported Damages		
				Fatalities	Injuries	Property Damages (dollars)[a]
December 25, 2008	December 26, 2008	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 3, 2009	January 4, 2009	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 9, 2009	January 9, 2009	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 12, 2009	January 13, 2009	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 13, 2009	January 14, 2009	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 21, 2009	February 21, 2009	Southeast and south-central Wisconsin	Winter storm	0	0	- -
February 26, 2009	February 27, 2009	Southeast and south-central Wisconsin	Winter weather	0	0	- -
March 2, 2009	March 2, 2009	Milwaukee County	Lake-effect snow	0	0	- -
March 28, 2009	March 29, 2009	Milwaukee County	Winter storm	3	0	- -
December 8, 2009	December 9, 2009	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 23, 2009	December 24, 2009	Milwaukee County	Winter storm	0	0	- -
January 7, 2010	January 8, 2010	Southeast and south-central Wisconsin	Winter storm	0	0	- -
February 9, 2010	February 10, 2010	Southern Wisconsin	Winter storm	1	0	- -
February 24, 2010	February 24, 2010	Milwaukee County	Winter weather	0	0	- -
March 19, 2010	March 20, 2010	Southern Wisconsin	Winter weather	0	0	- -
December 3, 2010	December 4, 2010	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 9, 2010	December 10, 2010	Milwaukee County	Winter weather	0	1	5,504
December 12, 2010	December 12, 2010	Southeast Wisconsin	Winter weather	0	0	- -
December 20, 2010	December 21, 2010	Southern Wisconsin	Winter weather	0	0	- -
December 25, 2010	December 26, 2010	Milwaukee County	Winter weather	0	0	- -
January 17, 2011	January 17, 2011	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 1, 2011	February 2, 2011	Southern Wisconsin	Blizzard	3	2	10,670
February 6, 2011	February 6, 2011	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 20, 2011	February 20, 2011	Southeast and south-central Wisconsin	Winter storm	0	0	- -
February 21, 2011	February 22, 2011	Southeast and south-central Wisconsin	Winter weather	0	0	- -
March 9, 2011	March 9, 2011	Southern Wisconsin	Winter weather	0	0	- -
December 29, 2011	December 29, 2011	Southeast and south-central Wisconsin	Winter weather	0	0	- -

Beginning Date	Ending Date	Affected Area	Event	Reported Damages		
				Fatalities	Injuries	Property Damages (dollars)[a]
January 12, 2012	January 13, 2012	Southeast and south-central Wisconsin	Winter weather	0	0	- -
January 17, 2012	January 17, 2012	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 23, 2012	February 24, 2012	Southern Wisconsin	Winter weather	0	0	- -
March 2, 2012	March 2, 2012	Southeast and south-central Wisconsin	Winter storm	0	0	- -
December 20, 2012	December 21, 2012	Southeast Wisconsin	Winter storm	0	0	- -
January 27, 2013	January 27, 2013	Southern Wisconsin	Winter weather	0	0	- -
January 30, 2013	January 30, 2013	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 7, 2013	February 7, 2013	Southeast and south-central Wisconsin	Winter storm	0	0	- -
February 22, 2013	February 22, 2013	Southeast and south-central Wisconsin	Winter weather	0	0	- -
February 26, 2013	February 27, 2013	Southeast and south-central Wisconsin	Winter storm	0	0	- -
March 5, 2013	March 5, 2013	Southeast Wisconsin	Winter weather	0	0	- -
March 18, 2013	March 19, 2013	Southern Wisconsin	Winter weather	0	0	- -
November 25, 2013	November 25, 2013	Milwaukee County	Winter weather	0	0	- -
December 8, 2013	December 9, 2013	Southern Wisconsin	Winter weather	1	0	- -
December 19, 2013	December 20, 2013	Southern Wisconsin	Winter weather	0	0	- -
December 22, 2013	December 22, 2013	Southern Wisconsin	Winter storm	0	0	- -
December 31, 2013	December 31, 2013	Southern and southeast Wisconsin	Winter weather	0	0	- -
January 1, 2014	January 2, 2014	Southern and southeast Wisconsin	Winter weather	0	0	- -
January 10, 2014	January 11, 2014	Southern Wisconsin	Winter weather	0	0	- -
January 14, 2014	January 15, 2014	Southern Wisconsin	Winter weather	0	0	- -
January 24, 2014	January 25, 2014	Milwaukee County	Winter weather	0	0	- -
January 26, 2014	January 26, 2014	Southern Wisconsin	Winter weather	0	0	- -
January 26, 2014	January 27, 2014	Southern Wisconsin	Winter weather	0	0	- -
February 4, 2014	February 5, 2014	Southeast Wisconsin	Winter weather	0	0	- -
February 13, 2014	February 13, 2014	Southern Wisconsin	Winter weather	0	0	- -
February 17, 2014	February 17, 2014	Southeast and east-central Wisconsin	Winter storm	0	0	- -
March 4, 2014	March 4, 2014	Southern Wisconsin	Winter weather	0	0	- -

Beginning Date	Ending Date	Affected Area	Event	Reported Damages		
				Fatalities	Injuries	Property Damages (dollars)[a]
April 14, 2014	April 15, 2014	Southeast Wisconsin	Winter weather	0	0	- -
November 22, 2014	November 22, 2014	Milwaukee County	Winter weather	0	0	- -
November 28, 2014	November 28, 2014	Milwaukee County	Winter weather	0	0	- -
December 18, 2014	December 18, 2014	Milwaukee County	Winter weather	0	0	- -
January 8, 2015	January 8, 2015	Southern Wisconsin	Winter weather	0	0	- -
February 1, 2015	February 2, 2015	Southern and eastern Wisconsin	Winter storm	3	0	- -
February 25, 2015	February 26, 2015	Southern Wisconsin	Winter weather	0	0	- -
March 3, 2015	March 3, 2015	Southern and southeast Wisconsin	Winter weather	0	0	- -
November 20, 2015	November 21, 2015	Southern and southeast Wisconsin	Winter storm	0	0	- -
December 28, 2015	December 29, 2015	Southern Wisconsin	Winter storm	2	0	5,063
February 8, 2016	February 8, 2016	Milwaukee County	Winter weather	0	0	- -
February 29, 2016	February 29, 2016	Southern Wisconsin	Winter weather	0	0	- -
March 1, 2016	March 1, 2016	Southern Wisconsin	Winter weather	0	0	- -
March 24, 2016	March 24, 2016	Southern and central Wisconsin	Winter weather	0	0	- -
April 2, 2016	April 2, 2016	Southern Wisconsin	Winter weather	0	0	- -
April 8, 2016	April 8, 2016	Southeast and south-central Wisconsin	Winter weather	0	0	- -
December 4, 2016	December 4, 2016	Southern Wisconsin	Winter weather	0	0	- -
December 10, 2016	December 11, 2016	Southern Wisconsin	Winter storm	1	0	- -
December 16, 2016	December 18, 2016	Southern Wisconsin	Winter storm	2	0	- -
December 19, 2016	December 19, 2016	Milwaukee County	Winter weather	1	0	- -
Total		- -	- -	32	9	122,505

[a]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

[b]*Federally Declared Presidential Emergency.*

Source: Milwaukee County Pre-Disaster Mitigation Plan and the National Climatic Data Center.

Table III-23

TOTAL NUMBER OF ACCIDENTS AMONG WEATHER AND ROAD CONDITIONS REPORTED WITHIN THE STATE OF WISCONSIN: 2013

Weather Conditions	Road Conditions							Total
	Dry	Wet	Snow/ Slush	Ice	Sand/Mud/ Dirt/Oil	Other	Unknown	
Clear	40,907	1,423	2,417	1,356	115	70	72	46,360
Cloudy	19,306	4,660	3,864	1,757	68	29	53	29,737
Snow	61	693	10,525	1,264	0	2	17	12,562
Rain	60	6,880	166	366	6	3	4	7,485
Sleet/Hail	4	153	502	947	1	1	2	1,610
Fog/Smog/Smoke	234	356	48	84	2	2	6	732
Blowing Sand/Dirt/Snow	3	12	361	248	1	1	0	626
Severe Crosswinds	28	12	14	20	0	1	0	75
Other	9	4	3	5	0	0	2	22
Unknown	202	38	99	25	5	2	18,673	19,044
Total	60,814	14,231	17,999	6,072	198	111	18,829	118,254

Source: Wisconsin Department of Transportation Bureau of Transportation Safety and SEWRPC.

Table III-24

NATURAL GAS AND HAZARDOUS LIQUID PIPELINE INCIDENTS IN THE CITY OF MILWAUKEE: 1970-2016

Date	Pipeline Incident	Fatalities	Injuries	Property Damage (in dollars)[a]
1971	Fuel oil	0	0	0
February 3, 1971	Natural gas	0	0	0
March 11, 1971	Natural gas	0	0	5,306
May 25, 1971	Natural gas	0	0	2,311
February 17, 1972	Natural gas	0	1	3,334
January 14, 1975	Natural gas	0	5	23,863
February 13, 1975	Natural gas	0	4	11,931
1977	Gasoline	0	0	338
March 23, 1977	Natural gas	0	0	1,473
September 30, 1977	Natural gas	0	0	8,423
December 18, 1977	Natural gas	0	0	2,104
January 19, 1978	Natural gas	0	1	1,169
November 21, 1978	Natural gas	0	0	3,895
November 25, 1980	Natural gas	0	0	2,339
1981	Gasoline	0	0	145
August 26, 1982	Natural gas	0	3	625
September 7, 1982	Natural gas	0	0	499
July 9, 1983	Natural gas	0	0	2,344
November 22, 1983	Natural gas	0	0	0
1984	Gasoline	0	0	0
March 19, 1984	Natural gas	0	0	0
May 21, 1984	Natural gas	0	0	7,730
May 21, 1984	Natural gas	0	0	12,141
August 9, 1984	Natural gas	0	2	220,856
April 24, 1988	Natural gas	0	12	2,966,405
October 15, 1990	Natural gas	0	0	181,958
February 15, 1991	Fuel oil	0	0	59,336
July 9, 1992	Natural gas	0	0	85,563
December 30, 2005	Natural gas	0	0	401,285
October 3, 2006	Gasoline	0	0	12,125
September 17, 2007	Natural gas	0	0	61,842
February 1, 2009	Natural gas	0	2	482,066
November 17, 2010	Jet Fuel	0	0	2,752
January 23, 2012	Jet Fuel	0	0	12,140,195
June 16, 2015	Petroleum product	0	0	354,410
Total	- -	0	30	17,058,763

[a]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: Federal Department of Transportation, Office of Pipeline Safety; and SEWRPC.

Table III-25

CASES OF SELECTED INFECTIOUS DISEASES REPORTED IN THE CITY OF MILWAUKEE: 2014

Disease	Number of Reported Cases
Babesiosis	0
Blastomycosis	9
Campylobacter enteritis	64
Cryptosporidiosis	11
E. coli, shiga toxin-producing (STEC)	10
Ehrlichiosis/Anaplasmosis	0
Giardiasis	57
Haemophilus influenzae, Invasive	8
Hepatitis Type A	0
Hepatitis Type B	116
Hepatitis Type C	597
Influenza-associated hospitalization	470
Legionnaire's	24
Lyme	<5
Measles	0
N. meningitidis (Meningococcal disease)	<5
Meningitis, other bacterial	<5
Mumps	8
Pertussis	98
Salmonellosis	80
Shigellosis	188
Streptococcus pneumonae, invasive	53
Streptococcal diseases, all other	89
Tuberculosis	10
Sexually Transmitted Diseases	
Chlamydia trachomatis	8,315
Gonorrhea	2,316
Syphilis	161
Immunizations (children in grades K-12) by Compliance	
Compliant	98,418
Noncompliant	11,102
Percent Compliant	89.9

Source: Wisconsin Department of Health Services, "Wisconsin Public Health Profile 2016: Milwaukee," accessed September 2017.

Table III-26

MORTALITIES DUE TO SELECTED DISEASES REPORTED IN THE CITY OF MILWAUKEE COUNTY: 2014

Disease	Number of Mortalities	Death Rates[a]
Heart Disease (total)	1,024	171.8
Ischemic heart disease	599	100.5
Cancer (total)	1,012	169.8
Trachea/Bronchus/Lung	265	44.5
Coleorectal	99	16.6
Female breast[b]	70	22.6
Cerebrovascular Disease	206	34.6
Lower Respiratory Disease	168	28.2
Pneumonia and Influenza	68	11.4
Accidents:	373	62.6
Motor Vehicle	64	10.7
Diabetes	111	18.6
Other Infectious and Parasitic Diseases	116	19.5
Suicide	56	9.4
Alcohol and Drug Abuse as Underlying Cause of Death		
Alcohol	60	10.1
Other Drugs	8	- -
Tobacco Use	673	112.9

[a]*Death rates are per 100,000 people.*

[b]*Based on female deaths from breast cancer and female population.*

Source: Wisconsin Department of Health Service, "Wisconsin Public Health Profile 2016: Milwaukee," accessed September 2017.

Table III-27

ARSON FIRES AND REPORTED DAMAGES WITHIN THE CITY OF MILWAUKEE: 2000-2015

Year	Total Number of Arson Fires	Reported Damages					
		Residential Arson Fires	Residential Arson Damages (in thousands of dollars)[a]	Mobile Property Arson Fires[b]	Mobile Property Arson Fire Damages (in thousands of dollars)[a]	Other Arson Fires[c]	Other Arson Damages (in thousands of dollars)[a]
2000	524	172	$ 2,886.3	210	$1,237.0	142	$1,649.3
2001	453	143	1,885.5	232	1,481.4	78	538.7
2002	382	141	2,266.1	158	933.1	83	1,333.1
2003	341	97	654.5	172	589.0	72	392.6
2004	263	79	892.4	132	637.5	52	382.5
2005	257	51	739.9	41	369.9	165	986.4
2006	322	55	1,016.7	39	112.1	228	454.6
2007	347	50	1,380.3	47	135.3	250	102.6
2008	319	48	536.5	31	129.1	240	25.9
2009	348	25	766.9	42	69.1	281	18.4
2010	221	73	248.3	25	41.9	123	37.8
2011	273	114	1,110.9	26	40.8	133	298.2
2012	268	87	405.9	34	163.4	147	5.4
2013	207	52	236.6	30	166.4	125	36.4
2014	193	60	1,244.4	22	89.1	111	522.7
2015	181	48	1,649.2	31	224.6	102	81.3
Total	4,899	1,295	$17,920.3	1,272	$6,419.8	2,332	$6,865.8

[a] *Dollar values are adjusted to year 2016 by using the Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

[b] *Total includes vehicles, trailers, and boats.*

[c] *Total includes storage facilities and all other arson incidents. For 2005-2009, this was calculated by difference.*

Source: City of Milwaukee Public Safety Report, Milwaukee Fire Department.

Table III-28

FIRE AND EMERGENCY RESPONSE RATES WITHIN THE CITY OF MILWAUKEE: 2000-2015

Year	Emergency Medical Service Responses	EMS Response per 100,000 Persons	Number of Residential Building Fires	Fire Fatalities Rate per 100,000 Persons	Reported Damages			Special Team Responses		
					Fatalities	Total Property Damages (in millions of dollars)[a,b]	Residential Property Damages (in millions of dollars)[a]	DIVE	HURT	HAZMAT
2000	49,833	8,347.6	1,542	1.17	Seven fatalities in five fires	$ 25.2	$ 16.5	29	13	24
2001	49,452	8,283.8	1,308	1.34	Eight fatalities in seven fires	29.8	16.1	24	18	24
2002	49,188	8,239.6	1,177	1.00	Six fatalities in five fires	28.0	15.1	56	83	209[c]
2003	48,593	8,139.9	1,612	1.70	10 fatalities in eight fires	15.7	11.6	12	15	14
2004	54,028	9,050.3	- -[d]	2.01	12 fatalities in nine fires	21.7	16.2	22	7	17
2005	50,442	8,449.6	641	2.68	16 fatalities in nine fires	19.7	12.5	29	9	20
2006	59,567	9,978.2	493	2.01	12 fatalities in nine fires	19.6	8.4	22	16	25
2007	48,890	8,110.7	583	2.32	14 fatalities in 13 fires	20.9	10.5	38	12	29
2008	55,898	9,273.3	343	1.00	Six fatalities in five fires	15.0	10.6	23	9	25
2009	53,047	8,886.0	305	1.16	Seven fatalities in seven fires	12.9	10.1	37	8	21
2010	54,927	9,234.0	958	0.50	Four fatalities in four fires	11.3	8.1	42	10	14
2011	56,085	9,417.7	1,166	1.68	11 fatalities in 10 fires	14.7	9.9	24	15	70
2012	59,587	10,005.5	1,151	1.34	8 fatalities in 8 fires	13.1	8.6	- -[d]	11	- -[d]
2013	60,499	10,142.3	1,074	0.34	Two fatalities in two fires	22.8	15.7	37	- -[d]	- -[d]
2014	62,766	10,531.3	1,107	1.68	10 fatalities in 10 fires	45.5	28.1	32	13	92
2015	70,504	11,833.8	1,039	1.68	10 fatalities in 10 fires	33.9	25.5	19	6	88

Total	883,306	- -	14,499	- -	142 fatalities in 121 fires	$349.8	$223.5	346	245	672

[a]*Dollar values are adjusted to year 2016 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

[b]*Includes buildings (residential and nonresidential), contents, vehicles, and other nonstructural fires.*

[c]*Total includes five responses outside of the City of Milwaukee.*

[d]*Data not available*

Source: City of Milwaukee Public Safety Report, Milwaukee Fire Department Annual Report, Milwaukee Fire Department.

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Chapter III

ANALYSIS OF HAZARD CONDITIONS

FIGURES

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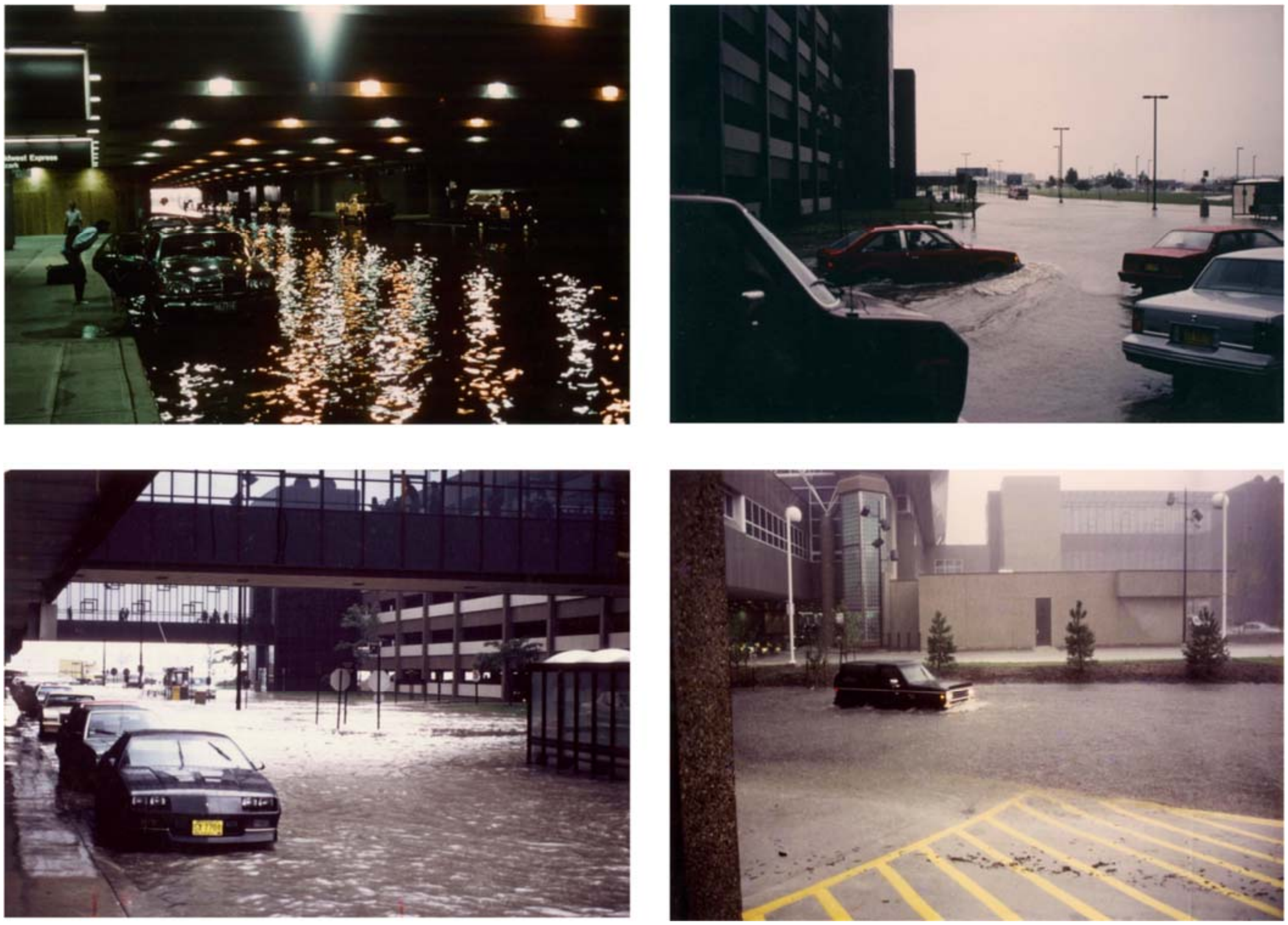
Figure III-1

FLOODING AT GENERAL MITCHELL INTERNATIONAL AIRPORT, AUGUST 1986



Source: Wisconsin Division of Emergency Management

Figure III-2

FLOODING AT THE CARGILL MEAT SOLUTIONS FACILITY NEAR THE MOUTH OF THE MENOMONEE RIVER, AUGUST 1986

Executive area parking spaces. Greg Tweed and Dick Kuehn. Elsie Haight, left, and Chris Zagorski, center, cast a line with an unidentified employee.

Source: Cargill Meat Solutions Corporation.

Figure III-3

FLOODING NEAR 42ND STREET AND CLYBOURN STREET, JUNE 21, 1997

Source: Milwaukee Metropolitan Sewerage Commission.

Figure III-4

FLOODING ALONG THE KINNICKINNIC RIVER AT 9TH PLACE AND CLEVELAND AVENUE: JUNE 7, 2008

Source: Milwaukee Metropolitan Sewerage District.

Figure III-5

SINKHOLE RESULTING FROM FLOODING NEAR NORTH AVENUE AND OAKLAND AVENUE, JULY 21, 2010

Source: Milwaukee Metropolitan Sewerage Commission.

Figure III-6

DAMAGE TO RESIDENTIAL PROPERTY CAUSED BY THE JULY 2010 FLOODING

Source: City of Milwaukee.

Figure III-7

WIND DAMAGE CAUSED BY SEPTEMBER 7, 2016 THUNDERSTORM

Source: National Weather Service.

Figure III-8

DAMAGE CAUSED BY THE MARCH 8, 2000 TORNADO

Source: National Weather Service.

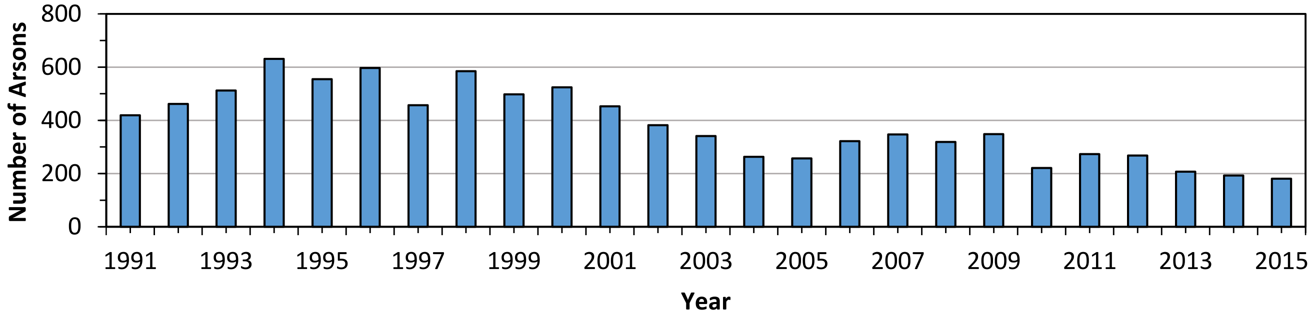
Figure III-9

SNOW FROM THE GROUNDHOG'S DAY BLIZZARD OF FEBRUARY 1-2, 2011

Source: National Weather Service.

Figure III-10

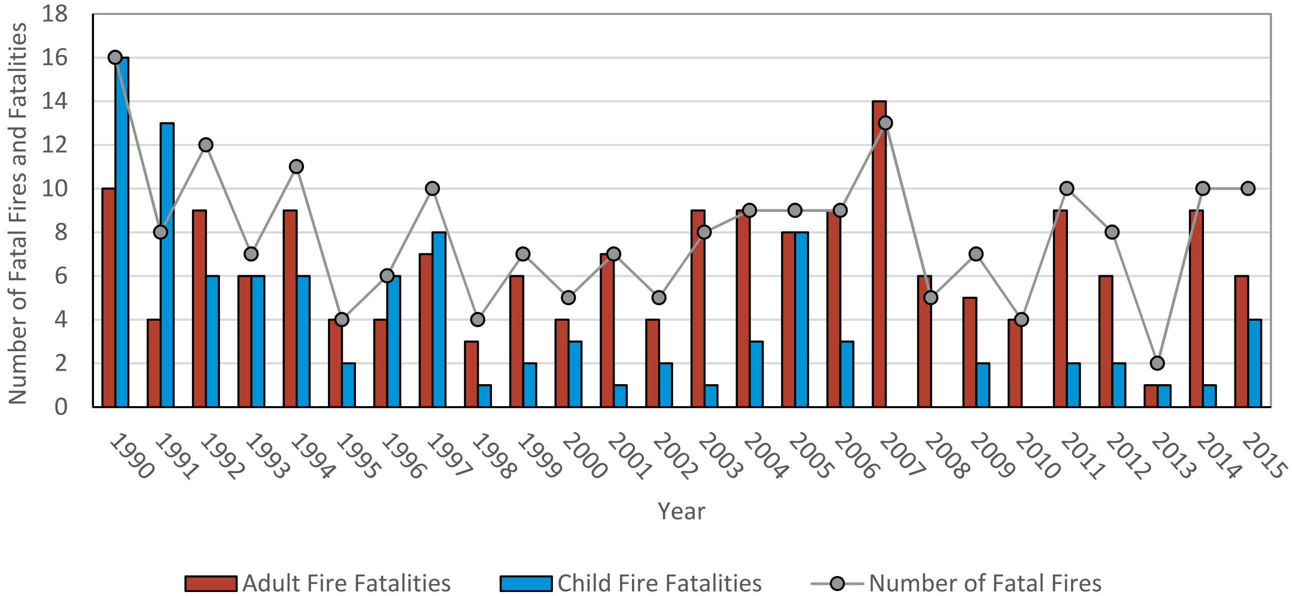
NUMBER OF ARSONS REPORTED IN THE CITY OF MILWAUKEE: 1991-2015



Source: City of Milwaukee Public Safety Report and City of Milwaukee Fire Department.

Figure III-11

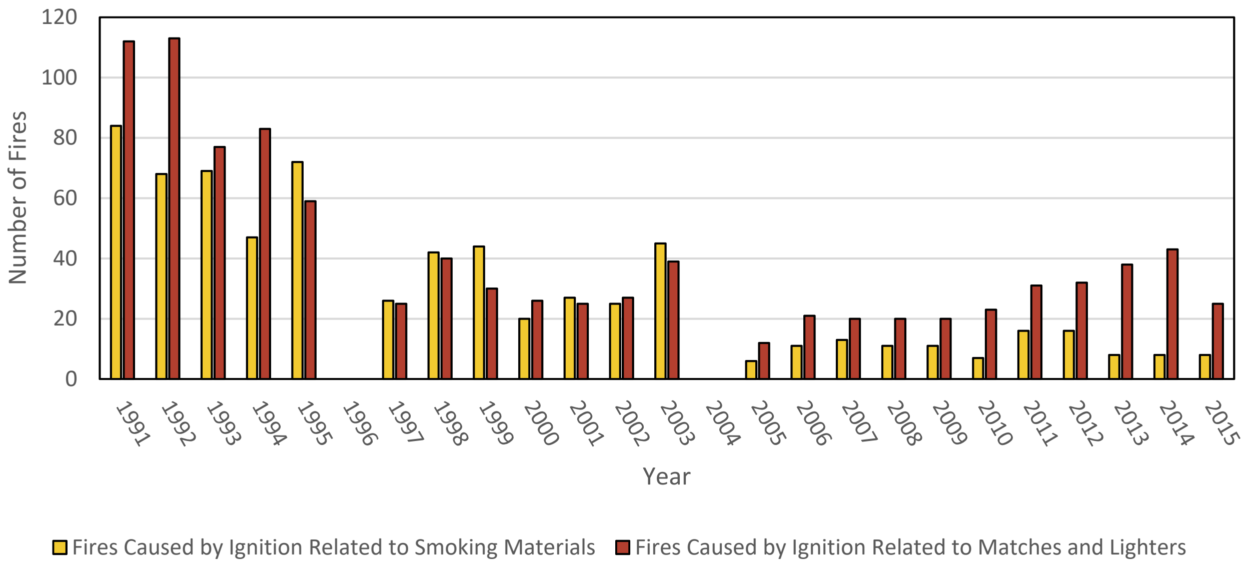
NUMBER OF FATAL FIRES AND FIRE FATALITIES IN THE CITY OF MILWAUKEE: 1990-2015



Source: City of Milwaukee Public Safety Report, City of Milwaukee Fire Department, and City of Milwaukee Police Department

Figure III-12

NUMBER OF FIRES IN THE CITY OF MILWAUKEE CAUSED BY IGNITION RELATED TO SMOKING MATERIAL OR MATCHES AND LIGHTERS: 1990-2015



Note: Data were not available for years 1996 and 2004.

Source: City of Milwaukee Public Safety Report, City of Milwaukee Fire Department, and City of Milwaukee Police Department

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Chapter III

ANALYSIS OF HAZARD CONDITIONS

MAPS

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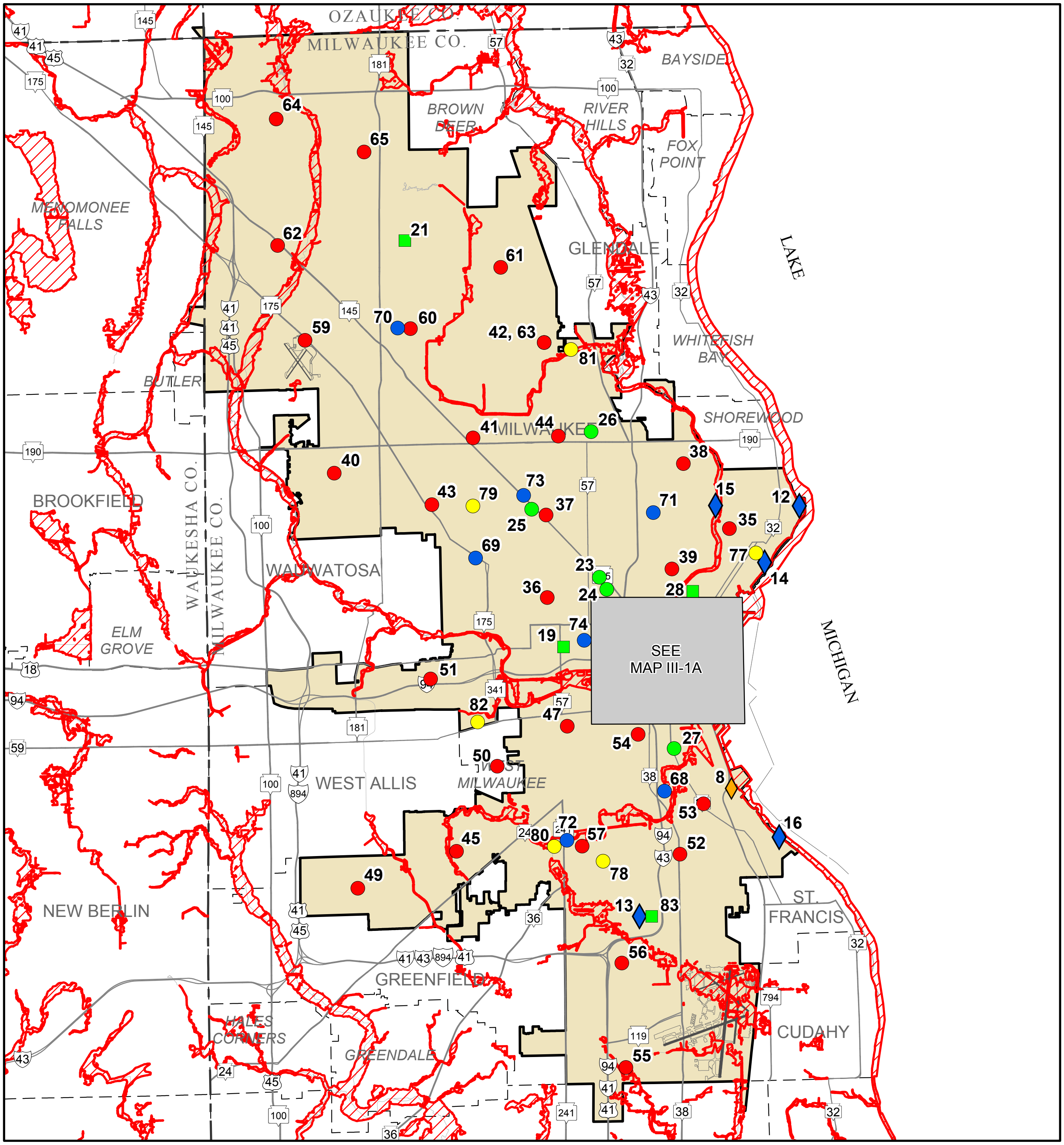
Map III - 1

LOCATION OF CRITICAL FACILITIES IN RELATION TO FLOODPLAINS IN THE CITY OF MILWAUKEE: 2016



CRITICAL GOVERNMENT FACILITY

LAW ENFORCEMENT STATION

FIRE STATION

HOSPITALS AND MEDICAL CENTERS

CITY OF MILWAUKEE

MILWAUKEE COUNTY TRANSIT SYSTEM FACILITY

PORT OF MILWAUKEE

WATER PURIFICATION PLANT OR PUMPING STATION

WASTEWATER TREATMENT PLANT

29 CRITICAL FACILITY REFERENCE NUMBER (SEE APPENDIX B, TABLES B-1 TO B-4)

ONE-PERCENT-ANNUAL-PROBABILITY (100-YEAR RECURRENCE INTERVAL) FLOODPLAINS (FEMA (JAN. 2018), SEWRPC MCAMLIS)

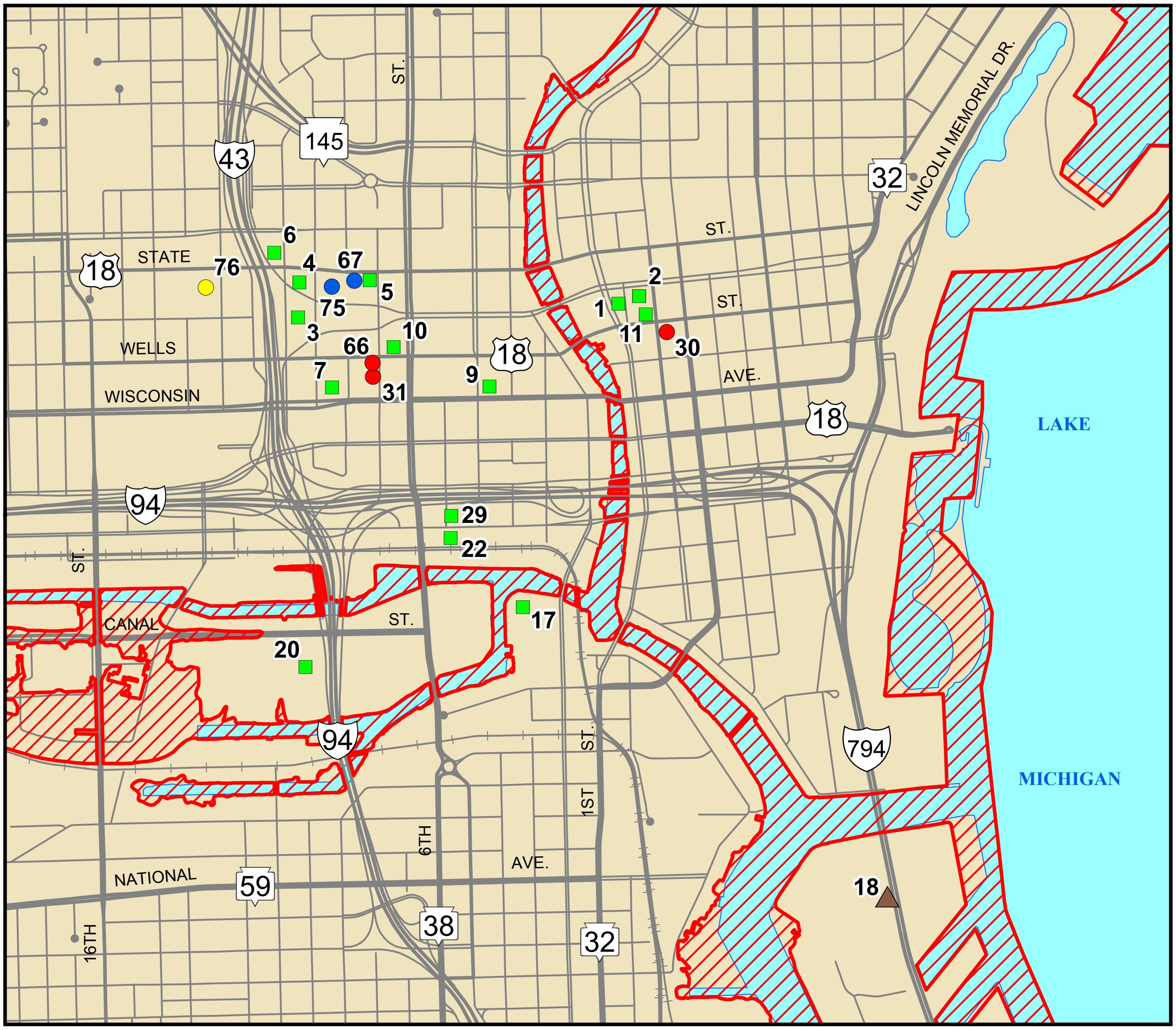
N

0 0.5 1 2 Miles

Source: Milwaukee County Automated Mapping and Land Information System (MCAMLIS), City of Milwaukee Master Property File (MPROP), Federal Emergency Management Agency, and SEWRPC.

Map III - 1A

LOCATION OF CRITICAL FACILITIES IN RELATION TO FLOODPLAINS IN THE CITY OF MILWAUKEE: 2016



CRITICAL GOVERNMENT FACILITY

LAW ENFORCEMENT STATION

FIRE STATION

HOSPITALS AND MEDICAL CENTERS

WASTEWATER TREATMENT PLANT

29 CRITICAL FACILITY REFERENCE NUMBER (SEE APPENDIX B, TABLES B-1 TO B-4)

ONE-PERCENT-ANNUAL-PROBABILITY (100-YEAR RECURRENCE INTERVAL) FLOODPLAINS (FEMA (JAN. 2018), SEWRPC MCAMLIS)

N

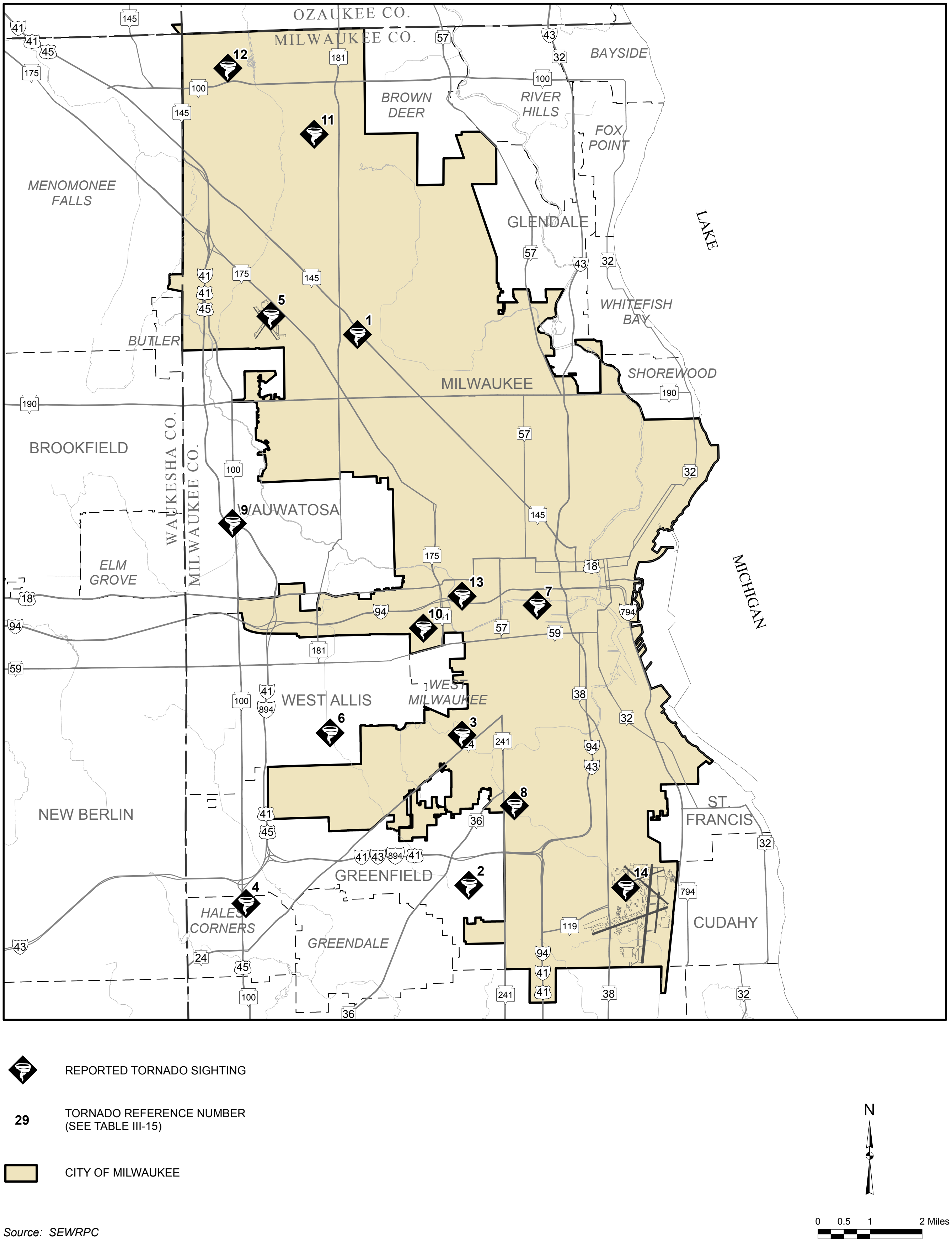
GRAPHIC SCALE

0 1,000 2,000 Feet

Source: Milwaukee County Automated Mapping and Land Information System (MCAMLIS), City of Milwaukee Master Property File (MPROP), Federal Emergency Management Agency, and SEWRPC.

Map III - 2

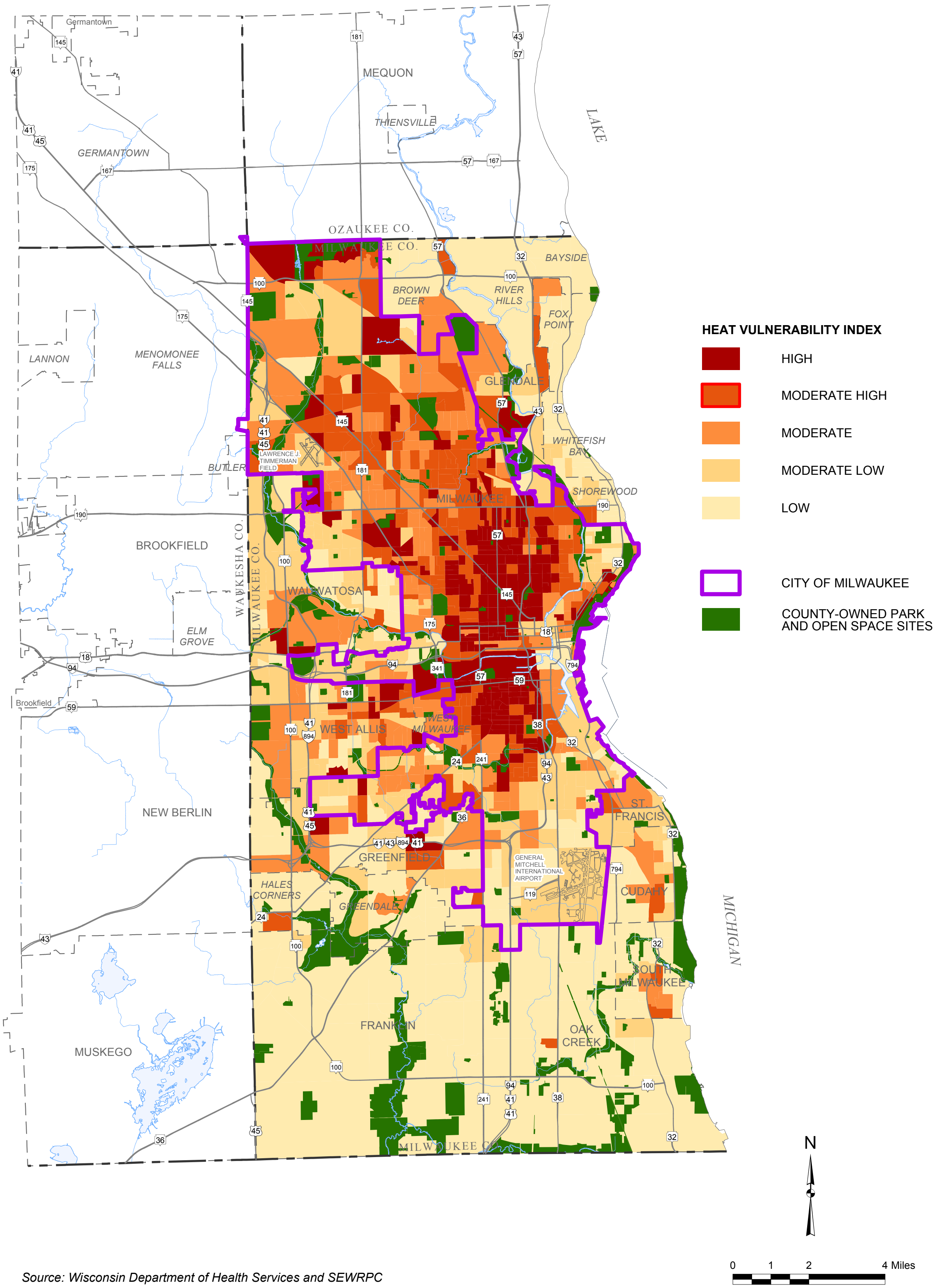
TORNADOES IN THE CITY OF MILWAUKEE: 1950-2010



Source: SEWRPC

Map III - 3

MILWAUKEE COUNTY HEAT VULNERABILITY INDEX: 2014



Source: Wisconsin Department of Health Services and SEWRPC