

Vulnerability Assessment for the Fox River Corridor Plan

Introduction

Climate vulnerability refers to the degree to which a community is exposed to climate change, is sensitive to its impacts, and is able to adapt to those impacts.¹ This assessment explores climate-related hazards affecting the communities and resources within the Fox River Corridor (“Corridor”), as well as their projected future exposure and adaptive capacity. The vulnerabilities identified in this report will be addressed in the Fox River Corridor Plan, which will identify a wide range of strategies for local and regional implementers.

This assessment was developed in partnership with the National Oceanic and Atmospheric Administration (NOAA), the American Planning Association (APA), and Illinois-Indiana Sea Grant, with the goal of identifying new ways to integrate climate science into the local planning process. The methodology and data sources used to develop this analysis will be compiled by the American Planning Association and integrated into a guidebook for local planners. This report adds to the conversation about climate resilience, an emerging field in planning.

Key Findings

1. **Communities within the Fox River Corridor are highly vulnerable to overbank flooding.** Prior to modern floodplain and stormwater management regulations, development in the Corridor and throughout the Chicago region occurred in flood-prone areas, such as floodplains, wetlands, and other low-lying areas. Eroded shoreline conditions and projected increased rainfall during spring and winter months will further expose riverfront communities to flood-related impacts.²
2. **Drought poses a significant risk to the communities within the Corridor that rely on groundwater for their water supply.** Increased temperatures and prolonged periods of drought caused by climate change can affect the Corridor’s water demand and further strain an already threatened source of water. These conditions could endanger downstream water supply as well as aquatic habitat because increases in (land and water) evaporation rates due to increased temperatures can reduce the baseflow of the Fox River, tributary streams, and lakes. Even before considering the effects of climate

¹ Intergovernmental Panel on Climate Change, 2007, “Synthesis Report,” https://www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-2.html.

² National Climate Assessment, 2014, *Precipitation Change*, <https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change>

change, portions of the shallow and deep aquifer are being drained at rates that exceed their ability to recharge.³

3. **Shifts in temperature and precipitation will likely affect water-based recreation and tourism—a major economic sector within the Fox River Corridor.** An increase in riverine flooding, particularly during the summer, will increase the number of days the Fox River is shut down to boaters. Although an increase in temperatures would extend the regular boating season, it will likely have a negative impact on other activities such as fishing, snowmobiling, and cross-country skiing.
4. **Climate change poses a risk of degraded ecosystems and habitat loss.** The Corridor's natural resources and ecosystem services are highly vulnerable to climate impacts. This vulnerability is significant because the Corridor's land cover supports a wide range of habitats for native flora and fauna that serve a crucial role in mitigating flooding, recharging groundwater, and filtering stormwater runoff current habitat and ecosystem services are significant. Increasing temperatures and precipitation as well as flooding, erosion, and an increase in invasive species will likely threaten the natural habitat and wildlife species found in the Corridor.

Community Profile

The Fox River originates near Menomonee Falls in Wisconsin and flows for over 200 miles before reaching the Illinois River in Ottawa, IL. Located approximately 45 miles northwest of downtown Chicago, the Plan study area is a scenic portion of the Fox River between Burtons Bridge in the north and Fox Bluff Conservation Area in the south (Figure 1). It spans portions of the Villages of Cary, Fox River Grove, Island Lake, Lake Barrington, Oakwood Hills, Port Barrington, Tower Lakes, and Trout Valley and unincorporated lands in southeast McHenry County and southwest Lake County.

The land within the Corridor contains extensive natural resources, including waterbodies, wetlands, floodplains, riparian areas, and protected open space that support diverse wildlife, including threatened and endangered species. Watersports, particularly recreational boating, are extremely popular on the Fox River and Chain O'Lakes to the north. Many homes along the river were originally constructed as summer homes and most businesses, including marinas and restaurants, depend on water-based recreation and tourism in the warmer months.⁴

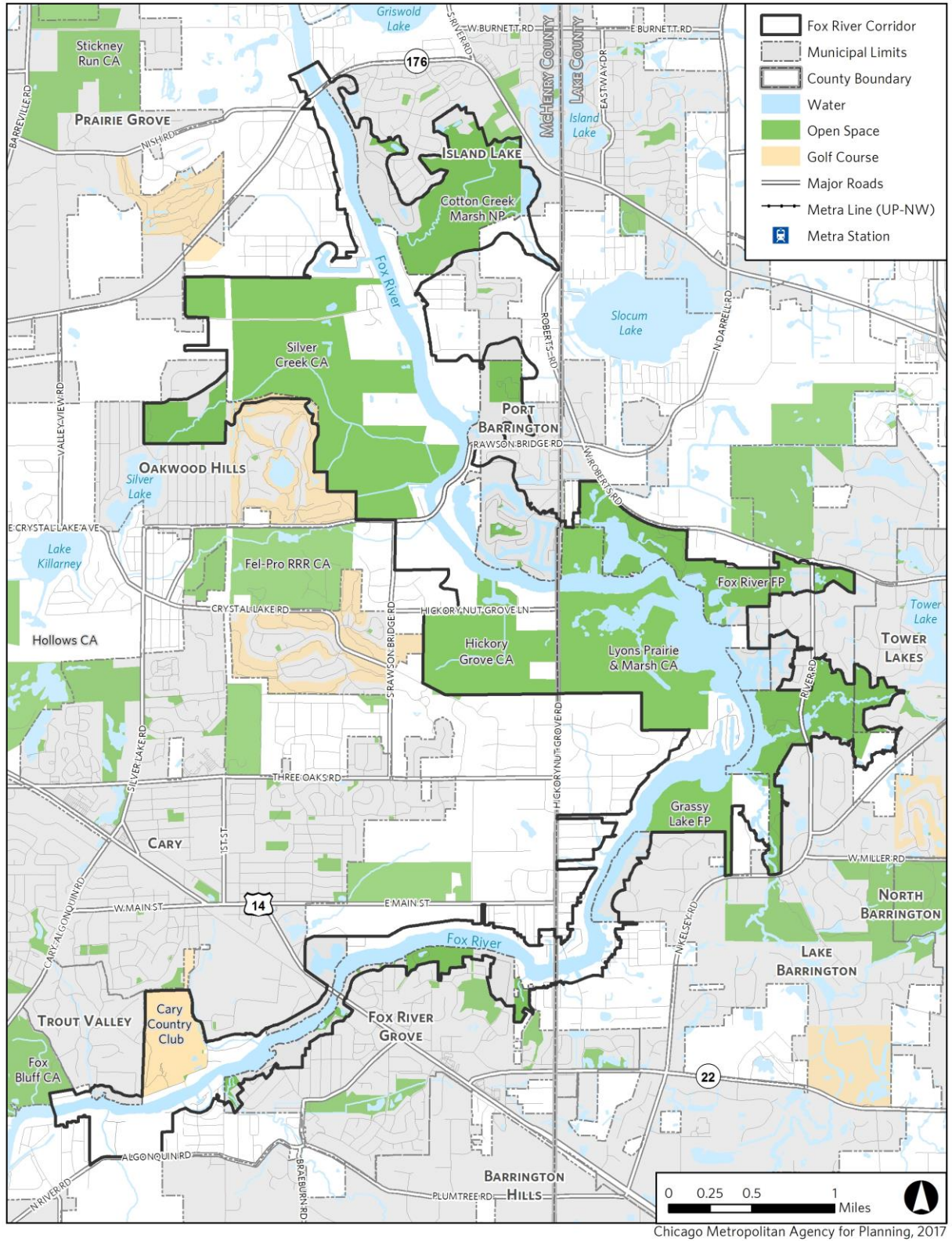
As of 2014, the Corridor is home to 9,408 residents, with an additional 206,192 residents living within a five-mile radius. Nearly 90 percent of the residents in the Corridor are white,

³ CMAP, "Water Resources Strategy Paper," 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/a54d17e1-a3fb-6bf7-1efb-f5515868ebeb

⁴ McHenry County, "2030 Comprehensive Plan," April 2010.

compared to 84 percent within a five-mile radius, 83 percent in McHenry County, and 52 percent in the Chicago region. The area is predominately middle- to upper middle-income with 58 percent of its households with an income of \$75,000 or greater, compared to 52 percent within McHenry County and 42 percent in the Chicago region. Single-family homes account for 90 percent of the Corridor's housing stock and 85.3 percent of all housing units are owner-occupied.

Figure 1. Fox River Corridor



Climate and Natural Hazards

The Fox River Corridor has a humid continental climate that is characterized by warm summers as well as cold and dry winters.^{5,6} This historical climate is the basis for the kinds of temperatures, precipitation patterns, and weather events that the Corridor has experienced for most of its recorded history. Summer months tend to be hot and humid, with relative humidity averaging 60 percent. Summer temperatures typically peak during the month of July, with daily averages highs reaching 82 degrees Fahrenheit.⁷ Summer rains and severe thunderstorms are also common, with over 55 percent of the area's precipitation falling between the months of April and September.⁸ Winter months tend to be cold and slightly drier, with an average seasonal snowfall of 34.3 inches. During the months of December through March, there are approximately 11 days that receive snowfall that is equal to or above one inch in depth.⁹ Temperature are lowest in January, when average minimum temperatures drop to 20 degrees Fahrenheit.¹⁰

While weather-related hazards have always been present in northeastern Illinois, climatic shifts associated with a warming atmosphere have led to clear changes in the frequency and intensity of some weather events. The Great Lakes region has warmed by two degrees Fahrenheit since 2000, which is a faster rate of

Climate vs. Weather

Weather is characterized by the variability in atmospheric conditions over a short period of time, such as a few hours or days. Thunderstorms, cold spells, droughts, and blizzards are all examples of weather.

Climate refers to long-term atmospheric trends, typically averaged over 30-years. In other words, climate reflects the weather of a place averaged over a long period of time.

It can be tempting to point to weather events as a sign that climate change is or is not happening, but the evidence of climate change is much harder to spot. Climate scientists analyze records going back many decades to find evidence of long-term changes. These changes may make individual weather events stronger, or more frequent, but the weather events themselves do not constitute a change in climate.

⁵ All climate and weather related data is based on McHenry County data. Although a portion of the study area is located within Lake County, the majority is within McHenry County.

⁶ NOAA, Koppen-Geiger Climate Classification – 2007, <https://sos.noaa.gov/datasets/koppen-geiger-climate-classification-2007/>

⁷ ISWS, Official Climate Normals for McHenry-WG Stratton LD, <http://www.isws.illinois.edu/atmos/statecli/newnormals/normals.USC00115493.txt>

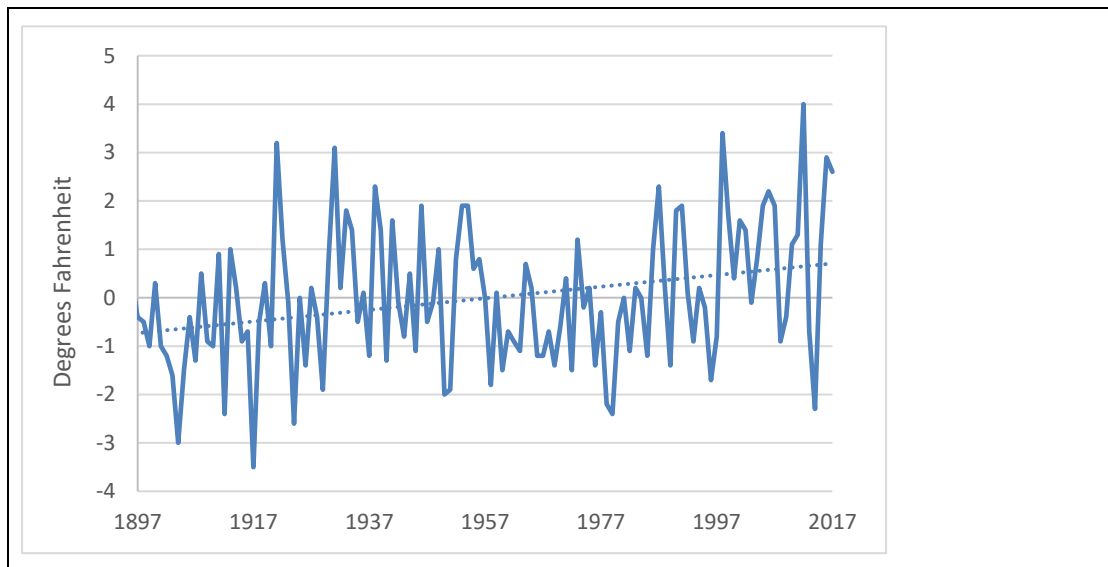
⁸ Santec and Molly O'Toole Associates, LTD, "McHenry County Natural Hazards Mitigation Plan," August 2017, <https://www.co.mchenry.il.us/home/showdocument?id=77420>

⁹ NOAA National Climatic Data Center, "Official 1981-2010 Climate Normals," <http://www.isws.illinois.edu/atmos/statecli/newnormals/normals.USC00115493.txt>

¹⁰ ISWS, Official Climate Normals for McHenry-WG Stratton LD,, <http://www.isws.illinois.edu/atmos/statecli/newnormals/normals.USC00115493.txt>

increase than in any other decade since 1900.¹¹ Despite fluctuations in average annual temperature since 1959, the overall trend has been a clear and significant increase in average temperature (Figure 2).

Figure 2. Change in average annual temperatures in Illinois



Source: National Centers for Environmental Information, “Climate at a Glance,” National Oceanic and Atmospheric Administration, <https://www.ncdc.noaa.gov/cag/>.

The Midwest has been experiencing an increase in precipitation and heavy storm events as regional temperatures rise. As air warms, its ability to retain water vapor increases, which allows for more frequent and more powerful storms.¹² Within the atmosphere, air can hold four percent more water vapor with each degree Fahrenheit of temperature increase.¹³ Between 1979 and 2009, northeastern Illinois saw 40 percent more precipitation than during the previous 30-year period.¹⁴ The increased precipitation has occurred as part of larger storms, with the amount of precipitation falling in very heavy storm events increasing by 37% between 1958 and 2012.¹⁵

The current trend of rising temperatures is primarily due to increasing concentrations of greenhouse gases in the Earth’s atmosphere.¹⁶ Given the relationship between greenhouse gas emissions and major shifts in temperature and precipitation, scientists have developed complex

¹¹ Great Lakes Integrated Sciences and Assessments, “Synthesis of the Third National Climate Assessment for the Great Lakes Region,” http://glisa.umich.edu/media/files/Great_Lakes_NCA_Synthesis.pdf.

¹² Illinois Department of Natural Resources, 2015, “Urban Flooding Awareness Act,” https://www.dnr.illinois.gov/WaterResources/Documents/Final_UFAA_Report.pdf.

¹³ Ibid.

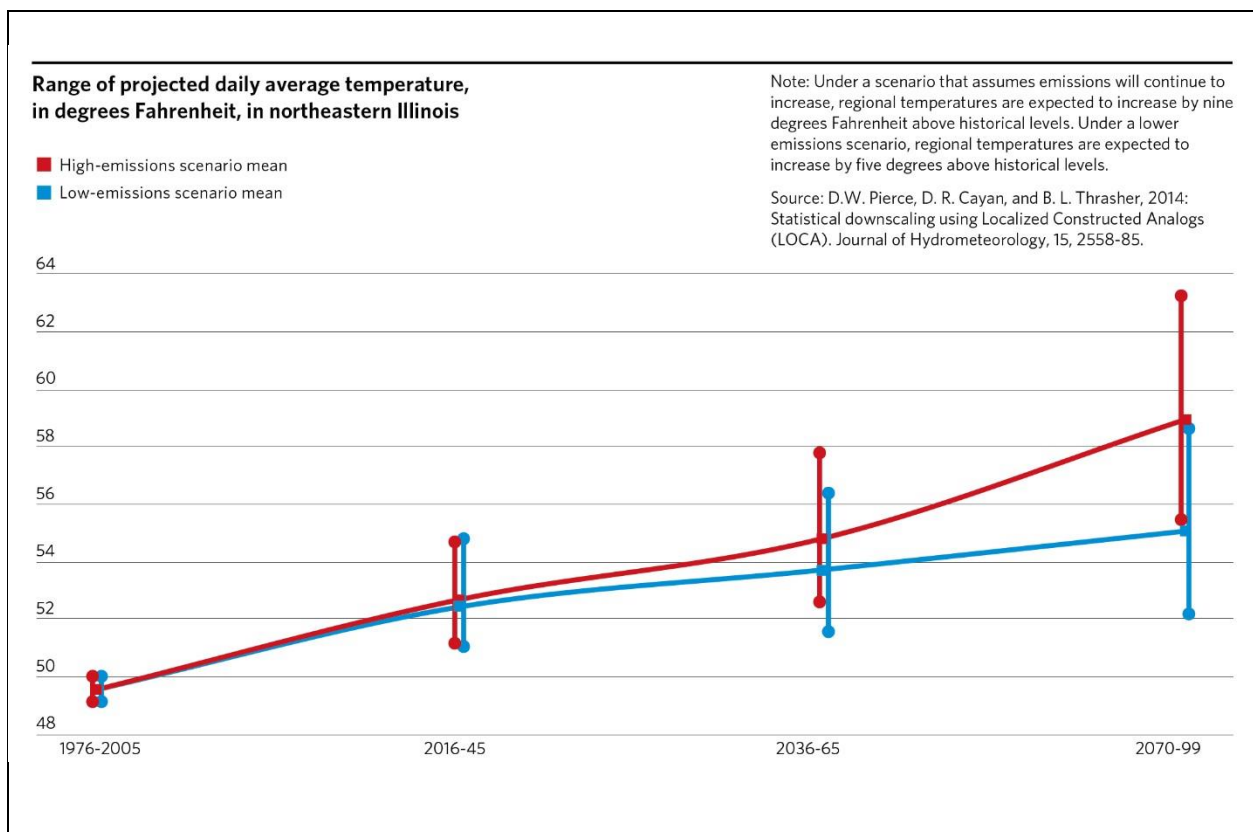
¹⁴ Ibid.

¹⁵ ‘Very heavy storm events’ is defined as the heaviest 1% of all daily events.

¹⁶ Intergovernmental Panel on Climate Change, “Climate Change 2014: Synthesis Report,” https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf.

models based on different emissions scenarios to predict future climatic conditions. These predictions are often referred to as climate projections. The most commonly used models that generate these climate projections are developed by the International Panel on Climate Change. Generally, these models include a low-emissions scenario that assumes drastic reductions in global greenhouse gas emissions, and a high-emissions scenario that assumes emissions will continue to increase. Under the scenario that assumes drastically reduced emissions (the blue line in Figure 3), the average temperature in Illinois is projected to increase by two to nine degrees Fahrenheit by the end of the century.¹⁷ Under the scenario that assumes moderately high emissions (the red line in Figure 3), the average temperature in Illinois is projected to increase by six to fourteen degrees Fahrenheit by the end of the century.

Figure 3. Projected Temperature Change in NE Illinois under Low and High Emission Scenarios



Under either of these cases, climate models project that by the end of the century, northeastern Illinois will likely start to experience a warm temperate climate that has greater variation in annual precipitation and high humidity.¹⁸ Experts project an additional four to eight inches of rain annually during wet years, and a reduction of four to eleven inches during dry years by

¹⁷ Illinois State Climatologist Office, derived from the B1 (low emissions) scenario of the [4th IPCC report](#).

¹⁸ Institute for Veterinary Public Health, "World Maps of Köppen-Geiger Climate Classification: Overserved and Projected Climate shift 1901-2100 Depicted by World Maps of the Köppen-Geiger Climate Classification," 2011, <http://koeppen-geiger.vu-wien.ac.at/shifts.htm>

2100. These models also suggest that a larger proportion of precipitation will fall during a small number of storms, resulting in longer periods of drought-like conditions, periodically interrupted by heavy rain, and that the periods of increased rain will primarily fall in the winter and spring (Figure 4).

Figure 4. Projected Precipitation Change by Season for 2071-2099 (compared to 1970-1999)

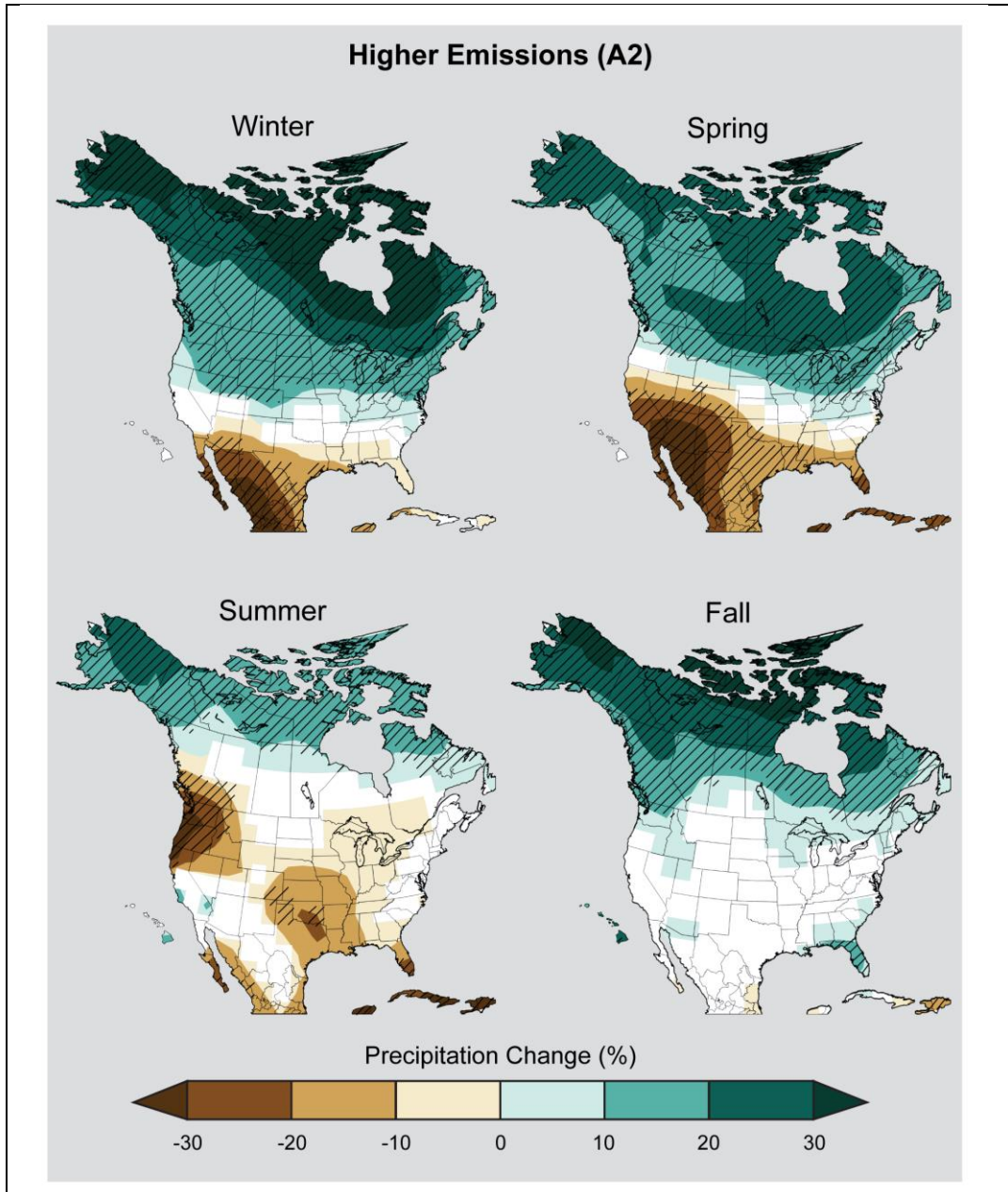


Figure 4 shows projected change in seasonal precipitation under an emissions scenario that assumes continued increases in emissions (A2). Hatched areas indicate that the projected changes are significant and consistent among models. White areas indicate that the changes are not projected to be larger than could be expected from natural variability. In general, the northern part of the U.S. is projected to see more winter and spring precipitation, while the southwestern U.S. is projected to experience less precipitation in the spring. (Figure and caption source: NOAA NCDC / CICS-NC).

Flooding

While flooding is a natural process, development and changing precipitation patterns have increased the amount of water that natural and systems must drain and changed the way water flows through the landscape. The Fox River Corridor is susceptible to riverine flooding, which occurs when the Fox River exceeds its capacity and overflows its banks into the floodplains. The Corridor is situated within the lower portion of the Upper Fox Subbasin spanning between 1,250 and 1,400 square miles across Illinois and Wisconsin.¹⁹ Due to its location within a much larger river system, upstream precipitation can cause significant flooding in the Corridor, particularly when multiple rainfall events occur within a ten-day period.²⁰

The areas most likely to suffer from riverine flooding are defined by the river's floodplains, the land surrounding the river where water flows when it overtops the river's banks. Floodplains are an important part of the natural process of flooding, and the types of vegetation and landscapes that naturally occur in floodplains are typically resilient to periods of inundation. Prior to modern floodplain and stormwater management regulations, development in the Corridor and throughout the Chicago region occurred in flood-prone areas, such as floodplains, wetlands, and other low-lying areas. These development patterns not only put the structures built in floodplains at risk, but also increased the risk of flooding throughout the river system by interfering with natural drainage and water flow patterns.

Floodplains

Floodplains are areas adjacent to waterways that are susceptible to inundation by floodwater and are based on modeled rain events, such as the 100-year or 500-year storms. However, the underlying data used to create some of the Chicago region's floodplain maps relies on outdated rainfall data, which results in maps that may not accurately reflect riverine flood risk.

Floodway: the area that is most prone to flooding as it is reasonably expected to come in contact with or convey floodwater.

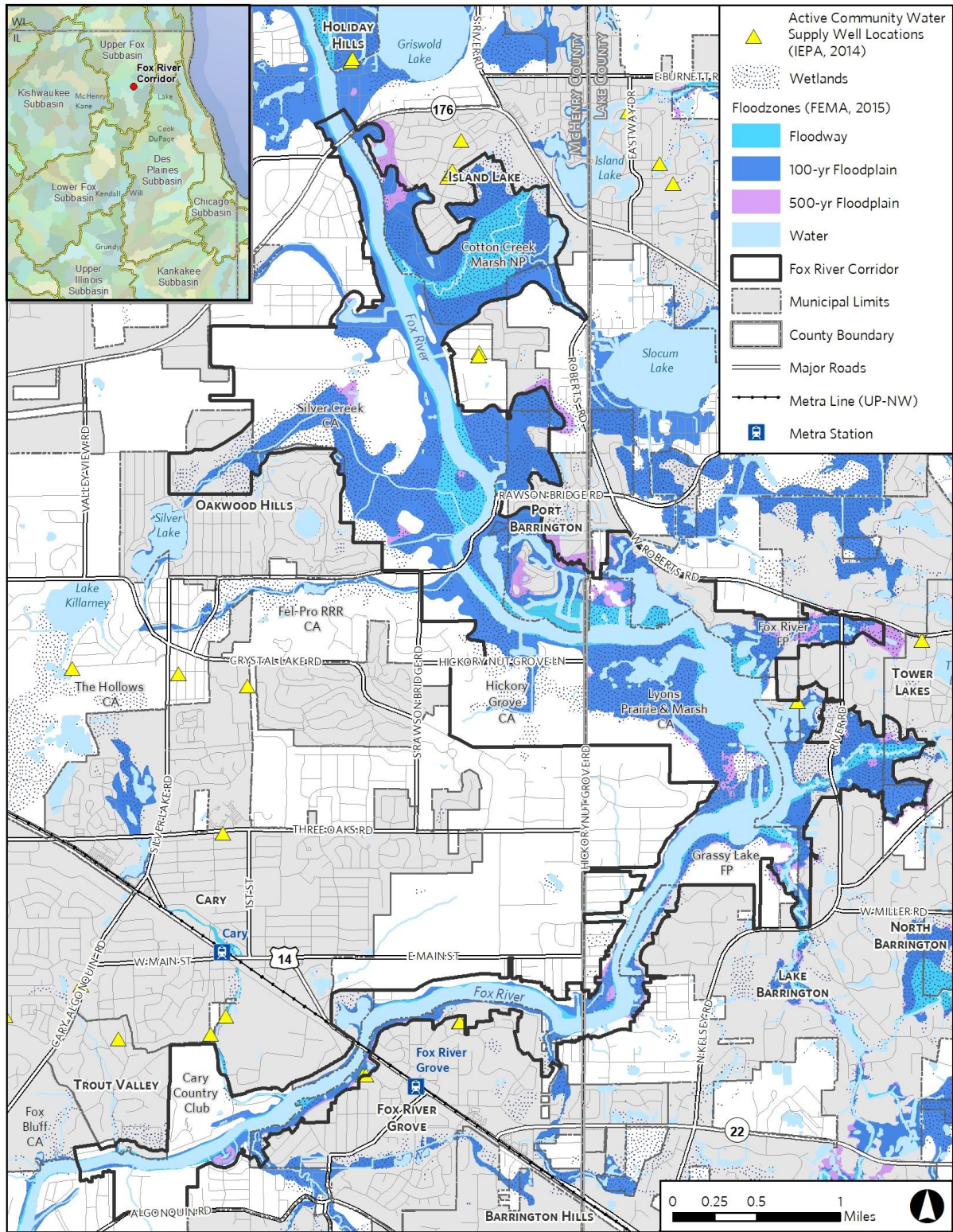
100-year floodplain: commonly known as the regulatory floodplain, is an area that has a 1% chance of flooding in a given year or a one-in-four chance of flooding during a 30-year mortgage. In northeastern Illinois, the 100-year storm is defined as 7.5 inches of rain over a 24-hour period.

500-year floodplain: area that has a 0.2% chance of flooding in a given year. The 500-year flood is the national standard for protecting critical facilities.

¹⁹ The Fox River watershed area at Stratton Dam is 1250 squares miles and 1400 square miles at Algonquin Dam. See <https://www.dnr.illinois.gov/WaterResources/Pages/StrattonLockandDam.aspx>

²⁰ Illinois Department of Natural Resources website, Stratton Lock and Dam. See <https://www.dnr.illinois.gov/WaterResources/Pages/StrattonLockandDam.aspx>

Figure 5. Water Resources (including floodplains) in the Fox River Corridor



Chicago Metropolitan Agency for Planning, 2018.

Recent storms have shown the strain that increased rainfall would place on the systems that state and local government have put in place to manage water levels for recreational use and flood management. In July 2017, rainfall caused the Chain O'Lakes to rise six inches overnight. The Stratton Dam reached its second highest crest on record at 7.60 feet, above major flood stage at 7.00 feet and slightly below the record crest of 7.62 feet in 2013.²¹ The floods of July 2017 far exceeded the 10-year storm, the largest storm that the Stratton Dam is designed to manage, and caused widespread damage to homes and businesses.²² The Fox Waterway Agency closed the Fox River for boating from the Algonquin Dam to the Chain O'Lakes for several weeks during the height of the busy season.

To gain a better understanding of riverine flooding in northeastern Illinois, CMAP staff created a regional riverine flooding susceptibility index (FSI) for developed areas that uses reported flood locations and topographic, land cover, and other data that reflects the existing landscape to determine the relative flood susceptibility of communities in the region.²³ The index is not intended to replace more technical floodplain mapping or modeling efforts, and should instead be used to identify general areas within a planning study where flooding susceptibility could be greater.

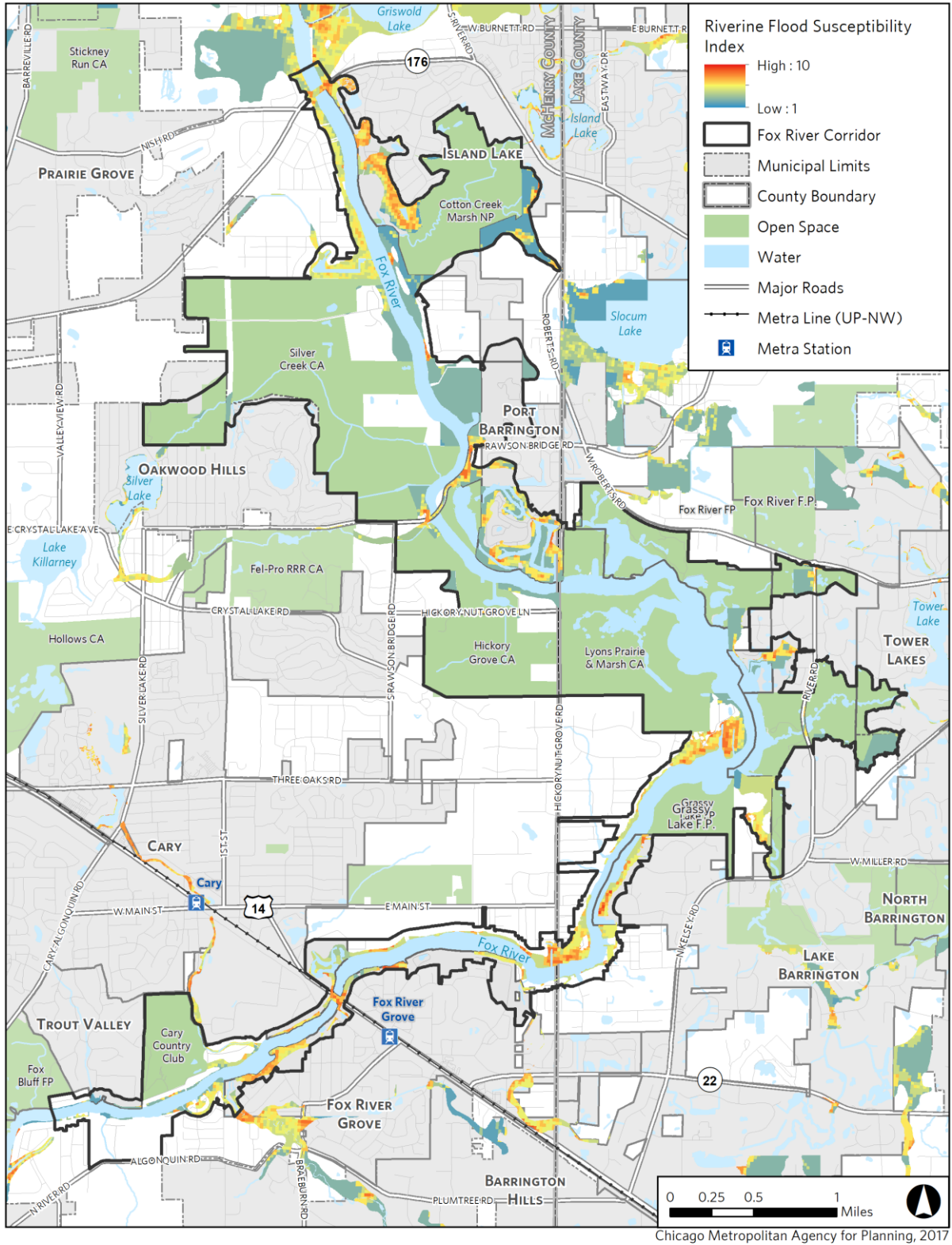
Figure 6 shows riverine flooding susceptibility for the Fox River Corridor. The scale shows the susceptibility relative to riverine areas across the seven-county CMAP region. Areas at the highest end of the scale are highly susceptible compared to the region as a whole, not just to the study area for this plan. The map shows that the flood susceptibility of the Corridor's developed areas is lower than in other areas throughout the region. The lower risk is partly due to the open space that buffers the river in the Corridor and the relatively little development in the Corridor's floodplains compared to those in much of the region. However, the map also illustrates that within the Corridor, developed areas are the most susceptible to riverine flooding. These areas could potentially become more vulnerable to flooding if development in the floodplain expands and precipitation patterns continue to change.

21 Northwest Herald, "McHenry County braces for 'unprecedented' Fox River flood," July 15, 2017. See <http://www.nwherald.com/2017/07/14/mchenry-county-braces-for-unprecedented-fox-riverflood/ayihf5a/>.

22 A 10-year storm has a 10% chance of occurring within a given year.

23 CMAP, Regional Flooding Susceptibility Index Appendix and Data, <https://datahub.cmap.illinois.gov/dataset/on-to-2050-layer-flood-susceptibility-index>

Figure 6. Riverine Flood Susceptibility in the Fox River Corridor



In the Fox River Corridor, warming air due to climate change will likely lead to an increase in precipitation, especially during the spring and summer. Between 1979 and 2009, extreme precipitation events in the central U.S. increased by as much as 40 percent when compared to the previous 30 years (1948-1978).²⁴ In the Fox River Corridor, the number of days within a year where precipitation is greater than one inch—a measurement commonly used as an indicator of flood risk—is seven.²⁵ The number of days is projected to increase to eight or ten (low or high emissions scenarios, respectively) by the end of the century.²⁶ If the frequency and severity of rain events increases, flooding issues will increase as well. Climate models also suggest the increase in precipitation will be concentrated in a small number of storms, rather than evenly distributed throughout the year, leading to heavy rainfall that will strain the capacity of stormwater systems and natural stormwater drainage.

Climate change is expected to result in more winter precipitation falling in the form of rain rather than snow. When snowfall does occur, it is projected to be more intense, with more snowfall accumulation per event and denser, heavier snow.²⁷ Snowfall can result in flooding if large amounts of it melt in a short period of time. The risk of flooding increases when the ground is frozen, drainage systems are blocked by snow or ice, and rainfall occurs on top of packed snow. Similarly, heavy rains that occur during drought conditions can exacerbate erosion and flooding, as dry soils are typically less stable and have a lower capacity to absorb stormwater runoff.

Drought

In recent years, drought conditions have become a growing concern for northeastern Illinois. Figure 7 shows drought frequency in northeastern Illinois by month from 1895 to 2015. During this period, droughts have become more frequent, and more severe. In particular, McHenry County experienced major droughts in 2005 and 2012 and Lake County experienced a drought in 2008.

Drought can have a significant impact on water supply and the health of a region's ecological assets. Prolonged periods of low precipitation can place stress on drinking water sources and

²⁴ Groisman, P.Y., Knight, R.W. & Karl, T.R., "Changes in intense precipitation over the central United States," 2012, *Journal of Hydrometeorology*, 13, 47-66.

²⁵ Illinois State Water Survey, "Official 1981-2010 Climate Normals: McHenry-WG Stratton LD," <http://www.isws.illinois.edu/atmos/statecli/newnormals/normals.USC00115493.txt>

²⁶ NOAA, U.S. Climate Resilience Toolkit, "McHenry County, IL," <https://toolkit.climate.gov/climate-explorer2/location.php?county=McHenry+County&city=McHenry+County,%20IL&fips=17111&lat=42.3039993000001&lon=-88.40160409999999>

²⁷ Jaffe, M. and Woloszyn, M. "An Initial Assessment of Winter Climate Change Adaptation Measures for the City of Chicago," 2014, *Sea Grant Law and Policy Journal*, Vol. 6, No. 2, pp. 5-25.

stunt vegetated growth rates.²⁸ As the climate continues to change, the Fox River Corridor is expected to see longer and more frequent droughts, periodically interrupted by large rainstorms. When heavy rains or snowmelt occur during dry conditions, erosion and flooding become major concerns, as dry soils are typically less stable and have a lower capacity to absorb stormwater. The summer months are expected to see the largest increase in drought conditions.

Figure 7. Monthly Palmer Modified Drought Index for Northeastern Illinois

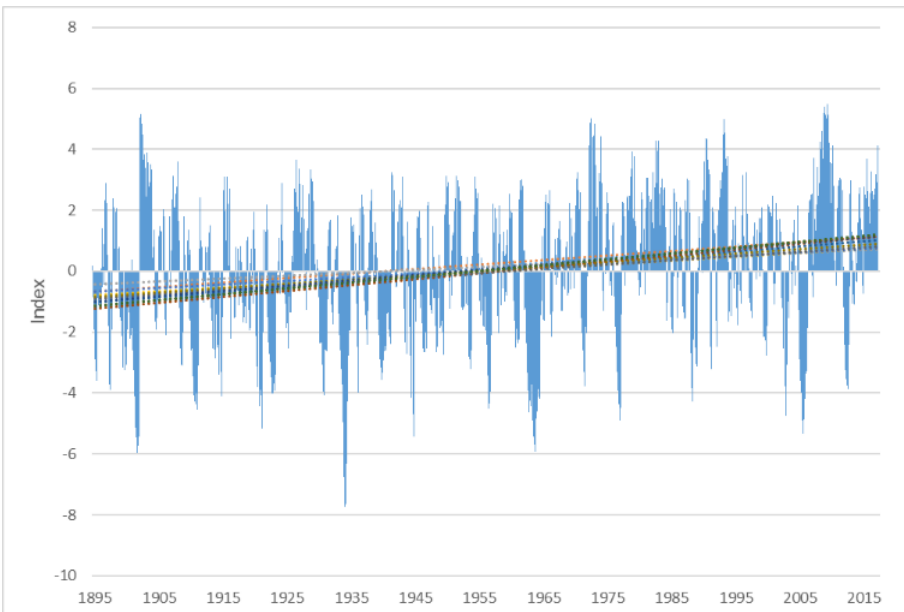


Figure 7 shows monthly Palmer Modified Drought Index scores for northeastern Illinois. Because scores are shown separately for each month, twelve trend lines are included. From 1895-2015, trend lines for all twelve months trended upwards. Source: Midwestern Regional Climate Center, <http://mrcc.isws.illinois.edu/CLIMATE/>.

Severe Storms

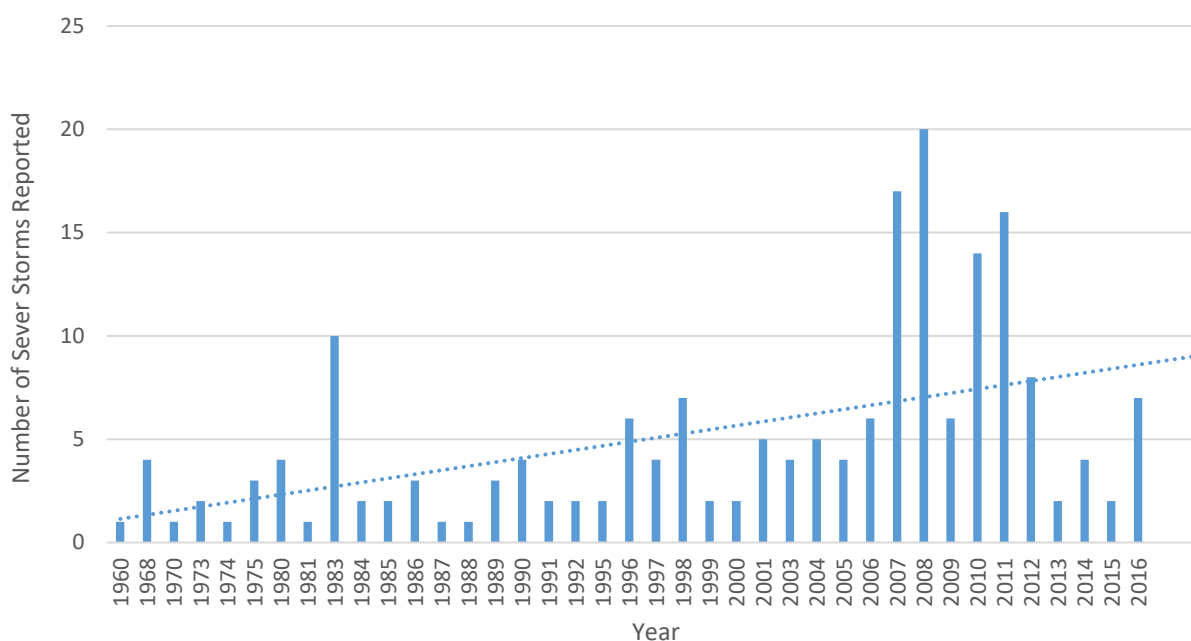
Severe storms, some capable of producing lightning, hail, strong winds, and tornadoes, are common in the Fox River Corridor. Atmospheric conditions within the Midwest, particularly during the summer months, are ideal for generating severe storms that bring one or more of these weather elements. Figure 8 shows the increasing trend in the occurrence of severe storms between 1960 and 2016.²⁹ McHenry County reported 133 severe summer storms, 113 of which produced winds with a speed of 58 mph or greater.³⁰

²⁸ Brandt, Leslie Leslie Alyson, Abigail Derby Lewis, Lydia Scott, Lindsay Darling, Robert T. Fahey, Louis R. Iverson, David John Nowak et al. "Chicago wilderness region urban forest vulnerability assessment and synthesis." *General technical report NRS*; 168 (2017). https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs168.pdf

²⁹ NOAA, National Centers for Environmental Information, Storm Events Database, Illinois, McHenry County, 1960-2016, <https://www.ncdc.noaa.gov/stormevents/>.

³⁰ Ibid.

Figure 8. Severe summer storms report in McHenry County, 1960-2016



Source: Centers for Environmental Information, Storm Events Database, McHenry County, IL, 1960-2016
<https://www.ncdc.noaa.gov/stormevents/>

As temperatures rise, severe storms can increase in intensity, and in some cases, frequency. The Midwest has warmed by two degrees since 2000, and the amount of precipitation falling during very heavy storm events³¹ has increased by 37 percent between 1958 and 2012. While the link between climate change, thunderstorms, and tornadoes is less well defined than some hazards, the region is expected to see modest increases in the frequency and severity of these severe storm events as the century progresses.³²

Snow and Ice

Throughout the Midwest, snowfall and ice accumulation are common hazards that disrupt daily life. Severe winter storms³³ can bring heavy snowfall, extremely cold temperatures, and freezing rain that can cause power outages, road closures, traffic delays, and vehicle crashes. According to the McHenry County Hazard Mitigation Plan, these types of storm-related impacts have frequently immobilized portions of the County. Between 1997 and 2016, there

³¹ 'Very heavy storm events' is defined as the heaviest 1% of all daily events.

³² 2014 National Climate Assessment, <https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing>

³³ The Illinois Emergency Management Agency (IEMA) defines severe winter storms as a) storms that produce at least six inches of snow within 48 hours or less, b) ice storms in which 10% of National Weather Service station report glaze, or c) snow or ice storms that result in death, injury, or property damage. These storms can be single events or they can be a combination of events (e.g. a moderate snowfall followed by freeze rain and extremely cold temperatures) that occur over the course of a few hours or multiple days.

were 26 recorded winter storms, two ice storms, 12 heavy snowfall events, and one sleet event.³⁴ Although property damage estimates are not available for these storm events, two deaths were reported.³⁵

Climate models suggest that northeastern Illinois will see an increase in winter precipitation.^{36, 37} Even if warmer temperatures mean that some winter precipitation will fall as rain rather than snow, the overall increase in precipitation will likely mean there will be enough snow and ice that managing it will remain a significant challenge during the years to come. Heavy snowfall events may also increase due to warmer temperatures, as snow crystal size increases as the temperature approaches the freezing point. Warmer average temperatures may also result in more frequent freezing rain and freeze-thaw events.³⁸ A freeze-thaw event occurs when precipitation collects in small cracks in hard rock surfaces, freezes and expands under cold temperatures, and then melts. The expansion of ice during the freezing period causes further splitting of the rock, damaging the hard surface.

Extreme Heat

As the climate warms, the Fox River Corridor will likely experience both an increase in average temperatures and an increase in the number of very hot days. Northeastern Illinois has historically seen three days over 95 degrees Fahrenheit each year. Between 1981 and 2010, the Fox River Corridor saw approximately seven days that reached 90 degrees Fahrenheit or greater each year. By mid-century, the McHenry County could see approximately 45-47 days over 95 degrees annually.³⁹ Average low temperatures on summer days are expected to see a substantial increase as well. In the past, the region has experienced 13.5 nights over 70 degrees Fahrenheit. By mid-century, these nights may occur 30-40 times each year, meaning that evenings and nighttime will provide less relief from high temperatures. Humidity is expected to similarly increase, which may intensify the impact of warm periods and heat waves.

As temperatures increase from climate change, there is a high probability that the Fox River Corridor will experience more episodes of extreme heat. However, the Corridor's land use and

³⁴ NOAA, National Environmental Satellite, Data & Information Service, National Climatic Data Center, Storm Events Database, Illinois, McHenry County, 1960-2016, <https://www.ncdc.noaa.gov/stormevents/>

³⁵ Santec & Molly O'Toole Associates, "McHenry County Natural Hazards Mitigation Plan," August 2017, <https://www.co.mchenry.il.us/home/showdocument?id=77420>

³⁶ Under a higher emissions scenario (A2), global climate models (GCMs) project average winter and spring precipitation by late this century (2071-2099) to increase 10% to 20% relative to 1971-2000, while changes in summer and fall are not expected to be larger than natural variations. For more information see, [NCA Midwest](#).

³⁷ National Climate Assessment, 2014, *Precipitation Change*, <https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change>

³⁸ Jaffe, Martin and Mary Woloszyn, "An Initial Assessment of Winter Climate Change Adaptation Measures for the City of Chicago," *Sea Grant Land and Policy Journal*, Vol. 6, No. 2.

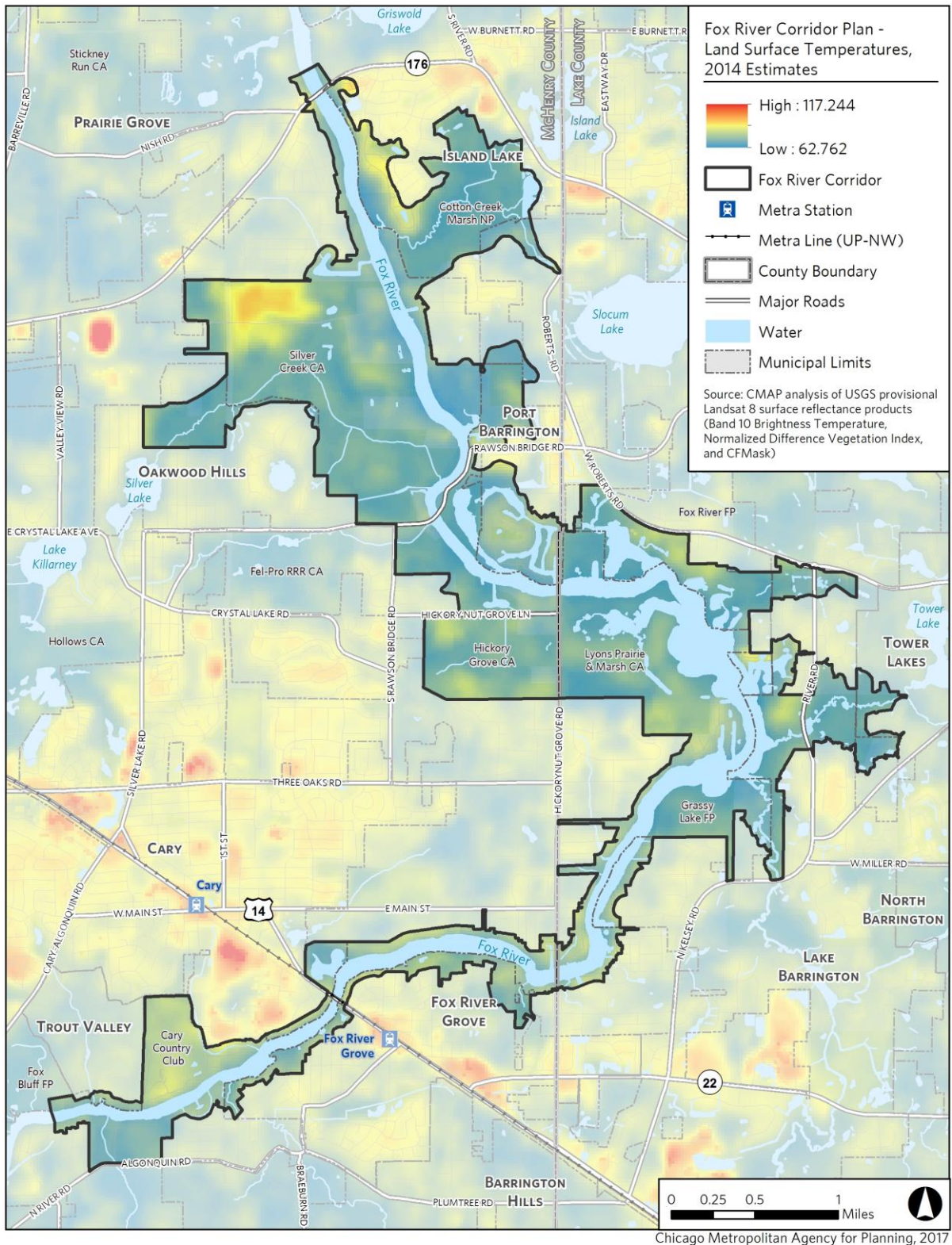
³⁹ NOAA, U.S. Climate Resilience Toolkit, "McHenry County, IL," <https://toolkit.climate.gov/climate-explorer2/location.php?county=McHenry+County&city=McHenry+County,%20IL&fips=17111&lat=42.3039993000001&lon=-88.40160409999999>

development patterns should make it more resilient during these episodes. Extreme heat often has the greatest impact on areas with dense development because of the urban heat island effect. Areas with substantial impervious surfaces – including roads, parking lots, rooftops, and other paved surfaces – heat up during the day, and remain warm long into the night. In northeastern Illinois, areas with greater than 50 percent impervious coverage have been found to be five to six degrees warmer than the regional average.⁴⁰ The impact of a five or six degree increase in temperature is usually negligible, but during periods of extreme, persistent heat, a difference of five degrees can result in significantly higher risk of dehydration, heat exhaustion, and other health impacts.

Given the large amount of open space, tree canopy, and vegetation, the Corridor's surface land temperatures are low (between 73 and 86 degrees) compared to temperatures in the surrounding area (Figure 9). Areas with higher surface temperatures include areas with larger road surfaces as well as residential and commercial land uses, some of which may have relatively less tree canopy.

⁴⁰ CMAP, "Climate Resilience Strategy Paper," <http://www.cmap.illinois.gov/documents/10180/470714/Climate%20Resilience%20Strategy%20Paper/dd610883-d00f-407d-808b-484f9800a3f6>.

Figure 9. Land Surface Temperature within the Fox River Corridor



Vulnerability and Risk Assessment

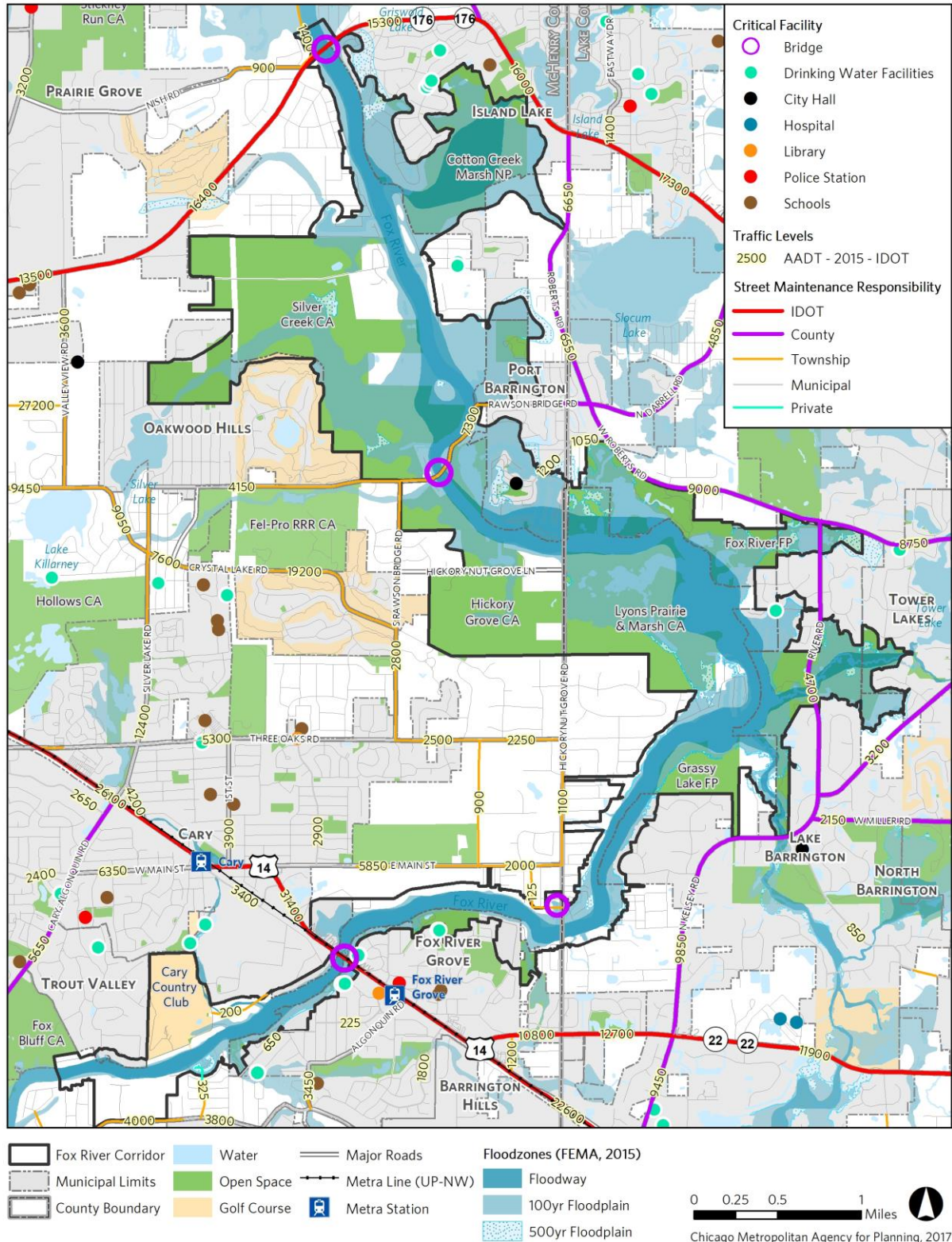
Natural hazards will create meaningful challenges to the Fox River Corridor's infrastructure, residents, and economy during the years to come. While natural hazards have always been a consideration in long-range planning, current climate projections indicate that increased temperature and precipitation are likely to exacerbate the hazards historically experienced in the Corridor. In many cases, the impacts of these hazards can be mitigated through cost-effective measures to reduce vulnerability and encourage resilience. Evaluating a community's risk and vulnerability to specific hazards and impacts can help determine how and where these challenges will most likely arise, and whom they are likely to affect. This kind of evaluation can help identify what elements of a community are in greatest need of protection as well as discover how they may improve upon their own adaptive capacity.

The following section of this report assesses the vulnerability of the residents, infrastructure, and economy of the Fox River Corridor to the impacts of climate change based on their exposure to climate-related hazards, the likelihood of an impact occurring, and the plans and programs in place to adapt to hazards.

Critical Infrastructure

Roads, sidewalks, bridges, sewers, power lines, and other forms of infrastructure are critical to providing essential services and functions to a community, especially during and after a natural hazard. These built infrastructure systems are complemented by natural systems, including wetlands, prairies, and forests, that help to manage stormwater, reduce air pollution, and provide recreational opportunities. Identifying what natural and human-made systems are vulnerable to climate-related hazards is an important first step to protecting them and creating a more resilient Fox River Corridor.

Figure 10. Critical facilities and transportation infrastructure in Fox River Corridor



Roads and Rail

The Corridor's transportation system, which primarily comprises roads and rail, is moderately vulnerable to the impacts of climate-induced hazards. Although there is a Metra stop just outside the Corridor, driving is the primary mode of transportation. Because residents heavily depend on automotive transportation, disruptions to roadways would have major consequences. There is also little infrastructure for alternative modes of transportation, with few sidewalks or off-street trails and no regular bus access.

Roadways, bridges, and railways are exposed to several climate-driven hazards. Increased precipitation will likely lead to more road closures due to flooding. Flooded roads and bridges can be a major safety concern for people in and outside of vehicles and significantly delay the movement of people and goods. The three bridges in the Corridor that provide access across the Fox River are elevated above flood elevation. However, according to the McHenry County Hazard Mitigation Plan and reports from IDOT, flooding is a risk on Route 14 and North River Road (Fox River Grove), Route 176 and Buhl Road (Prairie Grove), Roberts Road and Whippoorwill Drive (Nunda Township). Over 25,000 residents commute to work within a three-mile radius of the Corridor while an additional 40,000 commute out of the Corridor for work. Roads commonly used for these commutes carry the highest traffic volumes in the Corridor, with annual average daily traffic (AADT) for Route 176, Rawson Bridge Road, and Route 14 measured at 16,400, 7,300, and 31,400 respectively. Rawson Bridge Road, which is within the floodplain, is at particularly high risk. Away from major roads, flooding of residential streets can impede residents' ability to travel as well as cut residents in the floodplain off from receiving emergency services.

Temperature-driven impacts are likely to escalate maintenance needs across the Corridor's transportation systems. Roadways, bridges, and railways are vulnerable to extreme heat, which may cause buckling or cracking. More frequent freeze-thaw events during the winter months may accelerate the formation of cracks and potholes in roadways, parking lots, and sidewalks, increasing maintenance costs and possibly leading to more traffic delays. Maintenance of the Corridor's transportation infrastructure will be a critical investment to increase climate resilience. Roads that have been identified as more vulnerable to climate impacts are under the jurisdiction of the State, County, Townships, and local municipalities. Adequately preparing the transportation system requires the participation of several levels of government as well as private property owners.

Water Supply

The Corridor's water supply, which is entirely dependent on groundwater, is highly vulnerable to impacts from a projected increase in drought, flooding, and snow and ice events. Most communities, including the Villages of Fox River Grove, Lake Barrington, Port Barrington, Oakwood Hills, Tower Lakes, and Trout Valley and unincorporated areas of McHenry and Lake Counties, draw their water supply from the shallow aquifer. The Villages of Cary and Island Lake rely on groundwater from a mix of shallow and deep aquifer wells.

Drought will strain groundwater resources in two ways – by reducing the supply due to reduced recharge of aquifers and by increasing the demand from users. Prolonged dry periods will result in less precipitation to soak into the ground and increased runoff when it does rain, since dry soils are less able to absorb stormwater. The additional strain caused by drought, as well as by increased demand during projected periods of higher temperatures, will stress a water supply system that is already being overdrawn. The deep aquifer is currently being depleted by communities in the larger region and certain areas will likely be desaturated in the near future if pumping continues at its current rate.⁴¹ Natural ecosystems are also vulnerable to climate-driven impacts to aquifers. If drought and increased demand decrease aquifer levels, it will also threaten groundwater’s ability to provide the stream baseflow required to sustain aquatic ecosystems and other groundwater fed systems such as fens.

An increase in precipitation and flooding may increase pollution levels in the Fox River, tributary streams, lakes, wetlands, and shallow groundwater aquifers. An increase in stormwater runoff would increase non-point source pollutants (e.g., sediment, nutrients, chloride, and fecal coliform). High pollutant concentrations that enter these waterbodies could degrade the quality of groundwater and lead to increasing treatment costs for community water suppliers. The Fox River also supplies drinking water to downstream communities. While the Fox River is not part of the water supply within the Corridor itself, actions within the Corridor do impact water quality for the cities that draw from the Fox River.

Although the Corridor’s water supply is a highly vulnerable asset, the counties and municipalities are taking action to increase awareness of drought and proactively address its impacts. Lake and McHenry County are active members of the Northwest Water Planning Alliance, which aims to provide the region with a water supply that is both economically and environmentally sound. McHenry County has a Water Resources Action Plan to help protect groundwater aquifers.⁴² During the last drought, there were efforts to limit lawn watering, etc. to even/odd days. The Village of Cary has a water use restriction ordinance that restricts outdoor water usages on even/odd days.⁴³ The Village also notifies community of drought conditions with signage on the city’s boundaries and e-newsletters.

Septic Systems

Septic systems within the Fox River Corridor are highly vulnerable to flooding impacts. The Corridor’s naturally high groundwater levels and exposure to riverine flooding have made septic system failures a common problem. Stormwater from riverine and urban flooding can

⁴¹ CMAP, “Water Resources Strategy Paper,” 2017, http://www.cmap.illinois.gov/documents/10180/653821/Water+Strategy+Paper_FINAL_+9-21-17.pdf/a54d17e1-a3fb-6bf7-1efb-f5515868ebeb

⁴² McHenry County, “Water Resources Action Plan,” October 2011, <https://www.co.mchenry.il.us/county-government/departments-j-z/planning-development/divisions/water-resources/waterresactplancbapprove>

⁴³ Village of Cary, personal communication, May 03, 2017.

overwhelm the systems and cause them to stop functioning, which can then lead to basement backups and seepage. Septic system failures can become a threat public health as well as harm water quality and degrade habitat, as they are a suspected source of excess nutrients and fecal coliform. Furthermore, governments in the Corridor do not have centralized data on the location and condition of septic systems, which heightens the vulnerability of the Corridor to septic system failures.

Energy

The energy and electricity systems that power the Corridor's homes and businesses are vulnerable to a number of climate-related hazards. Dependable electrical service is important for the local economy and everyday life, making disruptions highly consequential for a wide range of stakeholders, including those who are sensitive to the loss of heat and air conditioning. In the Fox River Corridor, the vulnerability of the energy grid is mostly due to the effect that storms can have on transmission systems. Commonwealth Edison, the primary provider of electricity in the Corridor, transmits all electricity via overhead wires, which are vulnerable to damage from strong wind and freezing rain. Highly developed or vegetated areas within the Corridor where power lines are present are likely to be the most vulnerable to power outages. During summer months, strong wind, lightning, and debris such as branches or downed trees can cause power outages and damage electrical infrastructure (e.g., substations, power lines, and poles). Snow and ice accumulation during the winter months can lead to power outages as well. Because warmer air caused by a changing climate means summer storms are likely to increase in intensity and frequency and winter storms are more likely to include freezing rain, the Corridor is at risk for more outages in the future.

To address the threat of power outages, Commonwealth Edison has begun investing in smart grid infrastructure for its transmission system, which allows grid operators to isolate outages to smaller geographic areas, reducing the number of customers affected when power lines are damaged. These investments have resulted in a 44 percent reduction in storm-related power outages in the Chicago region since 2012, and a 42 percent reduction in average outage duration.⁴⁴

Vulnerability to electricity disruptions often depends on the availability of secondary or backup power systems. Critical facilities, including police, fire, and the sewer and water plants, typically maintain backup generators that allow them to remain operation during power outages. When power outages do occur, residents without electricity may be exposed to extreme heat or cold, depending on the season, and may have difficulty communicating with service providers. According to stakeholders connected to public works departments in the Corridor, many residents within the Corridor are aware of the frequency of severe thunderstorms and high winds, and as a result, have purchased emergency generators in the

⁴⁴ "ComEd Reports to the ICC on 2015 Record Results and Summer Preparedness Strategy," Commonwealth Edison Company, http://www.comed.com/News/Pages/NewsReleases/2016_05_26.aspx.

event of a power outage. It is also common for municipalities to have backup generators for public works facilities and well stations. The Cary Area Public Library and Fox River Grove Library function as cooling centers during extreme heat.

Green Infrastructure

The Fox River is one of the key river systems of the Chicago region, providing ecosystem services to communities, habitat to wildlife, and a north-south corridor within which plant and animal species can migrate.⁴⁵ The waterways, wetlands, and surrounding ecological communities serve a crucial role mitigating flooding, recharging groundwater, and filtering stormwater runoff. Over 55% of the Corridor comprises open space that supports prairies, oak forests, and wetlands. These areas, when protected, are extremely valuable and productive natural resources that increase the Corridor's resilience to the impacts of climate change. Currently, they help to control nonpoint source pollution, stabilize shorelines, reduce flooding in developed areas, maintain the baseflow of rivers, streams, and other waterbodies, protect shallow aquifers, provide fish and wildlife habitat and corridors for migration, and add recreational and aesthetic value. The Fox River system can only provide these functions if surrounding ecosystems remain healthy and diverse. While the Corridor's water, woods, and prairies provide a wide range of habitats for native flora and fauna, they are also moderately vulnerable to climate-related impacts.

The plants and animals that live in the Corridor have evolved based on local conditions over thousands of years, and may face significant challenges as the region's climate becomes warmer, wetter, and more variable. Extreme heat and drought may stunt the growth of the Corridor's forest and woodlands within the protected open space as well as the urban tree canopy within developed areas. Similarly, flooding, ice storms, and wet snow may damage stem and tree branches as well as lead to crown loss. A few native species that would be particularly vulnerable include Hackberry, Shagbark hickory, and White oak.⁴⁶ As temperatures rise, it will drive shifts in habitat as species migrate to areas with temperatures for which they are best suited. This shift may drive species historically found in the Corridor to migrate elsewhere, while also introducing new species that have not traditionally been present in the Corridor. An increase in temperature may also attract more pests and allow invasive species (e.g., European buckthorn and Amur honeysuckle) to thrive.⁴⁷ This type of habitat shift may compromise endangered and threatened species, which are already vulnerable under current

⁴⁵ Hellmann, Jessica J., Knute J. Nadelhoffer, Louis R. Iverson, Lewis H. Ziska, Stephen N. Matthews, Philip Myers, Anantha M. Prasad, and Matthew P. Peters. "Climate change impacts on terrestrial ecosystems in metropolitan Chicago and its surrounding, multi-state region." (2010). <https://naldc.nal.usda.gov/download/49775/PDF>

⁴⁶ Brandt, Leslie Leslie Alyson, Abigail Derby Lewis, Lydia Scott, Lindsay Darling, Robert T. Fahey, Louis R. Iverson, David John Nowak et al. "Chicago wilderness region urban forest vulnerability assessment and synthesis." *General technical report NRS; 168* (2017). https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs168.pdf

⁴⁷ Brandt, Leslie Leslie Alyson, Abigail Derby Lewis, Lydia Scott, Lindsay Darling, Robert T. Fahey, Louis R. Iverson, David John Nowak et al. "Chicago wilderness region urban forest vulnerability assessment and synthesis." *General technical report NRS; 168* (2017). https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs168.pdf

climatic conditions, and weaken ecosystem health. It is also possible that some species and ecosystems within the Corridor may not be able to adapt at the rate temperatures are changing. For example, fens are particularly sensitive and diverse ecosystems that are prominent throughout the Corridor.⁴⁸ They rely on unique hydrology (fed by both groundwater and surface water) and pH levels in the water. An influx of warmer surface waters or fluctuations in the nearby water tables driven by an increase in temperature, precipitation, or drought can drastically alter a fen's ecosystem functions. Additionally, warmer rivers and streams as well as increased stormwater pollution can lead to a loss of habitat (particularly for cold-water fish), and can degrade water quality and recreation.

The Corridor's green infrastructure is also vulnerable to changes in precipitation. More frequent and intense precipitation events during spring and winter months will increase the pollution—carried in stormwater runoff from urbanized areas upstream and tributary to the Corridor—that enters the Fox River as well as exacerbate streambank erosion. These impacts contribute high loads of sediment, nutrients (phosphorus and nitrogen), and fecal coliform bacteria from urban and agricultural runoff, which can deplete dissolved oxygen levels needed to sustain aquatic life. Stormwater runoff will also be warmer than in the past, and will drain into streams, fens, wetlands, and ultimately the Fox River, which can degrade water quality and healthy habitats. An increase in snow and ice events can lead to an increase in road salt use for de-icing by IDOT, counties, townships, municipalities, and property owners. When road salt is exposed to runoff from rain or melting snow and ice, chlorides enter waterbodies. Once in the water, chloride can be toxic to aquatic life and impact vegetation and wildlife. Chloride reduction programs, including sensible salting practices, will be increasingly important to mitigate the impact of winter-weather maintenance on all roadways.

As species and ecosystems contend with the stresses of climate change, open space may deteriorate and decrease in size, and as a result, may impact the quality of life in the region. Conservation and management within the Corridor may be challenging in the future, but restoring and maintaining its ecological health will be critical for sustaining both local and regional ecosystem services.

Economic Impacts

The Fox River Corridor's local economy heavily relies on the benefits the Fox River provides, including opportunities for outdoor recreation and tourism as well as ecosystem services. When natural hazards damage or interrupt these assets, the adverse economic impacts can affect the surrounding communities and the region as a whole. Often, some of these impacts can be mitigated in advance through strategic, cost-effective interventions. Identifying the most critical economic impacts is a useful strategy for prioritizing these interventions.

⁴⁸ Oakwood Hills and Bates Fens in McHenry County as well as Tower Lakes and Wagner Fens in Lake County are four distinct fens that span 292 acres and are designated Illinois Nature Preserves.

Private Property

Flooding poses the greatest climate-related threat to private property, particularly for structures located in the floodway and 100-year floodplain. The majority of the Corridor's 100-year floodplain is protected as open space (57.7 percent); however, residential development still makes up over 21 percent. Riverine flooding also impacts development adjacent to Fox River tributaries, including Cary Creek in Cary, Spring Creek in Fox River Grove, and Flint Creek near Lake Barrington.

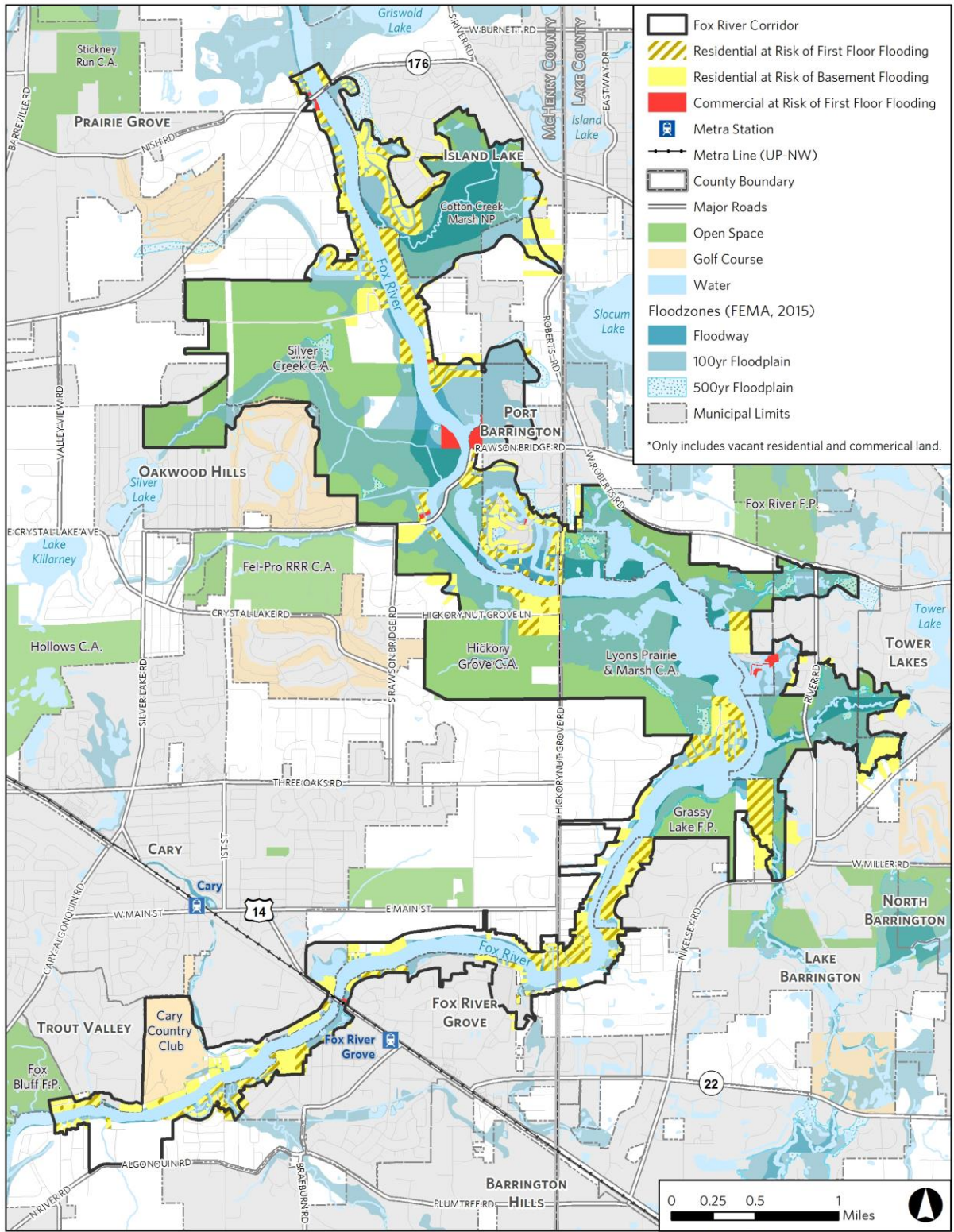
In the Corridor, there are 801 residential properties in the floodway and 925 in the 100-year floodplain. While these structures are at the greatest risk of flooding, buildings in low-lying areas outside of the floodplain, are at risk of riverine flooding as well. Figure 11 identifies residential properties that are prone to first-floor flooding, as well as residential properties that are prone to basement flooding, because of their location and elevation relative to the nearest Base Flood Elevation (BFE).⁴⁹ Properties with a base elevation that is within one foot of the BFE is considered to be more at risk of first floor or surface flooding. Those with a base elevation that is within six feet of the BFE is considered to be more at risk of basement flooding or seepage. In addition to the 925 residential properties that are within the 100-year floodplain, there are 235 residential properties outside of the 100-year floodplain and within one foot of the BFE. There are an additional 603 residential properties that are outside of the 100-year floodplain and within six feet of the BFE, which may be vulnerable to basement flooding or seepage

Flooding is a key concern in the Fox River Corridor, particularly for residents and business owners in flood-prone areas. Owners and tenants in these properties are vulnerable to property damage, a decrease in quality of life, and economic hardship. According to McHenry County's Natural Hazard Mitigation Plan, flood damage to building can range from \$4.6 to \$48.8 million. Within the United States, flooding causes more than \$2 billion in property damage each year.⁵⁰ Flooding will become an even greater concern as climate change drives an increase in the frequency and intensity of rainfall events.

⁴⁹ Since structure data is not available, calculations are based on the base elevation of the properties' centroid. Base flood elevation (BFE) is the expected level of floodwater during a 100-year flood event. See FEMA's website for more information, <https://www.fema.gov/base-flood-elevation>.

⁵⁰ Santec and Molly O'Toole Associates, LTD, "McHenry County Natural Hazards Mitigation Plan," August 2017, <https://www.co.mchenry.il.us/home/showdocument?id=77420>

Figure 11. Properties within 1500ft of the 100-year floodplain and within 1ft and 6ft of FEMA's Base Flood Elevation (BFE)



In addition to flooding, climate change projections predict an increase in other weather elements that can damage property. Erosion can be exacerbated by both an increase in the amount of stormwater runoff generated by intensified rain events, particularly when they occur following prolonged periods of drought. Riverfront properties are vulnerable to property loss as bank erosion becomes more severe. Straight-line winds, which include downdrafts, downbursts, and microbursts, are fairly common during a thunderstorm, and are often responsible for thunderstorm-related damages. These winds can down trees, cause temporary power outages, and tear roofing and siding materials from structures. Similarly, hail can puncture roofs, break windows, and damage other property such as vehicles and boats that may be exposed outside. Direct lightning strikes can trigger fires and damage structures as well as cause injury or death. Severe summer storms (thunderstorm and/or high winds) that were reported during 1960-2016 resulted in \$566,500 in property damages.⁵¹ In addition to severe summer storms, severe snow storms can cause power outages and collapse roofs, extremely low temperatures can cause pipes to burst, and freeze-thaw events can deteriorate building foundations over time.

Business Closures and Lost Revenue

Tourism within the Fox River Corridor is one economic sector that will be highly vulnerable to the impacts of climate change. Employment in this sector, particularly where tourism is driven by outdoor activities, can be dependent on temperature and precipitation.⁵² Warmer weather could increase interest in water-based summer tourism, but its effect on water quality and water levels may also negatively affect jobs and revenue from outdoor activities such as boating, fishing, hunting, and winter sports.

Summer tourism within the Corridor is heavily dependent on water sports, particularly recreational boating. Businesses ranging from marinas and boat storage to restaurants and marine gas stations rely on the influx of residents and tourists that travel to the Corridor for boating from June through September. Rising temperatures would likely extend the summer boating season to earlier in the spring and later in the fall. However, spring precipitation is projected to increase and summer storms will likely bring more intense rainfall to the Corridor and upstream communities, leading to riverine flooding that often temporarily shuts down recreational boating. The Fox River was closed for nearly three and half weeks following riverine flooding from heavy rain events in Wisconsin and the Chain O'Lakes in mid-July 2017.⁵³ The winter season may also lack the snow or freezing temperatures needed to sustain ice fishing, snowmobiling, and cross-country skiing. Snowmobiling can help boat-dependent

⁵¹ NOAA, National Environmental Satellite, Data & Information Service, National Climatic Data Center, Storm Events Database, Illinois, McHenry County, 1960-2016. <https://www.ncdc.noaa.gov/stormevents/>

⁵² The Regents of the University of Michigan and Headwaters Economics, 2017. Great Lakes Adaptation Assessment for Cities: Great Lakes Climate and Demographic Atlas. <http://graham.umich.edu/glaac/great-lakes-atlas>

⁵³ Mike Krauser, "Boating Resumes on Chain O'Lakes, Upper Fox River After Flooding," CBS Chicago, August 4, 2017, <http://chicago.cbslocal.com/2017/08/04/chain-o-lakes-fox-river-boating-reopens/>

business generate revenue in the off-season.⁵⁴ In 2017, the Norge Ski Club had to postpone their International Winter Tournament—an event that can attract more than 6,000 spectators—because of warmer temperatures and their inability to maintain snow.⁵⁵ Unpredictable closures or delays can have a negative impact on the local economy, especially if they occur more frequently and take place during the peak of the season. Businesses lose revenue during these times when people would otherwise be enjoying recreational activities or attending annual events.

Flooding is also a key concern for business owners in flood-prone areas. Of the 120 commercial parcels within the Fox River Corridor, 115 (96 percent) are within the 100-year floodplain. In addition to a decrease in business revenue during times when the river is closed to boaters, many riverfront businesses and marinas suffer from property damage, quality of life impacts, and economic hardship from flooding. The Broken Oar Marina Bar and Grill in Port Barrington earns 75% of their annual revenue during the summer months.⁵⁶ Riverine flooding in July 2017 inundated six of the seven acres used for the Broken Oar Marina Bar and Grill property. Although the restaurant and bar was able to stay open through this event, the combination of low patronage and grappling with clean up made it financially difficult.⁵⁷ Upstream of the Fox River Corridor, a restaurant estimated that damage to its piers and landscaping, alone, would likely cost \$50,000.⁵⁸

Increased precipitation and flooding, coupled with a longer summer boating season, would also exacerbate sedimentation within the Fox River. Increased sedimentation is likely to hinder recreational access for boaters and paddlers as well as harm the aquatic ecosystems that support fishing and fishing tournaments. Marinas have started to lose slips as sediment deposits in the river gradually shift and the waters become too shallow to navigate. The Fox River is naturally a shallow waterway and an increase in wake activity from boating can escalate bank erosion, which contributes to sedimentation. Stormwater runoff can carry sediment into surface waters as well. The flooding from the July 2017 rains brought over 100,000 cubic yards of sediment,

⁵⁴ Jordan J. Wilson, “McHenry County businesses deal with lack of customers, property damage amid Fox River flooding,” *Northwest Herald*, July 18, 2017, <http://www.nwherald.com/2017/01/18/norge-ski-club-in-fox-river-grove-postpones-winter-tournament-for-first-time-in-more-than-a-century/aolivjo/>

⁵⁵ Ibid.

⁵⁶ Megan Jones, “McHenry County agencies spend about \$3.6M on Fox River flooding cleanup “ *Northwest Herald*, September 3, 2017, <http://www.nwherald.com/2017/08/30/mchenry-county-agencies-spend-about-3-6m-on-fox-river-flooding-cleanup/amg701b/>

⁵⁷ Karen Jordan, “Along the Fox River, recovery continues after record-flooding,” *ABC 7 Chicago*, August 30, 2017, <http://abc7chicago.com/weather/along-the-fox-river-recovery-continues-after-record-flooding/2359200/>

⁵⁸ Jordan J. Wilson, “McHenry County businesses deal with lack of customers, property damage amid Fox River flooding,” *Northwest Herald*, July 18, 2017, <http://www.nwherald.com/2017/01/18/norge-ski-club-in-fox-river-grove-postpones-winter-tournament-for-first-time-in-more-than-a-century/aolivjo/>

which is more than what the lakes typically receive on an annual basis.⁵⁹ Sediment also degrades aquatic habitat, thereby depleting dissolved oxygen levels needed to sustain aquatic life.

Constrained Resources

Government agencies and private companies that provide public amenities and services are likely to be moderately vulnerable to flooding and severe winter storm impacts. The economic impacts of climate-related natural hazards have the ability to put unnecessary strain on county, municipal, and other private service providers.

Under likely climate scenarios, governments will need to spend more preparing and responding to flooding. Local government agencies estimated that they spent more than \$3.6 million on flood relief and cleanup efforts in response to the Fox River flooding in July 2017.⁶⁰ Lake County estimated that they spent \$12.7 million, while McHenry County estimated \$3.9 million. Similarly, the Fox Waterway Agency estimated their costs for water cleanup, support, and sediment removal were approximately \$3.5 million.⁶¹ In addition to the financial costs, more workers would be needed to provide support and allocate resources, such as activities associated with sand bags and emergency calls preceding and during a flood event as well cleaning and repairing public property. These are all costs that will impact residents of the Fox River Corridor.

If the Corridor sees heavier or more severe winter storms, budgets for snow removal and deicing could be exceeded. Budgeting for these activities can already be a challenge because of unpredictable weather and limited budgets, equipment, and personnel. In McHenry County, road maintenance during an average snow storm (lasting approximately two days) requires 12 hours of work each day, 40 tons of road salts, and 600 gallons of fuel.⁶² Although winter storms that bring snow are major triggers for road salt, McHenry County found that their salt use in 2017 was actually a result of ice and freezing rain. Salts have a negative impact on water resources and aquatic life as well.. The use of road salt in the Chicago region and salt concentrations in our waters has been increasing, while the cost of salt has also been on the rise.^{63,64} These trends have the potential to continue as natural hazards are worsened by climate change.

⁵⁹ Megan Jones, "McHenry County agencies spend about \$3.6M on Fox River flooding cleanup," *Northwest Herald*, September 3, 2017, <http://www.nwherald.com/2017/08/30/mchenry-county-agencies-spend-about-3-6m-on-fox-river-flooding-cleanup/amg701b/>

⁶⁰ Megan Jones, "Flood cost local government agencies about \$3.6M," *Lake County Journal*, September 7, 2017, <http://www.lakecountyjournal.com/2017/09/05/flooding-cost-local-government-agencies-about-3-6m/axz681n/>

⁶¹ Ibid.

⁶² Santec and Molly O'Toole Associates, LTD, "McHenry County Natural Hazards Mitigation Plan," August 2017, <https://www.co.mchenry.il.us/home/showdocument?id=77420>

⁶³ McHenry County and Minnesota Local Road Research, "McHenry Count Snow & Ice Control Handbook for Sidewalk and Parking Lots," October 2010, <https://www.co.mchenry.il.us/home/showdocument?id=8310>

⁶⁴ Lake County, "Winter Maintenance Best Practices," <http://www.lake.k12.il.us/DocumentCenter/Home/View/12345>

Social Vulnerability

Natural hazards do not affect everyone in the same way, or to the same degree. Key social, demographic, and economic characteristics may cause certain residents and visitors to be more vulnerable to the impacts of natural hazards than others. Identifying these groups is crucial for developing an inclusive strategy for addressing these hazards.

Health and Public Safety

The health and safety of the residents within the Corridor, particularly children under the age of five and adults over the age of 65, are moderately vulnerable to the increased impacts of flooding, extreme heat, and severe winter weather due to climate change. Older residents are more directly sensitive to certain hazards due to background health issues, and are at greater risk because limited mobility can affect their ability to relocate to unaffected locations. Older populations are, in particular, more susceptible to the impacts of extreme heat, which is projected to become more common, as well as extreme cold. Other population groups that are vulnerable to natural hazards include those that are in poverty, households isolated by language barriers, or people with low education levels. Many of the facilities that provide services to these groups may be difficult to access in the event of a natural hazard, such as riverine flooding.

Although extreme heat is considered to be one of the deadliest climate-related natural hazards, the Corridor will likely not be affected by extreme heat to a degree that threatens public health. The plentiful open space and green infrastructure in the Corridor keeps it relatively resilient to heat impacts. The Corridor's land surface temperature is relatively low (between 73 and 86 degrees, see Figure 9) in comparison to the surrounding region. However, areas with concentrations of older residents would be more vulnerable to heat than other parts of the Corridor. As of 2015, 12 percent of the Corridor's population was 65 years and older. An additional 23 percent that will reach that age by mid-century.

Riverine flooding within the Corridor also presents risks to health and safety. Flooding has been known to cause septic systems to fail, which can become a public health concern because there is no centralized data on the location and condition of septic systems. Riverine flooding that contributes to first floor and basement flooding can also cause mold, which in turn, can cause respiratory issues and poor indoor air quality. The Corridor's green infrastructure significantly reduces its residents' exposure to heat-related hazards.

Emergency Services

Police, fire, and emergency first responders that provide critical services to the Fox River Corridor are slightly vulnerable to climate-related impacts. Aside from Port Barrington's City Hall, which is outside of the 100-year floodplain but completely surrounded by the floodplain boundary, most critical facilities that provide emergency services are located just outside of the

floodplain.⁶⁵ Most of the emergency facilities that serve the Corridor are located outside the Corridor's boundaries, further from the river. However, there are only three access points where emergency service providers can cross the Fox River, and two of them have experienced flooding. Stress or damage to these thoroughfares will likely impede commutes, public safety, and the provision of services in the event that crossing the river is necessary. Residents and businesses within the 100-year floodplain, which are considered the most vulnerable to flooding, may be difficult to access during flood events. Provision of emergency services (including evacuation assistance) and adequate access to hospitals, heating/cooling facilities, and nursing homes for older adults can be especially challenging in the event of severe storms and flooding.

Looking Forward

The analysis contained within this assessment will inform the recommendations presented in the Fox River Corridor Plan. In many cases, the impacts of natural hazards can be mitigated through cost-effective measures to reduce vulnerability and encourage resilience, while others it is a matter of planning for response and recovery. As the Fox River Corridor plans for their future in light of climate change, actions to improve flood resilience, stormwater management, natural resources protection, and regional coordination should be prioritized.

Flood mitigation and recovery

Flooding will continue to impact the Fox River Corridor and require coordination among many levels of government, residents, businesses, and other stakeholders. The counties, municipalities, and Illinois Emergency Management Agency (IEMA) should continue to leverage resources to acquire flood-prone properties from willing sellers. Counties and municipalities should continue to participate in FEMA's National Flood Insurance Program, help residents implement flood proofing measures to protect homes, and coordinate assistance to residents and river-related businesses following a flood. Businesses along the Fox River should also consider diversifying their services to sustain revenue streams in light of flood-related closures.

Stormwater management and erosion control

An increase in precipitation and flooding may increase runoff which could degrade the water quality of the Fox River, tributary streams, lakes, wetlands, and shallow groundwater aquifers without adequate stormwater management and erosion control. Stormwater management can also reduce the temperature of runoff and mitigate the impact to water quality and aquatic habitat. Counties and municipalities should continue to invest in stormwater management,

⁶⁵ Santec and Molly O'Toole Associates, LTD, "McHenry County Natural Hazards Mitigation Plan," August 2017, <https://www.co.mchenry.il.us/home/showdocument?id=77420>

erosion control, and watershed planning. County stormwater ordinances should also be revised to accommodate for changes in precipitation.

Natural resources management

Restoring and maintaining the ecological health of the Fox River Corridor will be critical to sustaining the ecosystem services it provides as habitats shift. Villages, counties, open space administrators, and land conservation agencies should invest resources and collaborate to manage invasive species and restore habitat that is critical to threatened and endangered species. Land managers and municipalities should select hardier trees to withstand increased precipitation and prolonged drought and practice routine pruning to withstand severe summer and winter storms. Conserving and improving the quality of the Corridor's groundwater supply will also be important in the face of climate change. Communities that rely on this water resource should explore tools, such as ground protection and water conservation ordinances as well as education and outreach, to help protect and maintain groundwater supply and quality.

Regional Coordination

Regional coordination will continue to play an important role in building resilient communities in the face of climate change. Counties and municipalities should continue to participate in regional initiatives, such as the Northwest Water Planning Alliance, to engage residents and stakeholders on drought and proactively address its impacts. Road maintenance in the face of widely varying weather conditions from extreme heat to winter storms will also be critical, especially given that driving is the primary mode of transportation with the Corridor. It will require coordination across jurisdictions to ensure public safety, sustain government resources, and uphold the region's environmental quality.