

COASTAL RESILIENCY

PLANNING FOR COASTAL & CLIMATE TRENDS

AN APPENDIX TO THE 2021 MASTER PLAN FOR ALPENA COUNTY, GREEN TOWNSHIP, OSSINEKE TOWNSHIP & WILSON TOWNSHIP



COMPLETED IN PARTNERSHIP WITH THE STATE OF MICHIGAN COASTAL ZONE MANAGEMENT PROGRAM,
LAND INFORMATION ACCESS ASSOCIATION, UNIVERSITY OF MICHIGAN, AND NEMCOG

PLANNING FOR COASTAL AND CLIMATE TRENDS

THE IMPORTANCE OF PLANNING IN COASTAL COMMUNITIES

It is no secret that the Great Lakes are one of the most unique and precious environmental systems in the world. In fact, “the Great Lakes basin contains more than 20% of the world’s surface freshwater supplies and supports a population of more than 30 million people.”¹ Michigan is home to nearly 3,300 miles of Great Lakes shoreline, along with 36,000 miles of rivers and streams, and 11,000 inland lakes.²

Yet in general, riparian land (land adjacent to a water body) throughout Michigan is not adequately protected from development pressures.³ Coastal communities especially have an important role to play in protecting the Great Lakes. In 2001, the Michigan Department of Environmental Quality (DEQ), now the Department of Environment, Great Lakes & Energy (EGLE), acknowledged “fragmentation of coastal habitats, loss of agricultural and forest lands, increased impervious surfaces and resulting stormwater runoff, and the increased development in coastal hazard areas, wetlands, and Great Lakes Islands, could be improved through better coastal land-use planning.”⁴

Planning for coastal areas at the local level requires knowledge of both local conditions and state and federal regulations. This chapter aims to address these needs for Alpena County and provide clear, well-founded recommendations for future land-use planning.

OVERVIEW OF COASTAL DYNAMICS AND THE GREAT LAKES

The Great Lakes function differently than other inland water bodies and tidal oceans. Understanding these dynamics can help Alpena County plan for naturally occurring changes along the shoreline.

How are Great Lakes Water Levels Measured?

Great Lakes water levels are measured via the International Great Lakes Datum (IGLD), a reference system of benchmarks at various locations on the lakes that approximate sea level. Great Lakes water levels are expressed as measurements above this reference elevation.

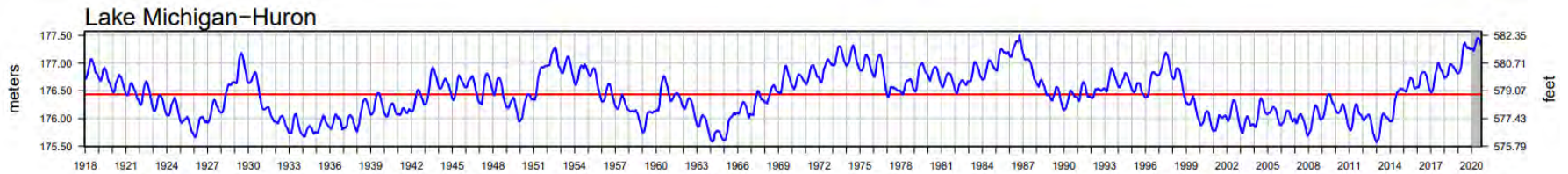
¹ Mackey, S.D. 2012: Great Lakes Nearshore and Coastal Systems. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators

² Ardizzone, Katherine A. and Mark A. Wyckoff, FAICP. Filling the Gaps: Environmental Protection Options for Local Governments, 2nd Edition. 2010.

³ As cited by Norton 2007 – Michigan Department of Environmental Quality. 2001. 309 Enhancement Grants Assessment/Strategy. Lansing, MI: DEQ Coastal Management Program.

⁴ Ibid

Figure 1. Lake Michigan-Huron Water Level Changes, 1918 – 2020



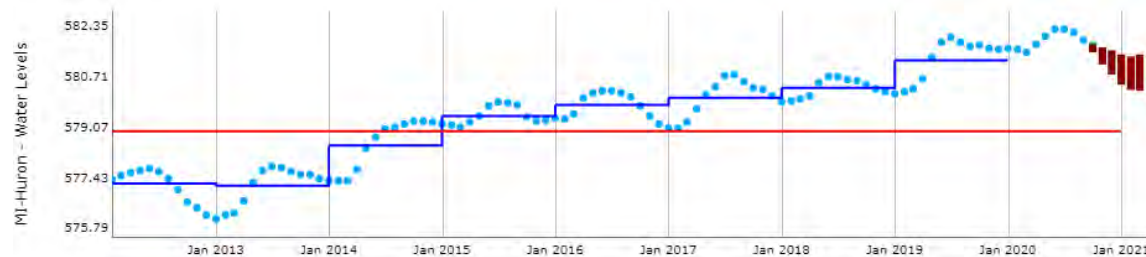
Source: <http://lre-wm.usace.army.mil/ForecastData/GLBasinConditions/LTA-GLWL-Graph.pdf>

Changing Water Levels of the Great Lakes

Great Lakes water level changes result not from the moon’s gravitational pull, but from cyclical changes in rainfall, evaporation, and river and groundwater inflows.⁵ These factors work together to raise and lower the water levels of the Great Lakes in small increments daily, and larger increments seasonally and over the course of years and decades. Long-term water levels fluctuate by multiple feet. Figure 1 illustrates the water level of Lake Huron from 1918 to 2020 (Lake Michigan and Lake Huron are technically considered one lake). However, under certain climate conditions, water levels can dramatically fluctuate over short periods of time. For example, following the extreme winters of 2014 and 2015, water levels in Lake Michigan rose between three to four feet from an all-time low (576 feet) set just a year earlier.

The Great Lakes have just experienced a period of rising lake levels (see Figure 2). Since the early 2000s, water levels had remained low, but historical patterns over the last century indicated that higher water levels were sure to return.⁶ After a period of lows in 2013, Lake Huron’s water level in July of 2020 averaged 582.2 feet, which was 34 inches above its long-term average

Figure 2. Lake Michigan-Huron Water Levels



Source: glerl.noaa.gov/data

⁵Norton, Richard K., Meadows, Lorelle A. and Meadows, Guy A. (2011) “Drawing Lines in Books and on Sandy Beaches; Marking Ordinary High Water on Michigan’s Great Lakes Shorelines under the Public Trust Doctrine.” Coastal Management, 39: 2, 133 – 157, First published on 19 February 2001 (iFirst).

⁶Meadows, Guy A., and Meadows, Lorelle, A., Wood, W.L., Hubertz, J.M., Perlin, M. “The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage.” Bulletin of the American Meteorological Society Series 78:4. (1997): 678-683. Print.

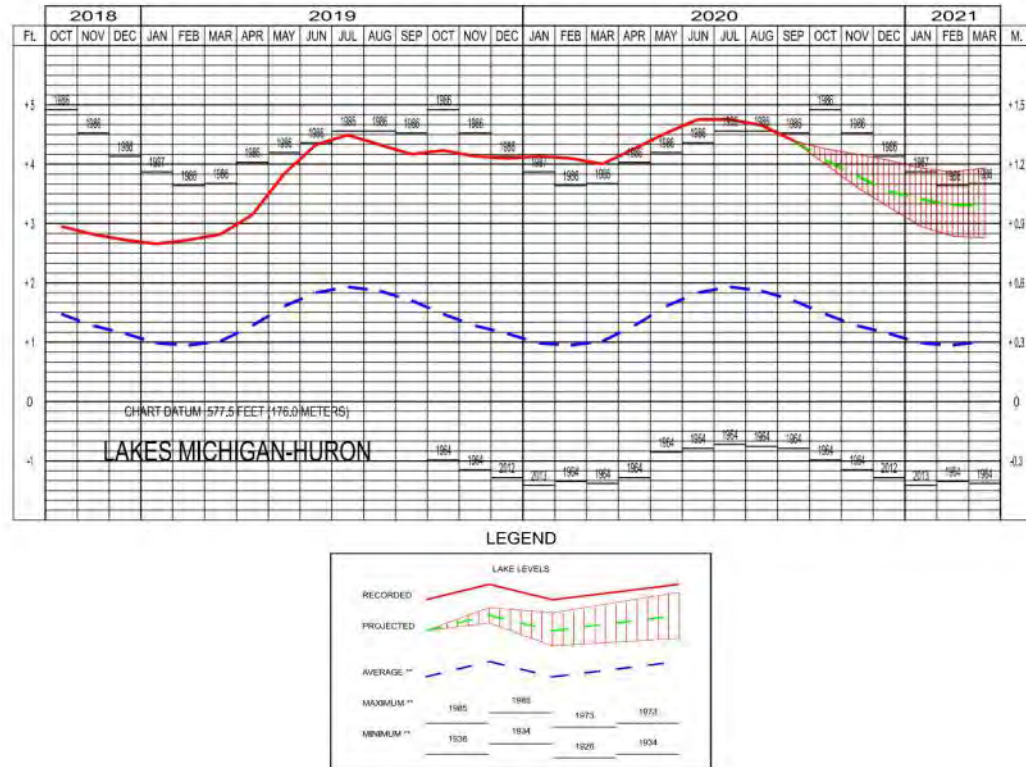
level for the month. According to a recent U.S. Army Corps of Engineers summary, based on current conditions, Lake Huron is expected to see lake levels decline through March, 2021, after seeing record highs throughout 2020 (see Figure 3).

It is important to note that changes in water levels are not solely responsible for the movement of the shoreline landward and lakeward over time. The velocity and height of waves, erosion of shorelines, and the pace of fluctuating water levels also contribute to coastal dynamics on the Great Lakes.

Wave Energy and Height

The Great Lakes experience high-energy waves and wave setup along the coastline. High-energy waves are high in speed and strong in intensity and are primarily created as fast winds move across the surface of the water for extended distances.⁸ “Wave setup” is the height of the water as waves reach the shore. High wave setup results as regional storms create high winds on the Great Lakes.⁹ Powerful and tall waves can quicken the rate of erosion and damage structures near the shoreline.¹⁰ In Alpena County, the prevailing winds are predominantly from the west (May to August and September to March) and north (March to May).

Figure 3. Lakes Michigan-Huron Water Levels—September 2020



⁷<http://www.lre.usace.army.mil>

⁸National Oceanic and Atmospheric Administration. “Coastal Currents” Ocean Services Education, NOAA, 25 March 2008. Web. Accessed July 2015.

⁹Norton, Richard K, Meadows, Lorelle A. and Meadows, Guy A. (2011) “Drawing Lines in Law Books on Sand Beaches: Marking Ordinary High Water on Michigan’s Great lakes Shorelines under the Public Trust Doctrine”, Coastal Management, 39: 2, 133 – 157, First published on: 19 February 2001 (iFirst)

¹⁰Ibid.

Erosion

The shorelines of Lake Huron are mostly made of gravel and sands that easily erode during times of high-energy waves.¹¹ Coastal erosion can cause flooding and damage infrastructure along bluffs and beaches. Erosion is caused mainly by storms and winds, and is exacerbated when lake levels are high.¹²

Quickly Changing Conditions

The Great Lakes are contained in gradually shifting and tilting basins. This tilting results as the Earth slowly decompresses and rebounds from the immense weight of the glaciers that created the Great Lakes.¹³ This shifting causes water levels to change more quickly in some places than others, because the shape of the water basin varies along the coast.¹⁴ This attribute of the Great Lakes makes it difficult to predict the pace of shoreline movement. Therefore, it is safest to plan for great variability and rapid change in water levels.¹⁵

CLIMATE CHANGE AND THE GREAT LAKES

Powerful waves, erosion, and changing shorelines on the Great Lakes have been well-documented throughout history, and each has implications for planning efforts along the coast. Climate change exacerbates these natural processes and requires preemptive planning in coastal communities. This section will discuss climatologist predictions of increased precipitation and storminess in the Great Lakes region, variable lake water levels, and rising water temperatures. First, it is important to understand the global context of climate disruption.

Global Changes in Climate

Climate and weather are directly related, but not the same thing. Weather refers to the day-to-day conditions in a particular place, like sunny or rainy, hot or cold. Climate refers to the long-term patterns of weather over large areas. When scientists speak of global climate change, they are referring to changes in the generalized, regional patterns of weather over months, years and decades. Climate change is the ongoing change in a region's general weather characteristics or averages. In the long term, a changing climate will have more substantial effects on the Great Lakes than individual weather events.

Evidence collected over the last century shows a trend toward warmer global temperatures, higher sea levels, and less snow cover in the Northern Hemisphere. Scientists from many fields have observed and documented significant changes in the Earth's

¹¹Ibid.

¹²Meadows, Guy A., and Meadows, Lorelle, A., Wood, W.L., Hubertz, J.M., Perlin, M. "The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage." *Bulletin of the American Meteorological Society Series 78:4.* (1997): 675-683. Print.

¹³Dorr, J. A. and D. F. Eschman. 1970. *Geology of the Great Lakes.* Ann Arbor: University of Michigan Press.

¹⁴Wilcox, D. A, Thompson, T.A., Booth, R.K., and Nicholas, J. R., 2007, *Lake-level variability and water availability in the Great Lakes: U.S. Geological Survey Circular 1311*, 25 p

¹⁵Ibid.

climate.¹⁶ Warming of the climate system is unequivocal and is now expressed in higher air and ocean temperatures, rising sea levels, and melting ice.¹⁷

To help predict what the climate will be in the future, scientists use computer models of the Earth to predict large-scale changes in climate. These General Circulation Models (GCMs) have been improved and verified in recent years, resulting in relatively reliable predictions for climate changes over large regions.¹⁸ Scientists downscale these techniques to predict climate change for smaller regions.

Climate Change on the Great Lakes

The Great Lakes Integrated Sciences and Assessments Program (GLISA) is a consortium of scientists and educators from the University of Michigan and Michigan State University that provides climate models for the Great Lakes region in support of community planning efforts like this Master Plan.

Figure 5.

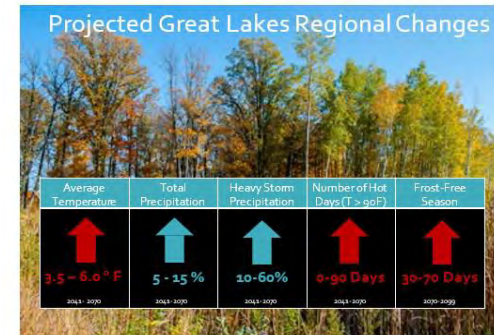
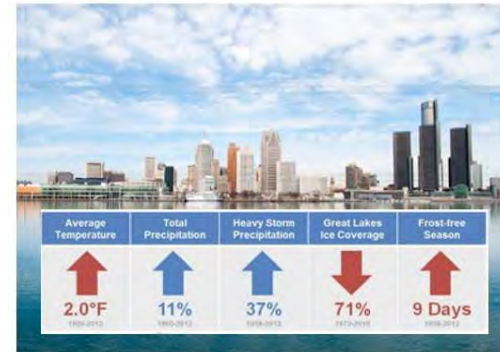


Model projections of summer average temperature and precipitation changes in Illinois and Michigan for mid-century (2040-2059), and end-of-century (2080-2099), indicate that summers in these states are expected to feel progressively more like summers currently experienced in states south and west. Both states are projected to get considerably warmer and have less summer precipitation.

Figure 4 illustrates the historical and predicted climate changes from GLISA for the Great Lakes region. According to GLISA, the Great Lakes region experienced a 2.3° Fahrenheit increase in average air temperatures from 1951 to 2017.¹⁹ An additional increase of 3° to 6° F in average air temperatures is projected by 2050. Although these numbers appear relatively small, they are driving very dramatic changes in Michigan’s climate and greatly impact the Great Lakes.

The National Climate Assessment for 2009 included a number of illustrations to help us understand the extent and character of anticipated climate change impacts.²⁰ One of these illustrations, Figure 5, shows Michigan under several emissions scenarios, each leading to changes in Michigan’s

Figure 4.



¹⁶Intergovernmental Panel on Climate Change. (2007). Observed changes in the climate and their effects. Eb. Accessed July 2015.

¹⁷Ibid.

¹⁸Intergovernmental Panel on Climate Change (2013). What is a GCM? Web. Access July 2015

¹⁹Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.

²⁰U.S. Global Change Research Program. Global Climate Change in the United States, 2009. Cambridge University Press, Cambridge, MA.

climate. Just by maintaining current emission levels, Michigan’s climate will feel more like present-day Arkansas or Oklahoma by the end of the century.²¹

Increased Precipitation and Storminess

There is strong consensus among climate experts that storms greater in number and intensity will occur in the Great Lakes region as a result of climate change.²² This is already happening as “the amount of precipitation falling in the heaviest 1% of storms increased by 35% in the Midwest from 1951 to 2017.”²³ As storms drop more precipitation and generate stronger sustained winds, the Great Lakes will see stronger and higher waves. In addition to direct damage caused by storms, sustained increases in the number of storms and their intensity can both directly and indirectly pollute waters by overloading sewage and stormwater capabilities.²⁴ Increases in the intensity of storms also quickens the pace of erosion on Great Lakes shorelines. In fact, the Federal Emergency Management Agency (FEMA) projects approximately 28% of structures within 500 feet of a Great Lake shoreline are susceptible to erosion by 2060.²⁵

Variability of Lake Water Levels

The natural ups and downs in the water levels of Lake Huron will continue regardless of the impacts of climate change.²⁶ However, climate change is likely to augment this natural process, resulting in more variable water levels as warmer air temperatures result in fewer days of ice cover and faster evaporation.²⁷ In other words, lake levels will rise and fall faster and with less predictability than in the past. Fortunately, much of Michigan’s coastal infrastructure was built in previous decades during times of high water levels.²⁸ However, fast-rising waters can erode shorelines, damage infrastructure, and cause extensive flooding in inland rivers.²⁹ When lake levels fall, access to infrastructure like docks may be restricted and navigation hazards in shallow waters may be exposed. Low lake levels pose a threat to coastal vegetation and can reduce the pumping efficiency of drinking water intake pipes.³⁰ Additional ramifications of changing lake levels include a drop in water supply,³¹ restricted fish habitats,³² more invasive

²¹Ibid.

²²Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed December 2019.

²³Ibid.

²⁴Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

²⁵The Heinz Center. (2000). Evaluation of Erosion Hazards. Web. Accessed July 2015.

²⁶Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

²⁷Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

²⁸Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

²⁹Ibid.

³⁰Ibid.

³¹Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

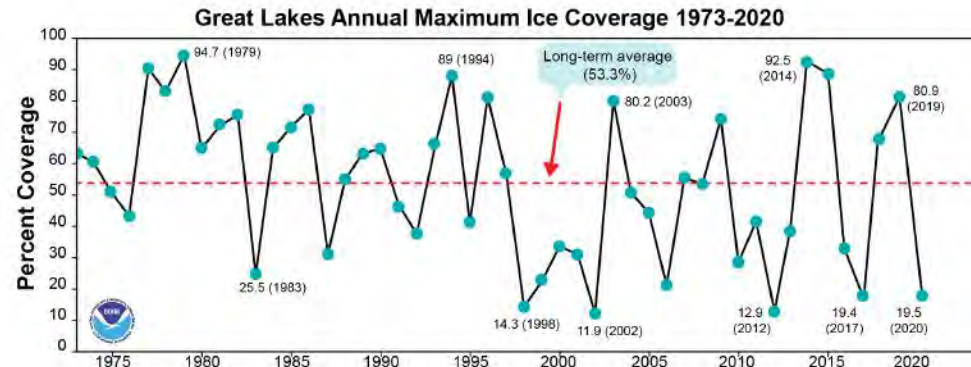
³²Ibid.

species,³³ faster erosion, and an overall decline in beach health.³⁴ Climate change is likely to augment the natural highs and lows of lake levels, causing more variability and a faster rate of change, making each of these potential ramifications both more likely and less predictable.

Water Temperature

Climatologists predict there will be fewer days below freezing in Michigan and other Great Lakes states. As temperatures remain warm for a greater part of the year, the winter season will shorten and the lake ice cover that accompanies winter weather will decline. In general, annual average ice cover on the Great Lakes underwent a shift from higher amounts prior to the 1990s to lower amounts in recent decades. However, there remains strong year-to-year variability, and high ice years are still possible.³⁵ Figure 6 illustrates the variability in ice coverage in the Great Lakes between 1973 and 2020.

Figure 6.



Lake ice cover allows heat radiation from the sun to be reflected, so when ice declines, the surface water temperature will increase as more heat is absorbed by the water. In the Great Lakes, average summer lake surface temperatures have been increasing faster than the surrounding air temperatures, with Lake Superior surface temperatures increasing by 4.5°F between 1979 and 2006.³⁶

The associated impacts of rising water temperatures include changes to where fish and other aquatic animals can live, increased vulnerability to invasive species, and increased risk of algae blooms.³⁷ Rising water temperatures also enable winds to travel faster across the surface of the lake, increasing the vulnerability of coastal communities to damaging waves as storms and winds increase.³⁸ Lastly, ice cover protects the shoreline during winter storms. With less ice cover, the shoreline is more susceptible to erosion and habitat disruption.

³³Ibid.

³⁴Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

³⁵Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.

³⁶Ibid.

³⁷Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

³⁸Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

DEFINING VULNERABILITY IN ALPENA COUNTY

The effects of climate change have been felt by everyone. With planning and preparation, communities can weather the storms and recover, becoming even better places to live and thrive. Through community-wide planning, resilient communities actively cultivate their abilities to recover from adverse situations and events, working to strengthen and diversify their local economies and communication networks, increase social capital and civic engagement, enhance ecosystem services, improve human health and social systems, and build local adaptive capacity.

Building Community Resilience

As defined by the Urban Sustainability Directors Network, community resilience is the ability of a community to anticipate, accommodate and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality and conservation of resources for present and future generations. The Rockefeller Foundation emphasizes equity as an important component of resilience, stating that community resilience is the capacity of people — particularly the poor and vulnerable — to survive and thrive no matter what stresses or shocks they encounter. Communities that are resilient are able to learn from adversity and adapt quickly to change. In general, the most important qualities of resilient communities are: (1) Reflective, (2) Flexible, (3) Integrated, (4) Robust, (5) Resourceful, (6) Redundant and (7) Inclusive. The Rockefeller Foundation has identified 12 indicators within these qualities that make for a resilient community (see inset). However, it is important to acknowledge that Alpena County is unique, and not all of these indicators or characteristics may be necessary for the community to be “resilient.”

According to the Rockefeller Foundation, a Resilient Community has...

1. Minimal human vulnerability
2. Diverse livelihoods and employment
3. Effective safeguards to human life and health
4. A collective identity and mutual support
5. Comprehensive security and rule of law
6. A sustainable economy
7. Reduced exposure and fragility
8. Effective provision of critical services
9. Reliable mobility and communication
10. Effective leadership and management
11. Empowered stakeholders
12. Integrated development planning

The following is a community vulnerability assessment focused on Alpena County. This assessment begins with an overview of regional climate trends and predicts societal impacts, then transitions to detailed assessments of the community's vulnerabilities to extreme heat and flooding events. Although the assessment is concentrated on these two specific types of events, many of the considerations and societal impacts identified would be present in other stresses and shocks within the community (e.g., a winter storm).

In completing the assessment, a variety of factors are considered, such as demographics, environmental conditions, locations of critical facilities and essential services, and the built environment. This assessment informs recommendations for reducing identified community vulnerabilities through policies, programs and projects, which will inevitably lead to a more resilient community.

Climate Variability

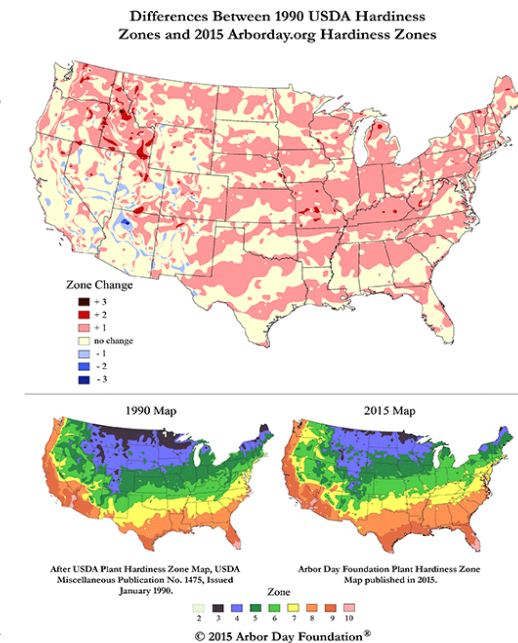
Based on the most recent models, the climate of Alpena County will continue to warm, with greater increases in average temperatures during the winter months and at night. There are a variety of weather impacts expected with this change in average temperatures. Some of the potential impacts of climate change in the county are listed below:

- Storms are expected to become more frequent and more severe
- Increases in winter and spring precipitation
- Less precipitation as snow and more as rain
- Less winter ice on lakes
- Extended growing season (earlier spring/later fall)
- More flooding events with risks of erosion
- Increases in frequency and length of severe heat events (heat waves)
- Increased risk of drought, particularly in summer

It is important to note that increased flooding and more intense drought are not mutually exclusive nor contradictory. In the Great Lakes region, scientists are predicting more intense rain events in the fall and winter along with more intense droughts in the summer months.

These changes in climate could have a number of both positive and negative effects in Alpena County. For example, an extended growing season could help support new crops and increase crop yields for area farmers. On the other hand, the highly variable weather conditions — such as severe storms and flooding mixed with summer droughts — present big challenges to farming.

Figure 7.



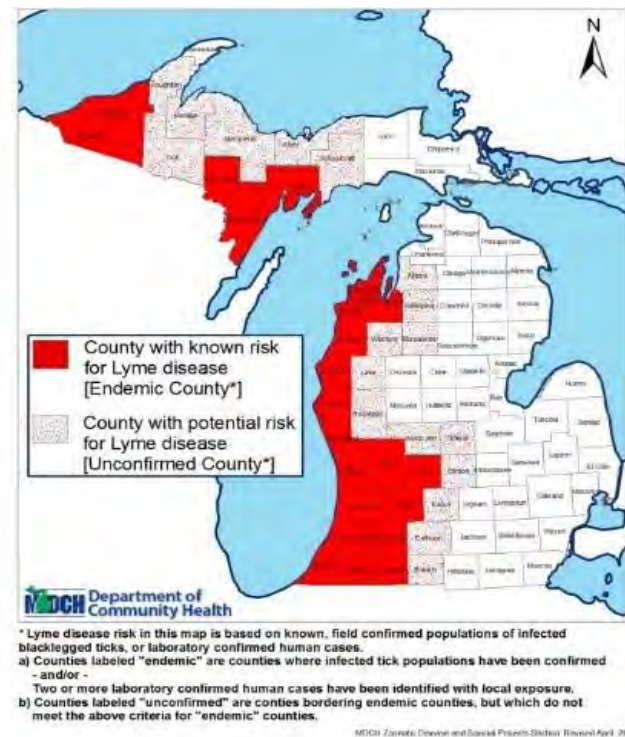
Much of the U.S. has been warmer in recent years, and that affects which plants grow best in various regions. The Arbor Day Foundation completed an extensive update of U.S. Hardiness Zones based on data from 5,000 National Climatic Data Center cooperative stations across the continental United States. As illustrated in Figure 7 on the previous page, zones in northeast Lower Michigan are shifting northward. A few decades ago, Alpena County was solidly in Zone 4; today, Zone 5 plants that once thrived in the southern reaches of the state may now successfully survive in Alpena County.

Public Health and Climate

Major health effects of long-term climatic change are predicted for the U.S. Midwest. Already, people in Michigan are experiencing higher rates of skin and eye damage from increased exposure to ultraviolet radiation, increased incidence of respiratory and cardiovascular diseases, and increased incidence of vector-borne and water-borne diseases.³⁹ Weather conditions and high heat events exacerbate health conditions like allergies, asthma, and obesity.

The Michigan Department of Health and Human Services (MDHHS) published the Michigan Climate and Health Adaptation Plan in 2011. The Plan indicates there is an increase in the number of illnesses and deaths as a result of extreme heat events; declining air quality as a result of increased production of ozone and particulate matter from heat and drought events; and adverse changes to water quality and availability following severe weather events. In the long term, health experts are most concerned with a rising incidence of infectious diseases and outbreaks of new diseases not currently endemic to Michigan; increasing numbers of disease vectors and the appearance of new vectors not currently established in Michigan; and a degradation of food safety, security and supply. For example, blacklegged ticks are one disease vector that has increased in recent years. According to the MDHHS, the first official reported human case of Lyme disease in Michigan was in 1985. Cases have now been reported in both the Upper and Lower Peninsula and are increasing. It is anticipated that the number of cases reported will continue to increase due to public and medical personnel education and expanding tick ranges. Figure 8 illustrates the distribution of the risk for Lyme disease in Michigan, which has increased in recent years.

Figure 8.



³⁹National Research Council. Reconciling observations of global temperature change. Washington, DC: National Academy Press, 2000:86.

Local and Regional Hazards: Severe Weather in Alpena County

The following text summarizes the major weather-related hazards in Alpena County. Oftentimes, severe weather events result in negative impacts to the local economy and to vulnerable populations in the community. According to the Alpena County 2014 Hazard Mitigation Plan:

Since January of 2006, 13 winter storm events have been recorded in Alpena County. Winter storms consisting of rapid snow accumulation, high winds, cold temperatures and low visibility are common seasonal hazards that can be expected to occur in Alpena County several times every year. The highest seasonal snowfall in recorded history at Alpena County Airport was 146 inches during the 1985 season.

The following snowfall extremes, based on the time period of the Midwest Regional Climate Center's published record, are:

- Greatest monthly total: 48.1 (recorded December 2008)
- Greatest seasonal total: 146.0 inches (recorded during 1985)

Severe winds (winds in excess of 58 miles per hour) also pose a threat to Alpena County's economic, social and environmental well-being. According to the National Weather Service, the northern Lower Peninsula can expect 3-4 severe wind events each year. Strong winds and thunderstorm winds are the most prevalent severe weather events that affect Alpena County. From 1955 to 2002, there have been 64 severe wind events recorded in Alpena County causing over \$100,000 in damage. Records from October of 2006 through May of 2012 show there were nine strong wind events, with six of those associated with thunderstorm activity. Total estimated damage was \$71,000. Strong winds are most likely in the summer months of June July and August, but can and have occurred at any time of year.

In regard to flooding, Alpena County's 2014 Hazard Mitigation Plan notes that two of the county's three hydro dams are high hazard due to their location, dam pool size and normal/max storage. In addition to these dams, the plan also cites riverine and urban flooding as a community threat, especially around the Washington Bridge on US-23 crossing the Thunder Bay River. Alpena County's flood hazard areas were last mapped by FEMA in 2011.

There are three key rationales to support regulation of floodprone areas: "(1) to protect the unwary from investing in or occupying floodprone property; (2) to protect other riparian landowners (upstream, downstream, or cross-stream) from higher flood levels due to ill-considered encroachment on floodplains by their neighbors; and (3) to protect the community from the costs of rescue and disaster assistance. The first two related to classical nuisance law while the third more closely related to public resource protection."

-From Rutherford H. Platt's *Disasters and Democracy: The Politics of Extreme Natural Events*. Three rationales originally proposed by University of Chicago Law Professor Allison Dunham in 1959.

VULNERABILITY ASSESSMENTS

Communities interested in becoming more resilient assess their vulnerabilities and make action plans to reduce their sensitivities and exposures to hazards of all kinds. This Community Vulnerability Assessment has been compiled by the Land Information Access Association (LIAA) to provide a wide variety of useful information aimed at improving climate resilience by reducing human and community vulnerabilities.

Vulnerability = Exposure + Sensitivity

A Vulnerability Assessment is designed to identify and help prioritize adaptation strategies in the community planning process. A model that defines vulnerability as “exposure plus sensitivity” is used to complete the assessment.⁴⁰ “Exposure” refers to hazards in the natural or built environment, while “sensitivity” refers to the degree to which a community or certain segments of a community could be impacted by an event. This concept has been used recently in a variety of studies, such as equity and adaptation assessments conducted by the NAACP,⁴¹ vulnerability and its relationship to adaptation,⁴² and hazard-specific vulnerability assessments aimed at measuring exposure, sensitivity, and resilience.⁴³

By assessing the potential for exposure to a hazard and the sensitivities of specific populations, maps are generated that identify the community’s areas with relatively greater vulnerability (that is, where exposure and sensitivity overlap). This tool provides direction for community planners and public health workers in reducing risks to human health by understanding where the areas of vulnerability lie and why the vulnerability exists.

For the purposes of this tool, based on the greatest risks in Michigan and most likely predicted climate changes, the vulnerability assessments for Alpena County were limited to extreme heat waves and flooding. However, climate change is predicted to result in increases of other

Exposure refers to hazards in the natural or built environment, while *sensitivity* refers to the degree to which a community or certain segments of a community could be impacted by an adverse event.

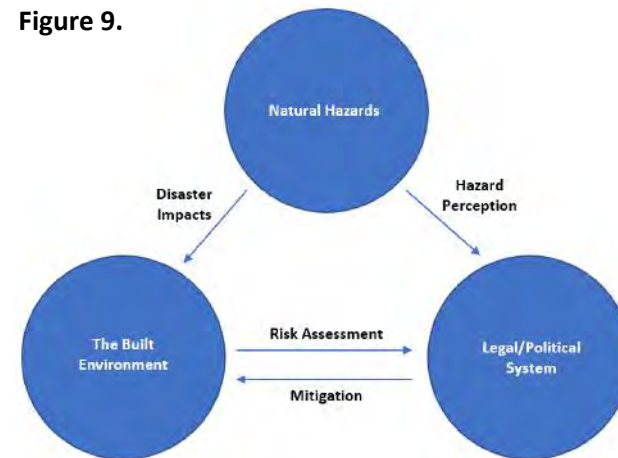


Figure 9.

Figure from *Disasters and Democracy* (Platt, 1999)

⁴⁰Foundations for Community Climate Action; Definition Climate change Vulnerability in Detroit. University of Michigan. December 2012.

⁴¹Equity in Building Resilience in Adaptation Planning. National Association for the Advancement of Colored People (NAACP).

⁴²Adger, W.N. (2006). “Vulnerability.” *Global Environmental Change* 16 (3): 268-281. Adger, W.N., N. Arnell, and E. Tompkins (2005). “Adapting to climate change-perspectives across scales.” *Global Environmental Change* 15(2): 77-86.

⁴³Polsky, C., R. Neff, and B. Yarnal (2007). “building comparable global change vulnerability assessments: the vulnerability scoping diagram.” *Global Environmental Change* 17(3-4): 472-485.

exposures that should also be considered in community planning and development (e.g., high winds, severe winter storms).

Our assessments were based in part on data obtained from the American Community Survey (ACS), a continuing survey program operated by the U.S. Census Bureau. This data includes information on housing, income and education characteristics of the population in geographic areas called “Block Groups,” which contain between 600 and 3,000 individuals. Data from the 2010 Census was also used, including population age and racial composition collected at the Census “Block” level, which is the smallest available geographic area for demographic data.

Heat Vulnerability

Community vulnerability to heat events varies spatially on local, regional and national scales. In Michigan communities, there are varying degrees of vulnerability to heat based on proximity to the Great Lakes, access to air conditioning, and surrounding environmental factors like tree canopy and impervious surfaces.

Studies have shown that heat-related mortality generally occurs in areas of the community that are warmer, less stable, and are home to more disadvantaged populations.⁴⁴ One study found that neighborhoods with the highest temperatures and the least amount of open space and vegetation were also likely to be the most socioeconomically disadvantaged.⁴⁵ The same study also found the strongest protective factor for residents was access to air conditioning in the home and in other places, as well as having access to transportation.

A 2012 literature review conducted by researchers at the University of Michigan indicates that children under five and persons over age 65 are highly sensitive to heat events, as are persons living in lower-income Census tracts and minority populations. Living alone, being confined to bed, having a mental illness, not leaving home daily, living on higher floors of multistory buildings, and suffering from alcoholism are additional factors that are associated with increased risk of heat-related mortality.

Many Michigan communities are rural and suburban. There have been limited studies conducted on how heat events impact rural and suburban communities, but one study notes that rural populations may exhibit patterns of vulnerability different from those of urban populations.⁴⁶

Heat Sensitivity Assessment

To create the sensitivity and exposure maps, as well as the resulting vulnerability maps, the project team relied on methodologies developed at the University of Michigan’s Taubman College of Architecture and Urban Planning in a 2012 report.⁴⁷

⁴⁴Foundations for Community Climate Action: Defining Climate Change Vulnerabilities in Detroit. University of Michigan. December 2012.

⁴⁵Semenza JC, Rubin CH, Falter KH, et al. Heat-related deaths during July 1995 heat wave in Chicago. *N Engl J Med* 1996; 335:84-90.

⁴⁶Mapping Community Determinants of Heat Vulnerability. *Environ Health Perspectives* 117: 1730-1736 (2009). Doi:10.1289/ehp.0900683 available via <http://dx.doi.org/>[Online 10 June 2009]

⁴⁷Foundation for Community Climate Action: Defining Climate Change Vulnerability in Detroit (December 2012) University of Michigan’s Taubman College of Architecture and Urban Planning.

Table 1. Needs of Stakeholders and Participants in Disaster Recovery

Immediate and long-term needs	
Individuals and families	Housing
	Restoration of employment
	Health and welfare
	Restoration of schools and other educational facilities
Business and industry	Reconstitution of business, business recovery
	Rehiring of workers
	Insurance supplementation or coverage of uninsured losses
	Business altruistic activity
Communities and local government	Restoration of utilities and lifeline services
	Support of nonprofit charitable organizations
	Infrastructure repair and replacement
	Supervision of local recovery
	Debris removal
	Post-disaster planning
State and federal government	Repair or replacement of state-owned infrastructure or facilities
	Repair or replacement of federally-owned infrastructure or facilities

To conduct the heat sensitivity assessment of Alpena County, the project team used a geographic information system (GIS) for spatial data analyses to show the relative distribution of people most at risk. Five factors have been identified as primary contributors to the sensitivities and risks of people exposed to a heat wave, including: people over 65 years of age; people living alone; people over 25 with less than a high school education; minority populations; and people living below the poverty line. Using U.S. Census data, the project team identified the percentages of people living in each area (by Block Group or Block) for each sensitivity factor.

People who are older have greater sensitivity to extreme heat events. The technical literature also indicates that older age is associated with higher hospital admission rates in heat waves. The Percent of Population 65 and Older (Maps 1.1, 2.1, 3.1) depicts the relative concentration of older adults in the community by Census Block.

Another sensitivity factor is living alone, which serves as a measure of social isolation. Although living alone is not necessarily a risky thing, people who are socially isolated are at greater risk during an extreme heat event. Isolated people may not be able to recognize symptoms of heat-related illness and take proper action. In this case, the project team used the American Community Survey data for Census Block Groups, broken out into individual Census Blocks for geographic representation (Blocks with no population were not included). Maps 1.2, 2.2 and 3.2 depict the concentrations of people living alone.

Literature suggests that minorities are at greater risk during extreme heat events for various reasons, including less reliable access to health care, transportation and other social supports needed to reduce heat exposures.⁴⁸ Census Blocks were used to map the relative percentages of non-white populations in the county (see Maps 1.3, 2.3 and 3.3).

Two socioeconomic factors associated with increased heat-related morbidity and mortality are the percentage of the people living in poverty

Cited in *Disaster Policy & Politics* (Sylves, 2008). Original source: *Introduction to Emergency Management* (Haddow & Bullock, 2006).

⁴⁸Waugh and Tierney (eds.) *Emergency Management: Principles and Practices for Local Government*. Chapter 13: Identifying and addressing social vulnerabilities by Elaine Enarson.

and percentage of people without a high school diploma. In general, persons living at or below the poverty line have less access to air conditioning or cooling options for their residences. This could limit a person's access to relief from an extreme heat event. Census Block Groups were used to map the relative percentages of households living below the poverty threshold in Alpena County (please see Maps 1.4, 2.4 and 3.4).

Similarly, University of Michigan researchers found studies that demonstrate a direct link between low education attainment and poor health as well as income.⁴⁹ There is also an established correlation between lower educational attainment and income. Based on these findings, Census Block Groups were used to map the relative percent of persons 25 years and older with less than a high school education in Alpena County (see Maps 1.5, 2.5 and 3.5).

To complete the heat sensitivity assessment, a cumulative score for all five sensitivity factors for each Census Block was created. In each of the sensitivity factors, the percentages were grouped into five categories (ranging from a very low percentage of people to a relatively high percentage living with the identified sensitivity). The five categorical groupings were generated by the GIS software ArcMap using natural breaks in the data (groupings). A ranking of 1 to 5 was assigned to each of the categories, ranging from 1 for the lowest percentage to 5 for the highest. Finally, the team combined the scores within each Census Block. Thus, the most sensitive Census Blocks could be scored up to 25. The sensitivity is color-coded for ease of identifying areas with the greatest sensitivity.

The Alpena Sensitivity to Excessive Heat Maps (Maps 1.6, 2.6 and 3.6) provide reasonably detailed depictions of locations where the highest percentages of at-risk residents live. This does not mean these community residents are in immediate danger. Rather, the map provides planning officials a new way of identifying areas where heat waves could present serious problems for a significant number of citizens. These are populations that could be sensitive to extreme heat events.

The Census data used likely double-counts some people, such as in cases where a person is both a minority and over 65; this may overestimate the severity of the sensitivities in some locations. Conversely, the sensitivity analysis may underestimate risk in some areas because it leaves out several key sensitive populations, such as those with preexisting health concerns that denote vulnerability to heat (for example, cardiovascular disease or psychiatric disorders), since such health data is not often available publicly. Emergency managers, hospitals, and community health departments may have additional data available that can be included as the community looks to better understand its sensitive populations. To further improve the analysis, additional variables could be collected through local surveys and observations, such as the degree of social connections among individuals within a community, or materials used in housing.⁵⁰

⁴⁹Currier FC, Heiner KS, Samet JM, et al. Temperature and mortality in 11 cities of the eastern United States. *American Journal of Epidemiology*. 30 (2001): 1126-8.

⁵⁰Mapping Community Determinants of Heat Vulnerability. *Environ Health Perspectives* 117: 1730-1736 (2009). Doi:10.1289/ehp.0900683 available via <http://dx.doi.org/>[Online 10 June 2009]

Heat Exposure Assessment

When larger communities experience heat waves, air temperatures can vary significantly from place to place both during the day and at night. Some of these differences can be attributed to the varying types of land cover found throughout the community. For example, temperatures can be significantly lower at night in locations with a heavy tree canopy and very little pavement, versus locations with little greenery and lots of pavement.

Impervious surfaces such as paved parking lots, roadways, and buildings absorb large amounts of heat from the air and from sunshine that is then radiated back into the surroundings, and this heat continues to radiate even after the sun has set. Conversely, tree canopy and other vegetation tend to help cool an area through evaporation and transpiration of water, and by providing shade. In places with a high percentage of impervious surface and little tree canopy, the immediate surroundings can be much warmer. Urban areas typically have higher heat indexes (combinations of temperature and humidity) than surrounding suburban or rural areas. This condition has been termed the Urban Heat Island Effect.⁵¹

People living in settings with an Urban Heat Island Effect suffer greater exposures to heat over longer periods of time (e.g., warmer nights), making them more vulnerable to health impacts. Studies of the Urban Heat Island Effect (whereby air temperatures in an urban area are 2° to 9° F higher than in a nearby rural area) have shown that the albedo, or reflectivity, of an urban area is one of the most important determinants in reducing the magnitude of the heat island.⁵² Increasing the tree canopy cover can also reduce air temperature by 2° to 5° F. Green roofs (vegetative plantings on roofs) may also decrease the Urban Heat Island Effect and decrease stormwater runoff and building energy use. Added benefits from increasing albedo and vegetation include reductions in ground level

FOUR PHASES OF DISASTER MANAGEMENT

Mitigation

Mitigation involves deciding what to do where a risk to the health, safety, and welfare of society has been determined to exist, and then implementing a risk-reduction program.

Preparedness

Preparedness involves developing a response plan and training first responders to save lives and reduce disaster damage, identifying critical resources, and developing necessary agreements among responding agencies, both within the jurisdiction and with other jurisdictions.

Response

Response entails providing emergency aid and assistance, reducing the probability of secondary damage, and minimizing problems for recovery operations.

Recovery

Recovery involves providing the immediate support during the early post-disaster period necessary to return vital life-support systems to minimum operational levels and continuing to provide support until the community returns to normal.

From *Disaster Policy & Politics* (Sylves, 2008)

⁵¹Basu and Samet. (2002) Relation between Elevated Ambient Temperature and Mortality: A Review from the Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD.

⁵²Kolokotroni M, Giridharan R. Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. *Solar Energy* 2008;82(11):986–998.

ozone pollution and reduced energy costs associated with air conditioning use.⁵³

To complete a heat exposure assessment, the project team focused on the Urban Heat Island Effect, and two separate exposure maps were created. The first exposure map depicts the percentage of impervious surfaces within each Census Block, as used in the sensitivity assessment (Maps 1.7, 2.7 and 3.7). These percentages are divided into five categories using the GIS software's natural breaks calculation. Since exposure is lowest in areas with the lowest percentage of impervious surfaces, those scored a 1, with a rating of 5 assigned to areas with the highest percentage of impervious surfaces.

The second exposure factor is percentage of tree canopy. Here, tree canopy is mapped within each Census Block (Maps 1.8, 2.8 and 3.8) and scored using a similar five-category process. The highest percentage of tree canopy (and therefore the lowest heat exposure) received a score of 1, and the areas with the least amount of tree canopy received a 5.

The project team combined the results of the two exposure maps to provide a single Community Excessive Heat Exposure Map (Maps 1.9, 2.9 and 3.9), which provides a reliable depiction of where the Urban Heat Island Effect would be most or least intense during a heat wave. Officials in Alpena County can use these maps to better assess where new vegetation and tree canopy would be helpful to reduce the heat impact.

Composite Heat Vulnerability Map

The Alpena Heat Vulnerability Map is a simple additive combination of the overall sensitivity map and the overall exposures map (see Maps 1.10, 2.10 and 3.10). The resulting vulnerability index depicts where concentrations of exposures and sensitive populations create a higher risk for community residents. In general, those areas with a composite score of 8 to 9 (red) have residential populations that may be particularly vulnerable to extreme heat events.

HEAVY RAIN AND FLOODING

Climate scientists say that Alpena County and northeast Lower Michigan can expect more frequent storms of increasing severity in the decades ahead. The total amount of rainfall per year is also likely to increase. However, climate models suggest the precipitation will be more concentrated in the winter, spring and fall seasons and there will be more localized, intense storms at almost any time of year. The potential for substantially larger rain events raises concerns over the potential for harm to human health and damage to buildings and infrastructure.

In assessing vulnerability to flooding, community planners evaluate potential exposures as well as sensitivity. Buildings, roads, bridges, sewer lines and other infrastructure located in a flood zone are exposed to greater risks. Where flowing floodwaters have the greatest energy, structures may be undercut, collapse or move, and soils will erode. Even areas outside of an identified floodplain are subject to flooding from heavy downpours. Where the soils have low permeability and physical drainage is inadequate, water will accumulate and cause ponding during large storm events. Appropriate planning and land-use regulations

⁵³Akbari H. Shade trees reduce building energy use and CO2 emissions from power plants. *Environmental Pollution* 2002;116:S119–S126. [PubMed: 11833899]

can help reduce exposures caused by poor site selection. The sensitivity of structures can be modified to reduce risk of damage by applying flood-resistant design standards.

Exposure to Flooding Hazards

The Digital Elevation Model Maps (Maps 1.11, 2.11 and 3.11) offer a useful view of the topography of Alpena County, including the most prominent drainage patterns. On this map, the darkest green colors identify the lowest elevations, while the darkest brown colors identify the highest elevations. FEMA Flood Zones are shown on Maps 1.12, 2.12 and 3.12.

COASTAL HAZARD ANALYSIS

As part of this master planning process, LIAA and the University of Michigan analyzed shoreline and riverine ecosystem and physical dynamics to help Alpena County manage its shoreline and riverine areas. This chapter presents a brief summary of the team’s framework, results and recommendations.

Overview of Research Framework

The Research Framework for this study employs scenario planning to assess environmental and land-use conditions under different climate futures. Scenario planning, in general, identifies driving forces to inform a range of scenarios that are then analyzed and evaluated. In this context, the project team identified natural forces, especially increasing storminess and lake-level fluctuations causing increased problems with flooding. These forces informed the creation of multiple climate futures. Each climate future was tested and evaluated for impacts on the environment and land use in the community.

Climate Future Definitions

Rather than presenting a prediction of what the future will bring, each of the following “climate futures” lays out a possible future that might occur. These varying climate futures — all of which are reasonably anticipated possibilities — are arranged from a least impactful to a most impactful condition in terms of the potential for wave damage and flooding hazards they would bring. The following descriptions outline the key assumptions made in defining each of the climate futures as compared to the others. Maps 1.13, 2.13 and 3.13 show the estimated land areas that would be affected by waves and flooding under these three climate futures.

“Lucky” Future: Under the Lucky Climate Future, Great Lakes water levels will stay relatively low. Although there will be wave and wind action, major storm events and wave impacts will not encroach on properties landward of current beaches. A Lucky Future projection, indicating the land areas that would be affected by high-energy waves along the shorefront and/or adjacent riverine flooding under these conditions, is shown in yellow.

“Expected” Future: Under the Expected Climate Future, Great Lakes water levels will continue to fluctuate according to long-term decadal patterns, including recent extreme storm events incorporated into the ongoing Great Lakes Coast Flood Study by the Federal Emergency Management Agency (FEMA). Given those ongoing fluctuations, this Climate Future accounts for periods when Great Lakes still-water elevations are closer to the long-term average. In addition, this Climate Future anticipates the so-called “100-year storm event” (or 1% storm) becoming more like a 20- or 50-year storm event (i.e., an expected storm within the normal community planning time horizon) because of increased storminess. The Expected Future projection is shown in orange.

“Perfect Storm” Future: Under the Perfect Storm Climate Future, Great Lakes water levels will continue to fluctuate according to decadal patterns, consistent with assumptions made for the Expected Future. However, for this Perfect Storm Climate Future, the estimated still-water elevation is set higher than the long-term average and closer to the long-term high (583 feet). In addition, this Climate Future anticipates the occurrence of a so-called “500-year storm event” (or 0.2% storm) occurring within the planning time horizon while lake levels are high. The Perfect Storm Future projection is shown in red.

Management Scenarios

Under the scenario planning algorithm, one can analyze the potential for development impacts in the City of Alpena and Alpena Township. There are three rows that each describe a different development scenario (Tables 4 and 5). The first row shows the impact on the number of current structures (i.e., current development). The second row shows the impact if the community experiences a full buildout of residential development according to its existing zoning code.

The final row in Tables 4 and 5 summarizes the number of structures that could be constructed if the municipalities were to implement best practices into their land use regulations. The BMPs modeled in this management option are:

- 50-foot buffers around any inland water (rivers, lakes and streams).
- 50-foot buffers around any wetland 5 or more acres in size, as defined by the State of Michigan’s Final Wetland Inventory data.
- A complete restriction of any development within a wetland 5 or more acres in size, as defined by the State of Michigan’s Final Wetland Inventory data.

Scenario Planning to Assess Land Use and Environmental Conditions

The three Climate Futures were used to create distinct scenarios, which can then be analyzed for selected conditions as noted above. This array of scenarios represents a range of conditions the county could reasonably encounter in the foreseeable future regarding potential wave and flooding impacts, given changing natural conditions and the development management decisions

made in response. For analysis here, each scenario focuses on potential impacts to land use and environmental conditions in the county. Land-use impacts include the acreage, parcels, and structures that would be at risk under different futures.

LAND USE RESULTS

Structures Impacted

Tables 2 and 3 illustrate the number of structures that are at risk of being impacted by flooding in each of the three climate futures. The three scenarios demonstrate the extent to which the community is exposed to a certain level of risk, highlighting potential options for land use planning going forward. For example, one community may find that the potential impact in the Lucky scenario is within the amount of risk the public is willing to take. Others may want to use particular land use strategies for one climate scenario while implementing separate policies for another. Alpena County and the two coastal municipalities used as examples in this analysis should proactively engage the public to determine the feasibility of accomplishing sustainable policies and initiatives for one or more of the at-risk areas.

Shown in Tables 2 and 3, the number of impacted structures in the city and township increases significantly from “Lucky” to “Perfect Storm”. The increase is more pronounced in Alpena Township than the city. While 381 structures are at risk in the township when the lake levels are low and the storm impact is fairly average, the total number of structures at risk increases by 119% to 835 structures in the Perfect Storm scenario.

Table 2. Total Number of Structures Impacted by Flooding, City of Alpena

Zoning District	Lucky	Expected	Perfect Storm
Residential	145	171	234
Non-residential	34	37	49
Total Number of Structures	179	208	283

Table 3. Total Number of Structures Impacted by Flooding, Alpena Township

Zoning District	Lucky	Expected	Perfect Storm
Residential	378	684	823
Non-residential	3	6	12
Total Number of Structures	381	690	835

Structures Impacted in Different Buildout Scenarios

Up to 283 structures may be impacted in the city and 835 in Alpena Township depending on the severity of the Climate Future experienced. Tables 4 and 5 illustrate how many more structures would be affected in different buildout scenarios. As previously mentioned, the first buildout scenario is based on current zoning. The latter buildout employs best management practices, thereby reducing potential damages from storm events. Tables 4 and 5 summarize how many more structures could be added in the city and township based on two buildout analyses. One can see that for the city and township, there is room for much more development in both buildout scenarios. However, as Tables 4, 5, 6, 7, 8 and 9 illustrate, the amount of risky development is significantly reduced in the Best Management Practices (BMPs) scenario.

Table 4. Development Scenario Impacts, City of Alpena

	Total	Lucky	Expected	Perfect Storm
Current Development	5,244	179	208	283
Buildout According to Current Zoning Ordinance (Additional Structures Impacted)	6,452	340	391	483
Build-out According to Best Management Practices (Additional Structures Impacted)	6,094	290	337	422

Table 5. Development Scenario Impacts, Alpena Township

	Total	Lucky	Expected	Perfect Storm
Current Development	6,739	381	690	835
Buildout According to Current Zoning Ordinance (Additional Structures Impacted)	15,982	544	1016	1302
Build-out According to Best Management Practices (Additional Structures Impacted)	13,833	520	967	1243

Tables 6 and 7 show how much tax revenue the city and township could add if they were to build out under the two different scenarios. The City of Alpena could add relatively the same amount of tax revenue in both scenarios. However, the city reduces its potential lost revenue by about \$100,000 for each of the climate futures. The township’s potentially impacted tax revenue does not differ greatly between a full buildout and a buildout based on BMPs. However, shown in Tables 8 and 9, the potential damages between each of the buildout scenarios is more drastic, especially for the city.

Table 6. Tax Revenue of Affected Properties, City of Alpena

	Total	Lucky	Expected	Perfect Storm
Tax Revenue	\$8 million	\$382,778	\$504,882	\$613,542
Buildout According to Current Zoning Ordinance (Potential Additional Tax Revenue Impacted, average)	\$10.9 million	\$639,819	\$816,167	\$944,977
Build-out According to Best Management Practices (Potential Additional Tax Revenue Impacted, average)	\$10.2 million	\$542,552	\$718,901	\$847,710

Table 7. Tax Revenue of Affected Properties, Alpena Township

	Total	Lucky	Expected	Perfect Storm
Tax Revenue	\$8.5 million	\$507,199	\$1 million	\$1.3 million
Buildout According to Current Zoning Ordinance (Potential Additional Tax Revenue Impacted, average)	\$17.7 million	\$777,477	\$1.6 million	\$2 million
Build-out According to Best Management Practices (Potential Additional Tax Revenue Impacted, average)	\$8.8 million	\$718,578	\$1.5 million	\$1.9 million

Table 8. Potential Property Damages for Different Flooding Scenarios, City of Alpena

	Lucky	Expected	Perfect Storm
Damages	\$71,250	\$481,489	\$1.8 million
Buildout According to Current Zoning Ordinance (Additional Damages, average)	\$804,131	\$2.1 million	\$4.6 million
Build-out According to Best Management Practices (Additional Damages, average)	\$453,756	\$1.5 million	\$3.6 million

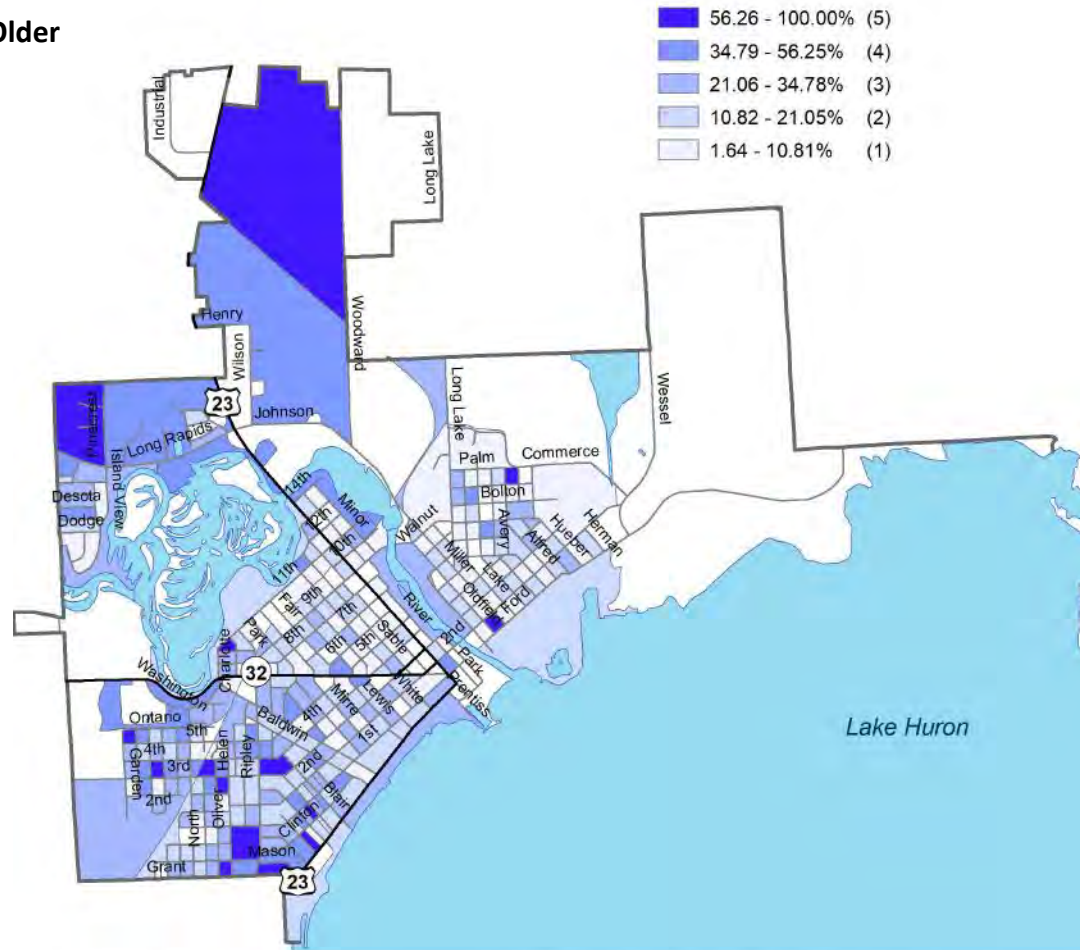
Table 9. Potential Property Damages for Different Flooding Scenarios, Alpena Township

	Lucky	Expected	Perfect Storm
Damages	\$23.1 million	\$23.3 million	\$40.3 million
Buildout According to Current Zoning Ordinance (Additional Damages, average)	\$28.3 million	\$37.7 million	\$69 million
Build-out According to Best Management Practices (Additional Damages, average)	\$28 million	\$35.5 million	\$65.3 million

City of Alpena

Map 1.1

Percent of Population 65 Years and Older
(male and female)



Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.

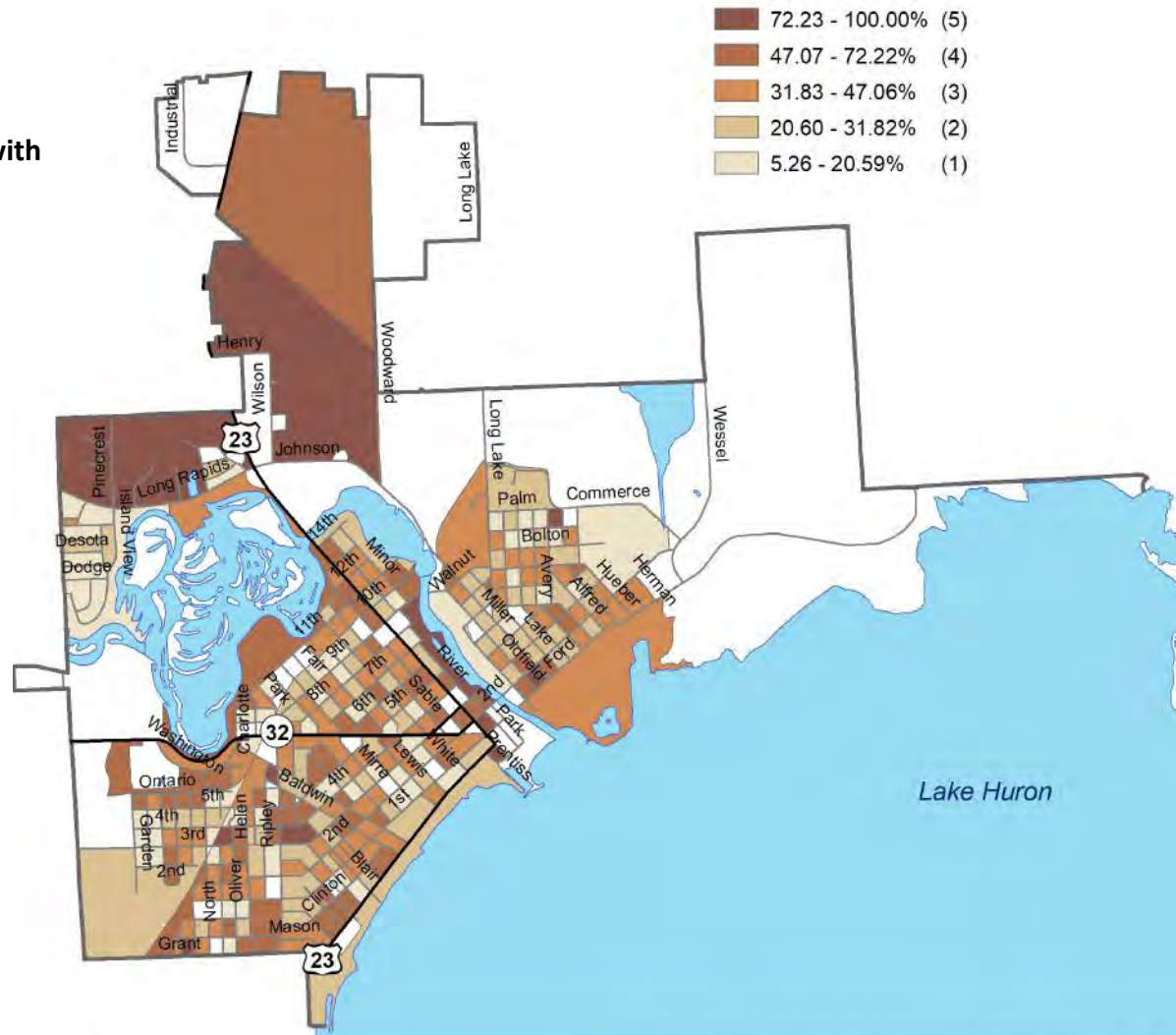
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City of Alpena

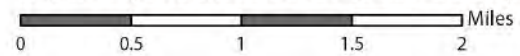
Map 1.2

Percent of Households with People Living Alone



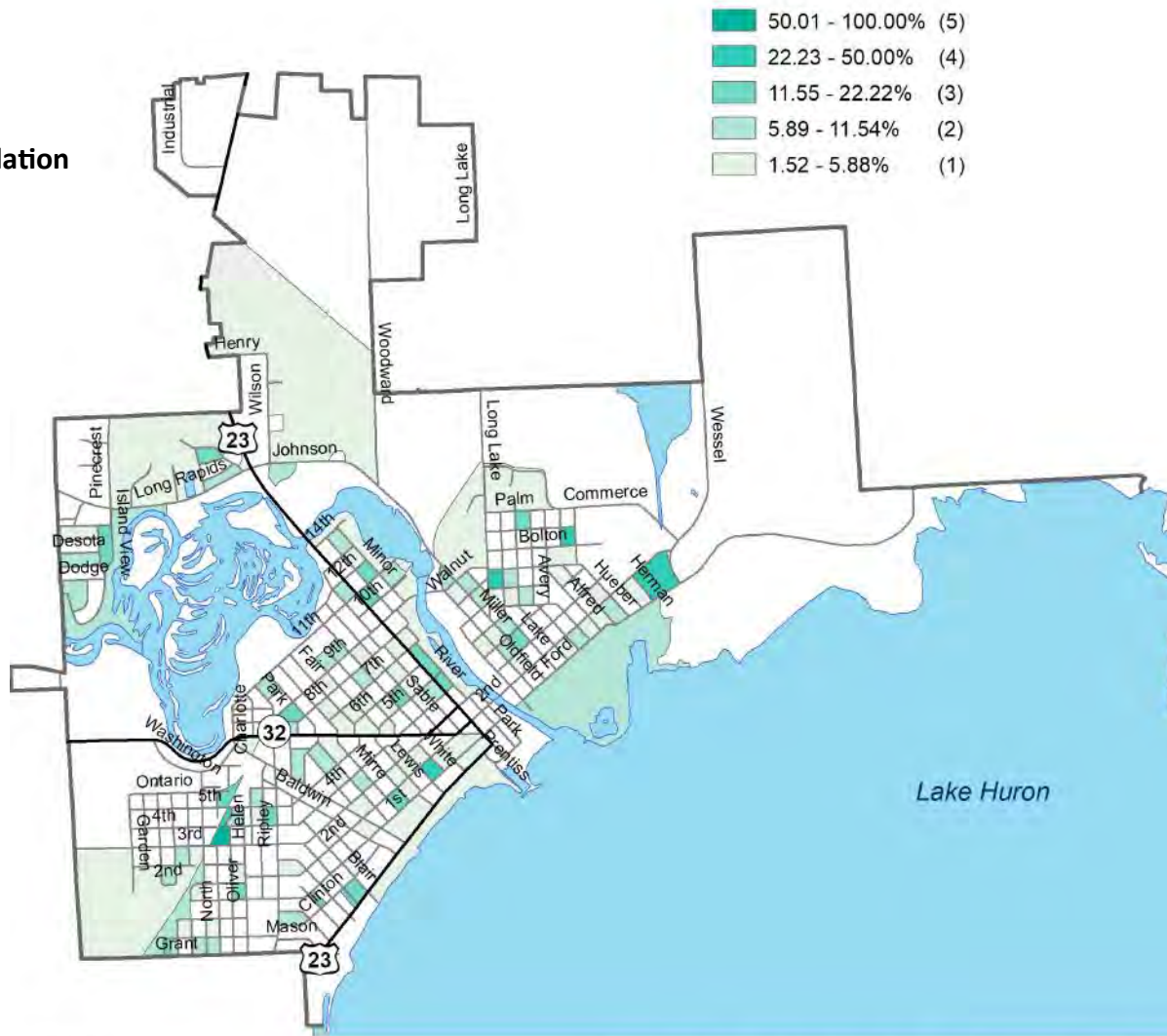
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



City of Alpena

Map 1.3
Percent of Non-white Population



Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

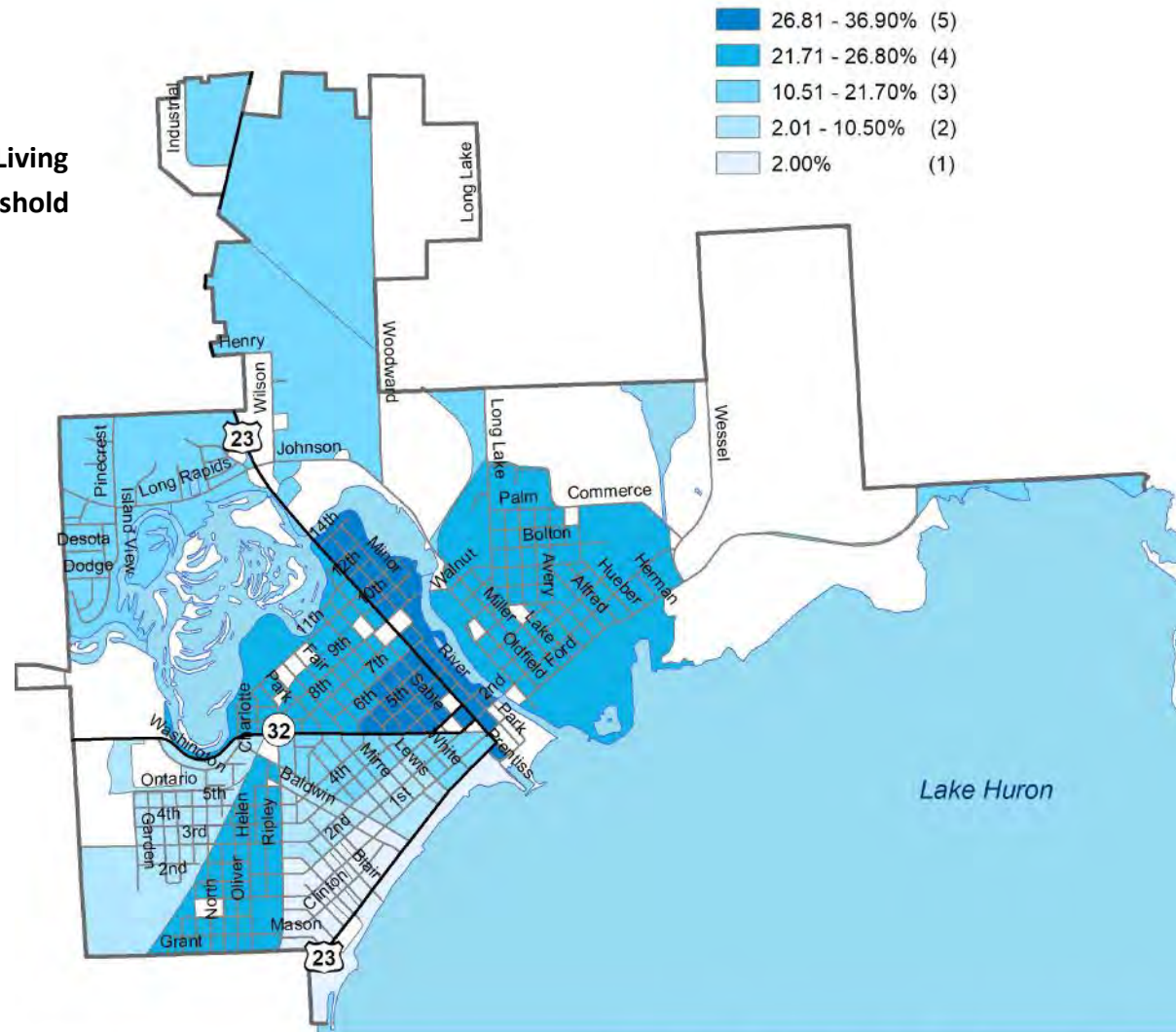
Prepared May 2020 by LIAA for the Alpena Community.

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City of Alpena

Map 1.4
Percent of Households Living Below the Poverty Threshold



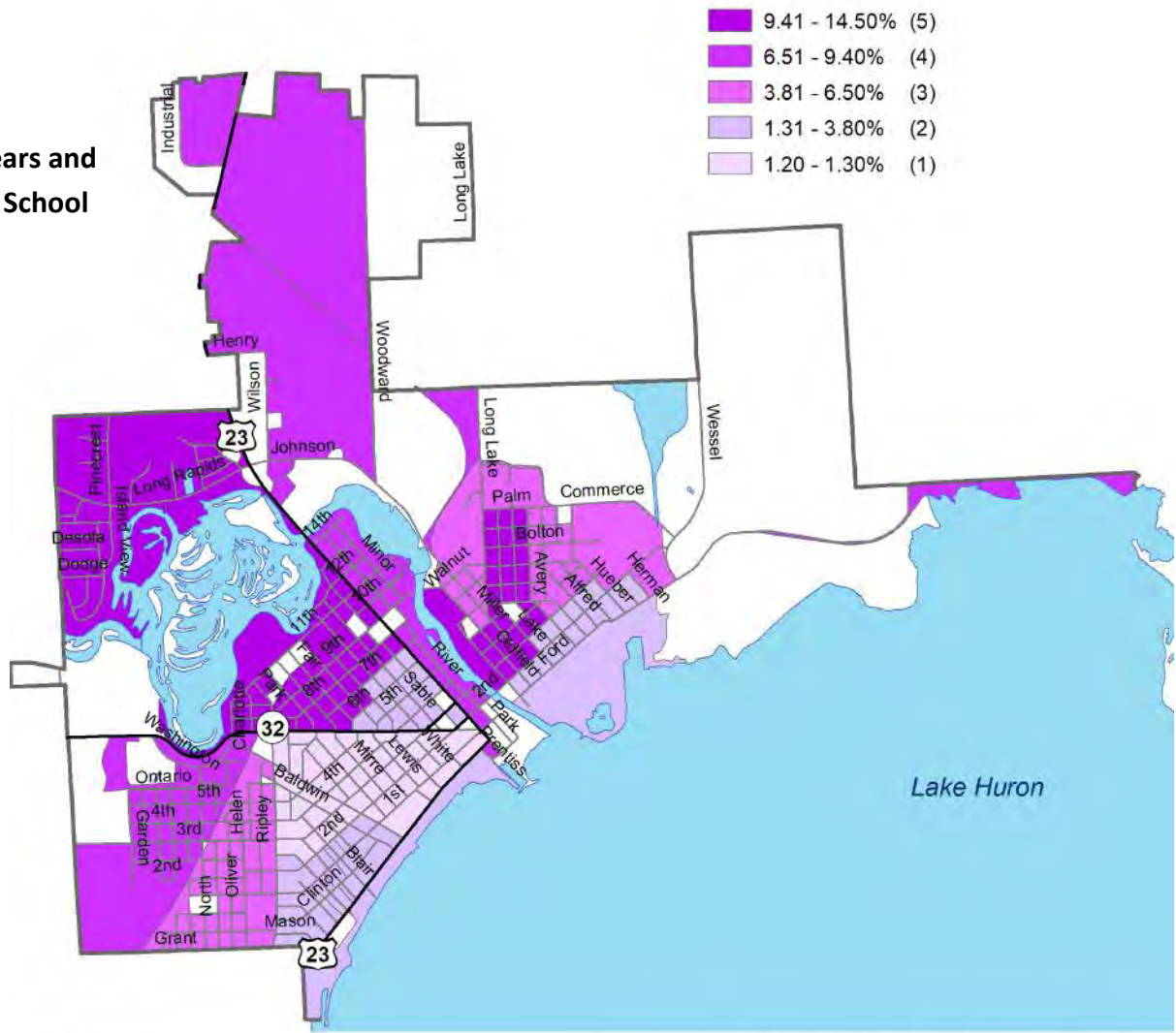
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

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City of Alpena

Map 1.5
Percent of Population 25 Years and Older with Less than a High School Education



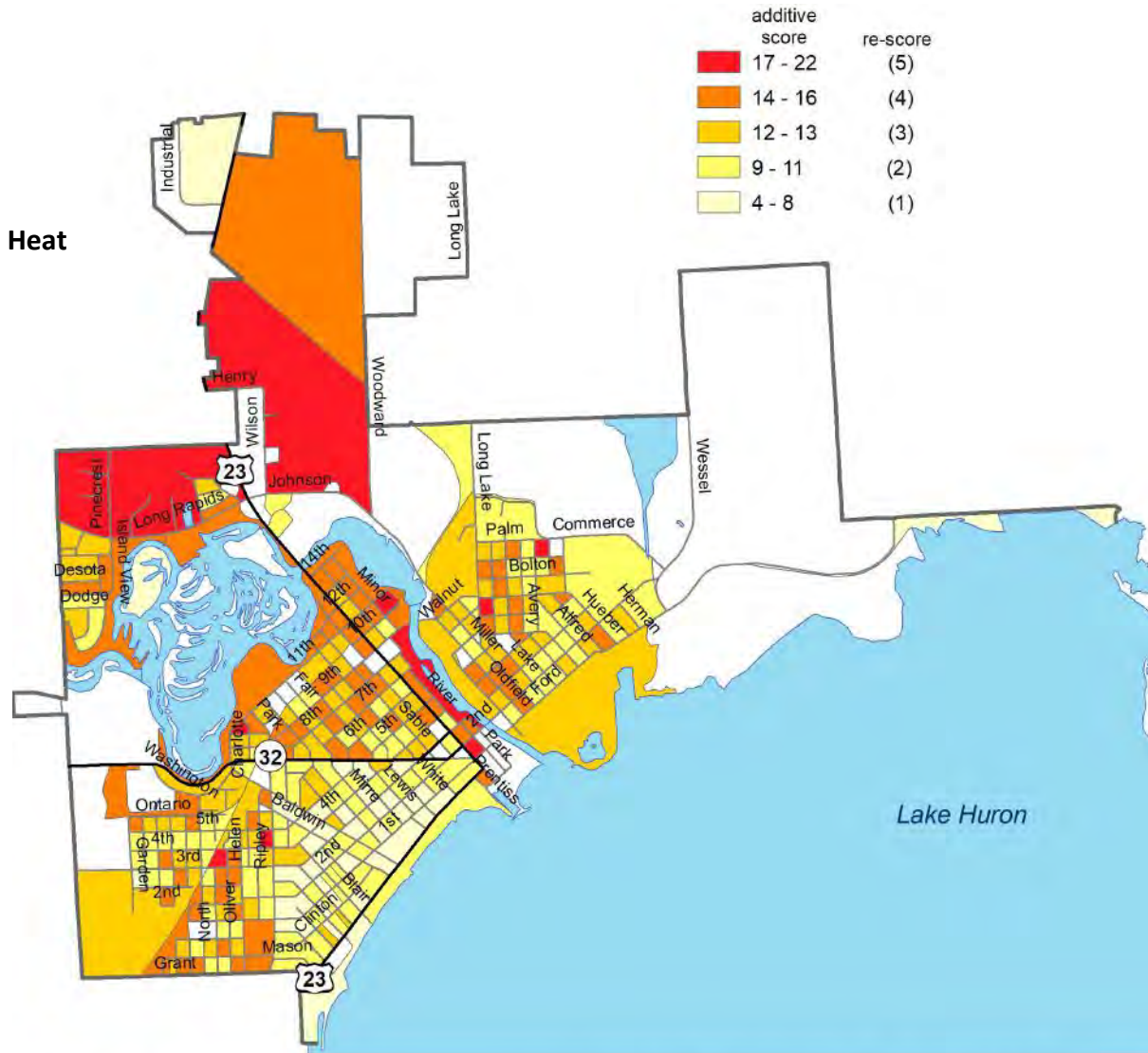
Data Sources:
 NEMCOG,
 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.
 0 0.5 1 1.5 2 Miles



City of Alpena

Map 1.6
Relative Sensitivity of
Populations to Extreme Heat
Events



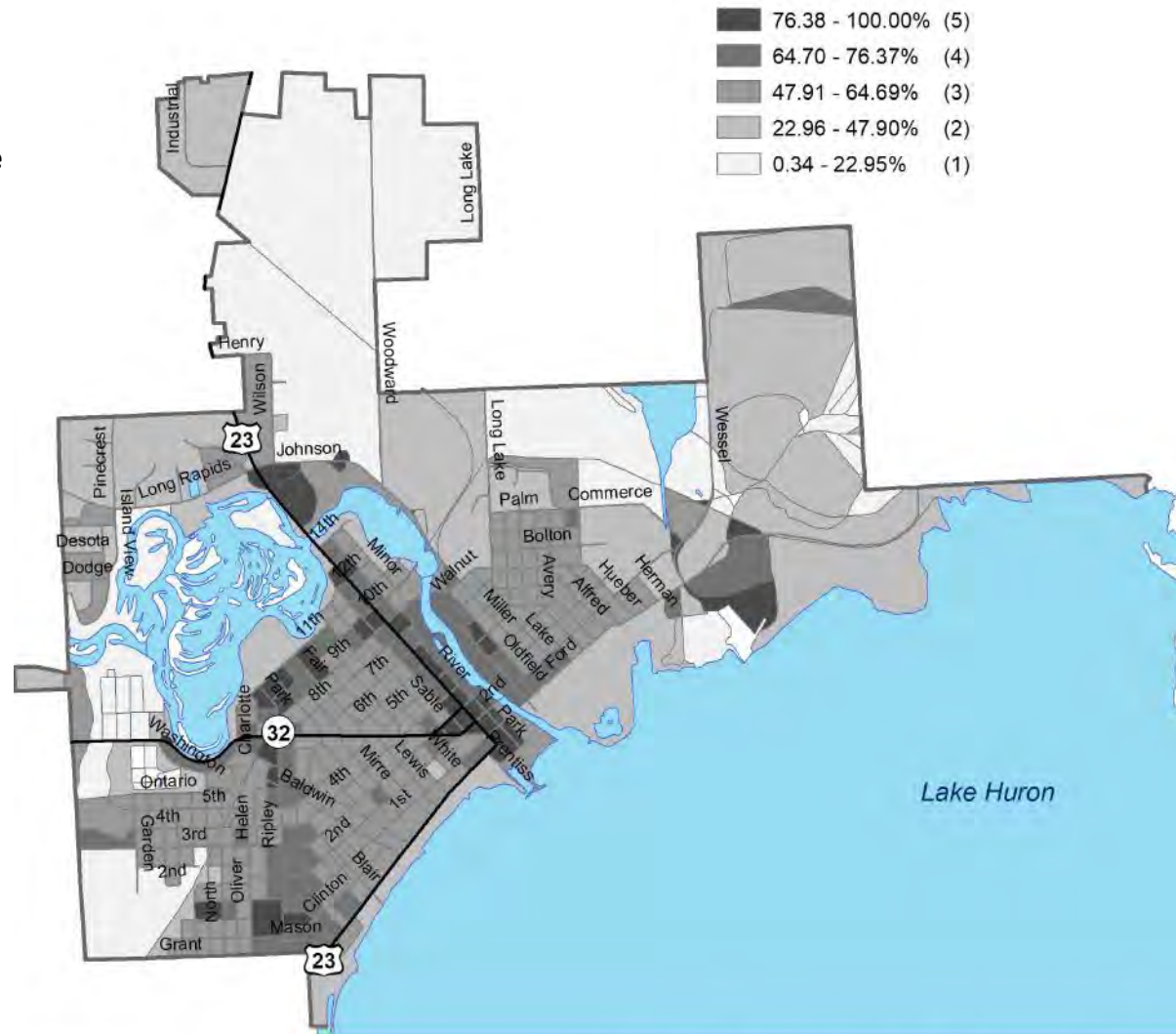
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 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



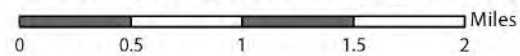
City of Alpena

Map 1.7
Percent Impervious Surface



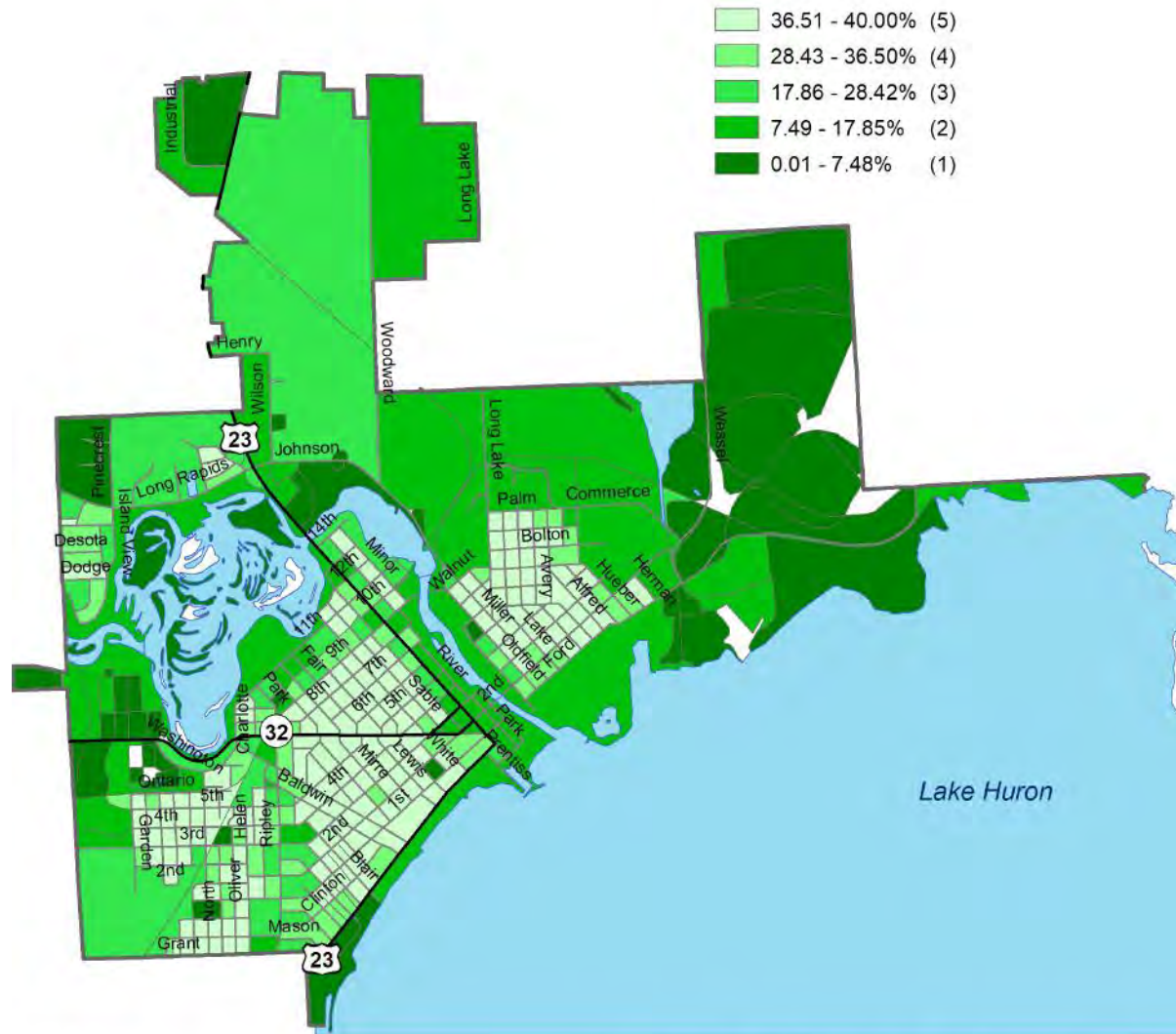
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U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



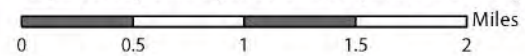
City of Alpena

Map 1.8
Percent Tree Canopy



Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

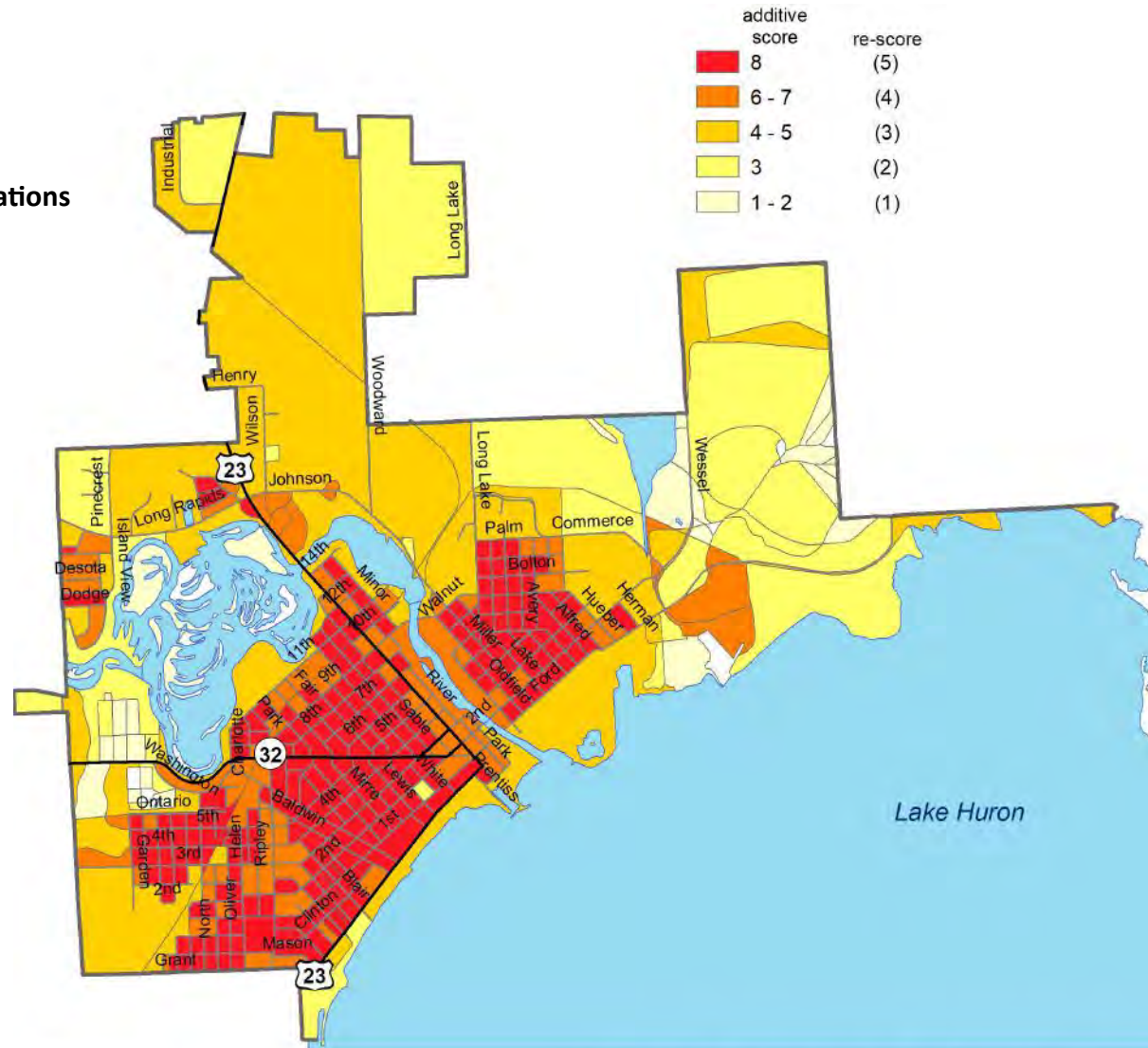
Prepared May 2020 by LIAA for the Alpena Community.



City of Alpena

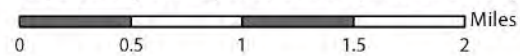
Map 1.9

Relative Exposure of Populations to Extreme Heat Events



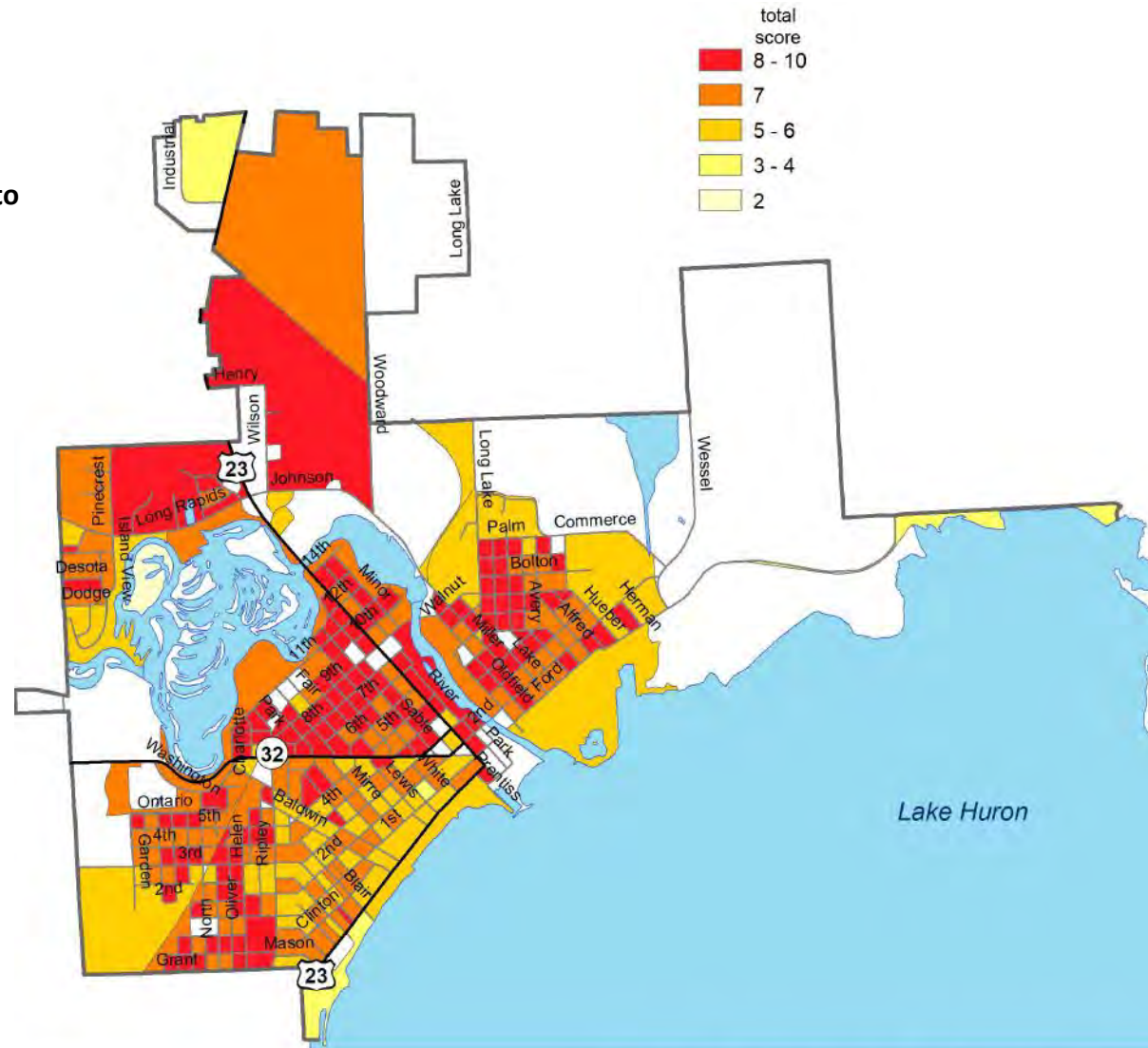
Data Sources:
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 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



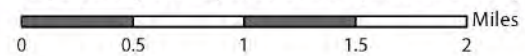
City of Alpena

Map 1.10
Population Vulnerable to
Extreme Heat Events



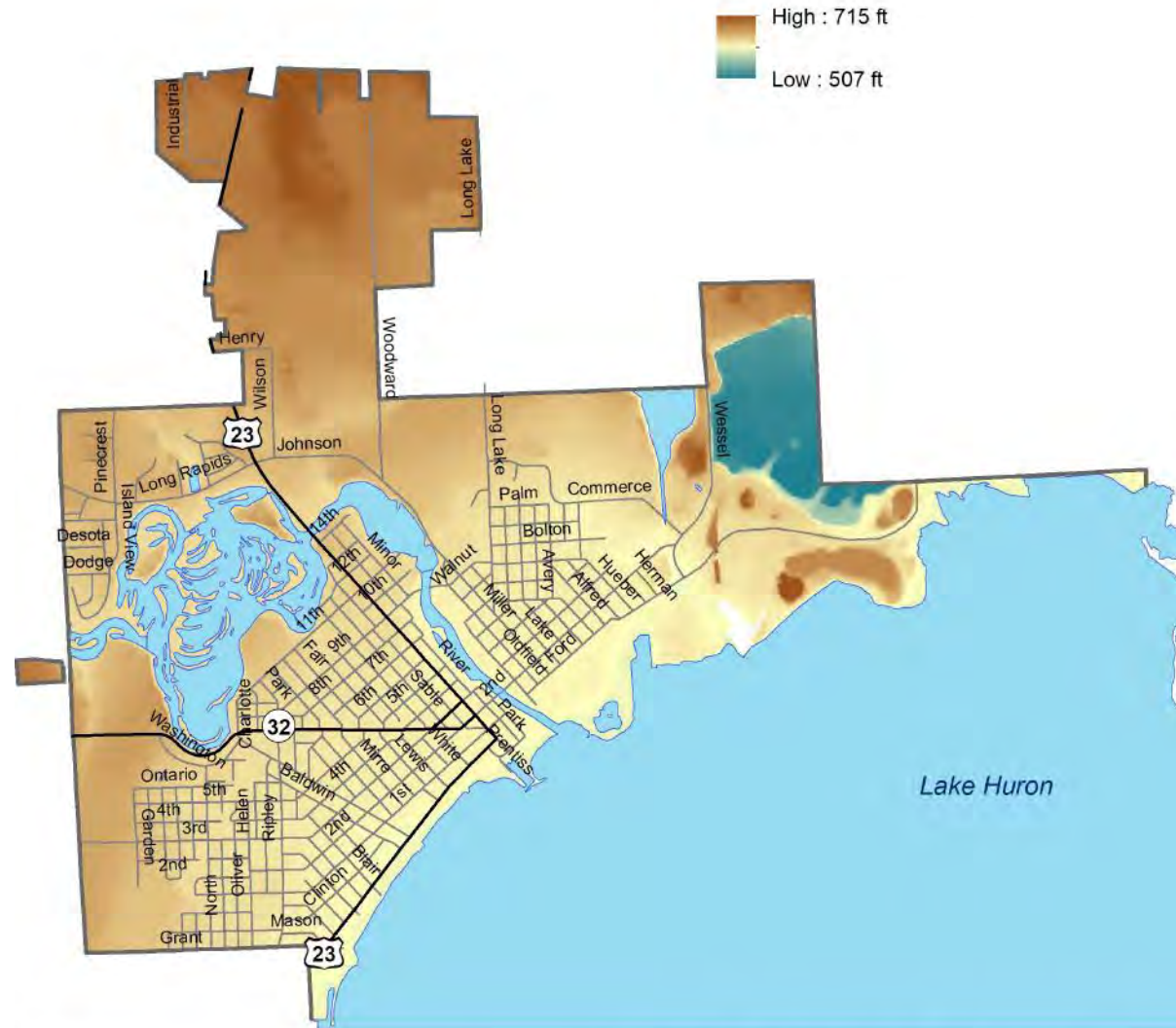
Data Sources:
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U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



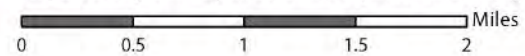
City of Alpena

Map 1.11
Digital Elevation Model



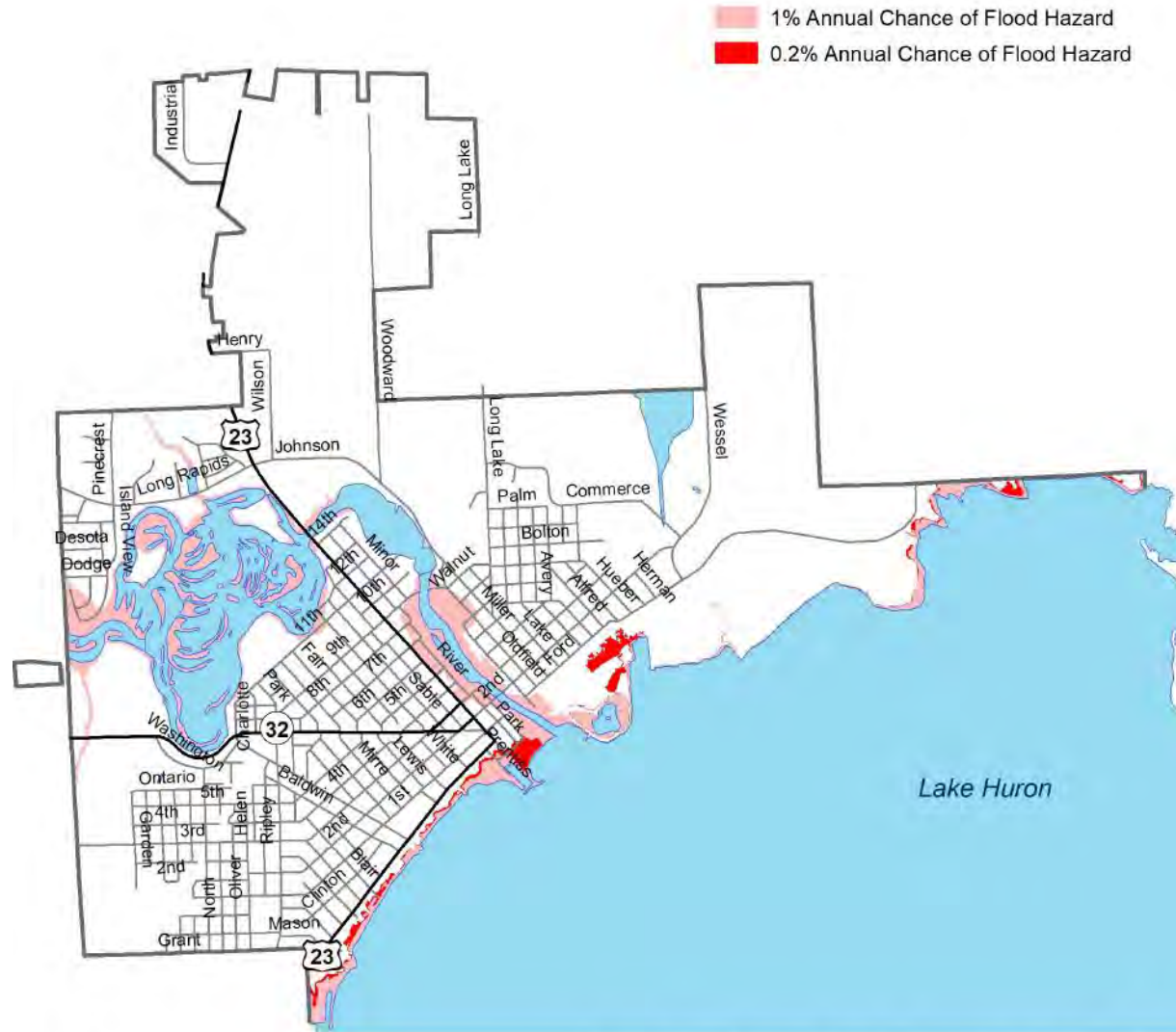
Data Sources:
NEMCOG, USDA Geospatial Data Gateway,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



City of Alpena

Map 1.12
FEMA Flood Zones



Data Sources:
NEMCOG, FEMA,
Michigan Geographic Data Library.

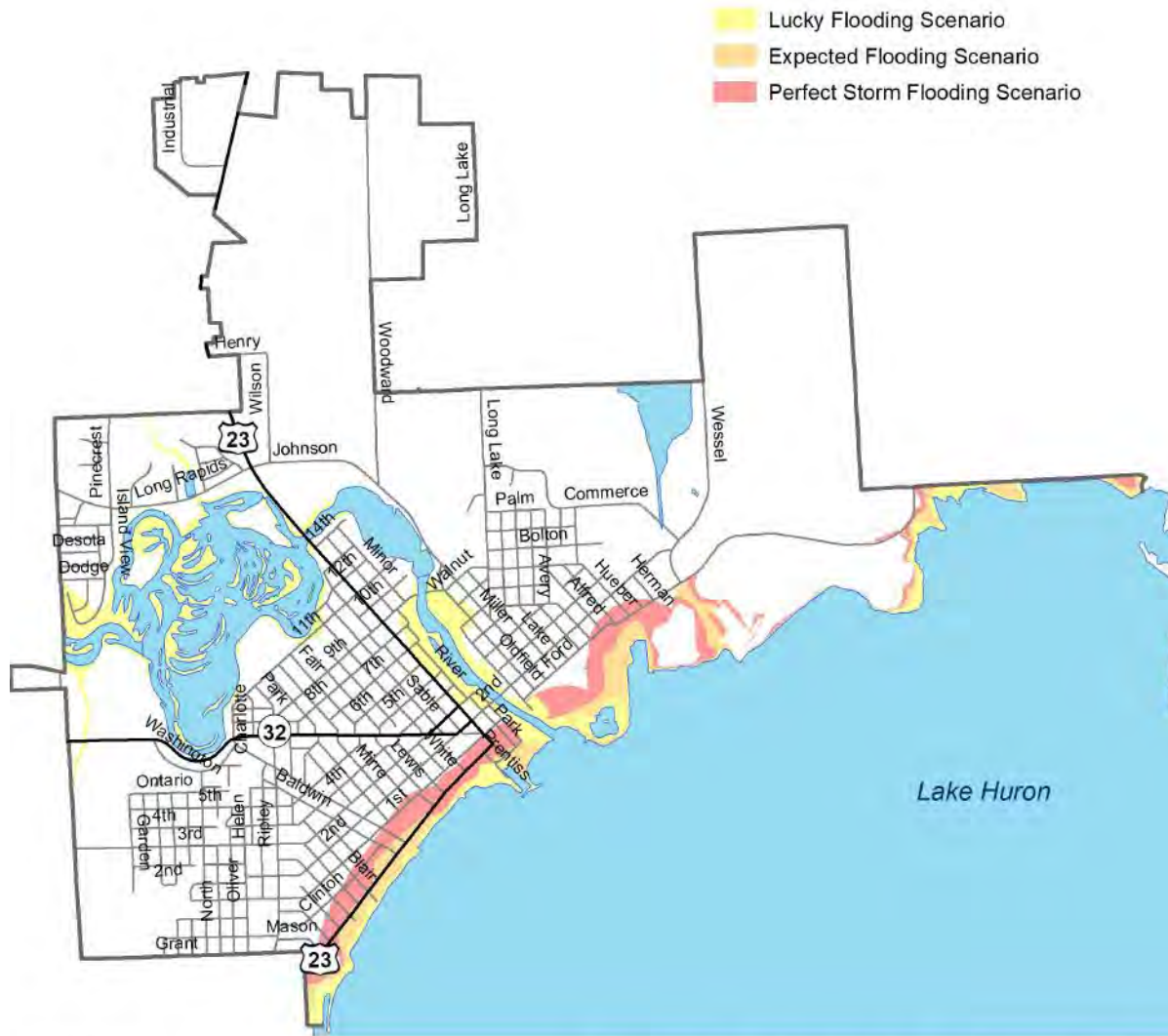
Prepared May 2020 by LIAA for the Alpena Community.

0 0.5 1 1.5 2 Miles



City of Alpena

Map 1.13
Future Climate Scenarios



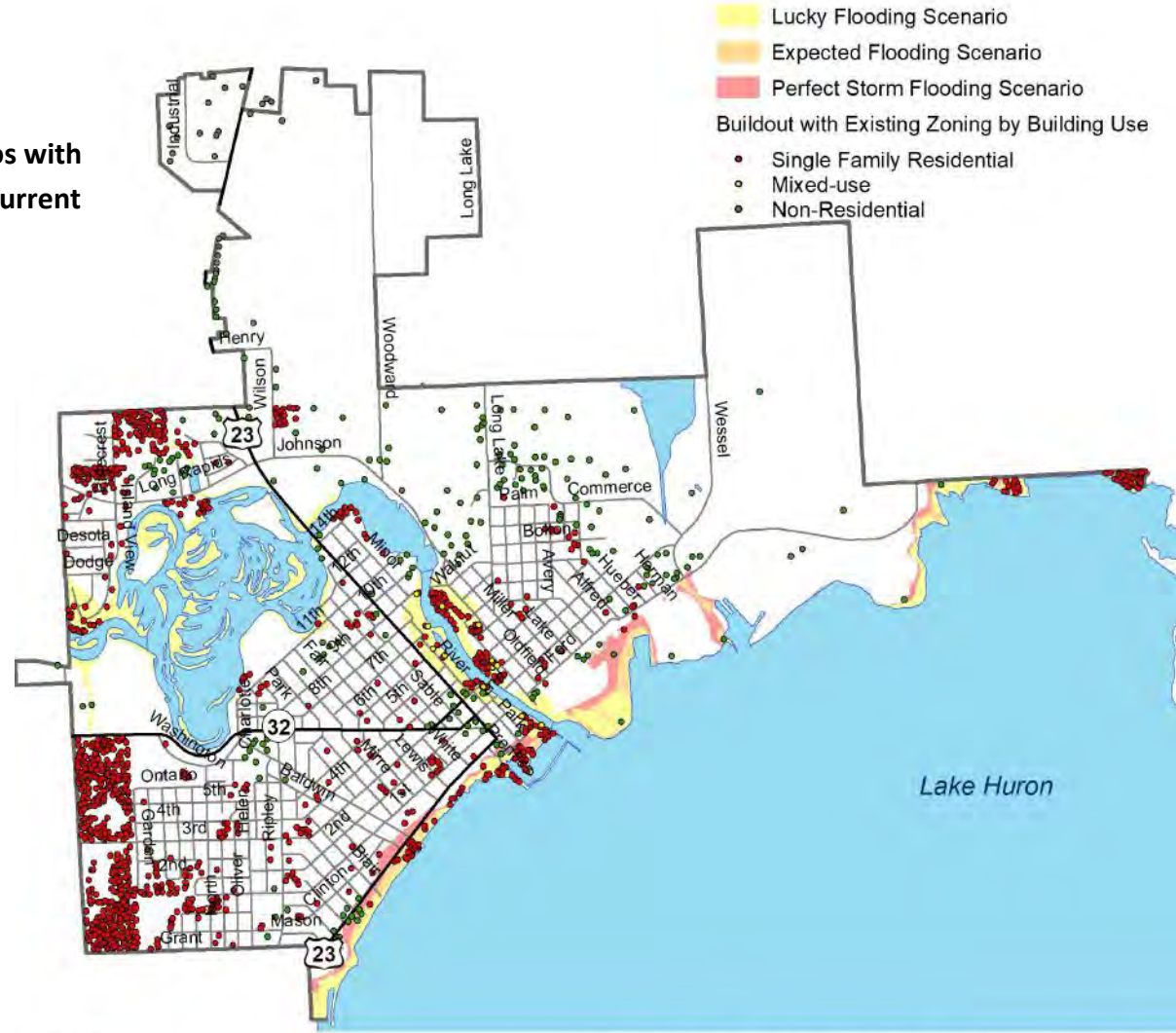
Data Sources:
NEMCOG, U.M.,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.
0 0.5 1 1.5 2 Miles



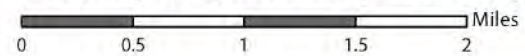
City of Alpena

Map 1.14
Future Climate Scenarios with
Buildout According to Current
Zoning



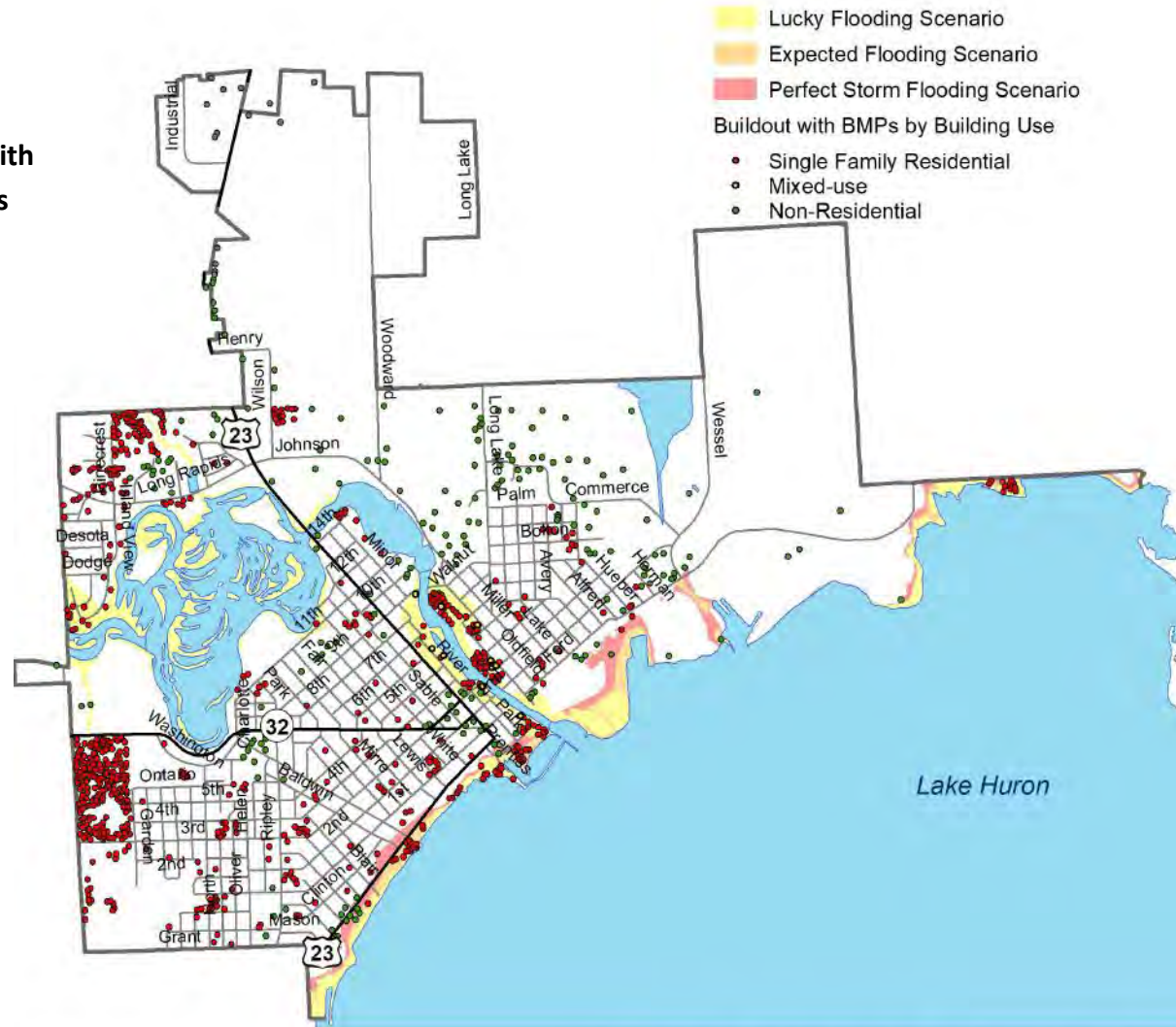
Data Sources:
NEMCOG, U.M.,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community.



City of Alpena

Map 1.15
Future Climate Scenarios with
Buildout According to BMPs



Data Sources:
 NEMCOG, U.M.,
 Michigan Geographic Data Library.

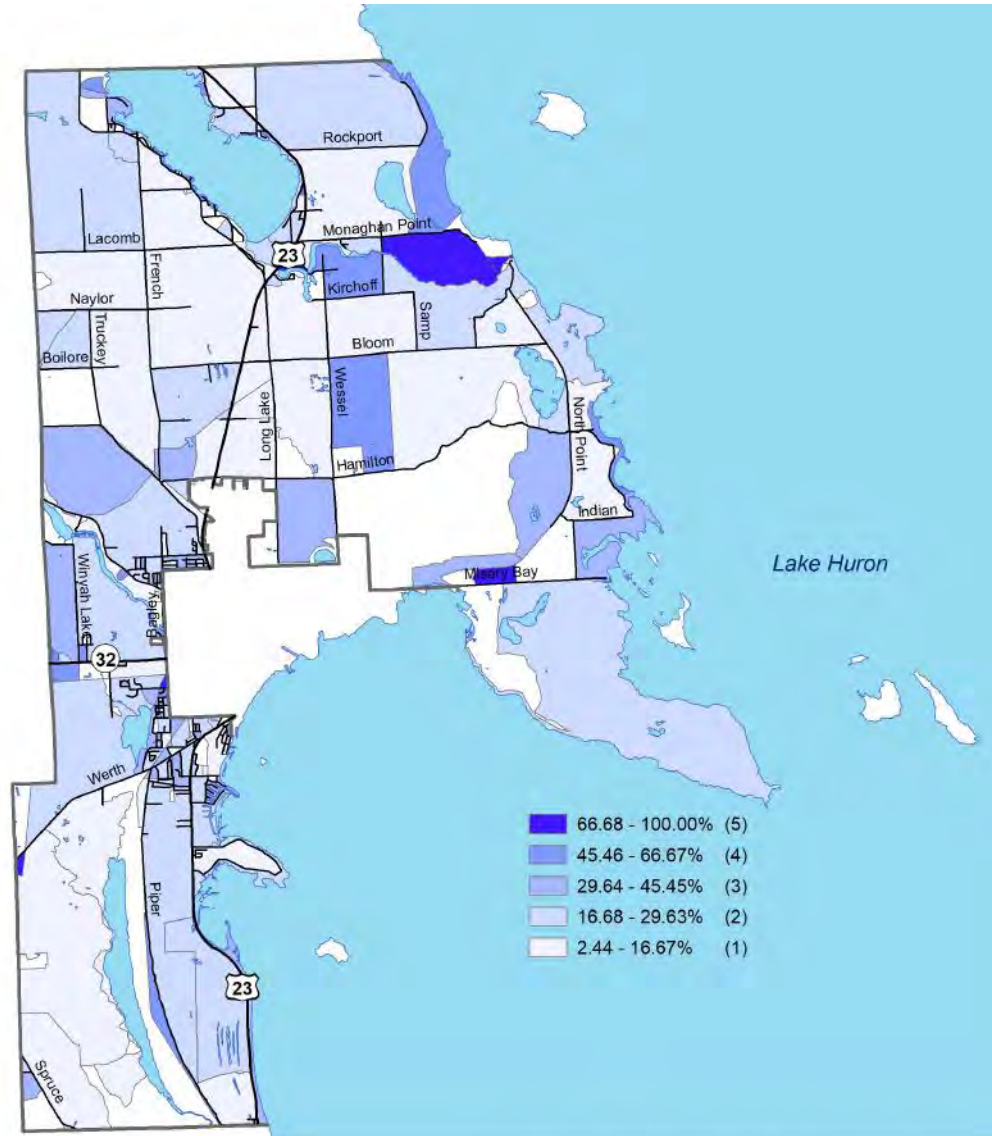
Prepared May 2020 by LIAA for the Alpena Community.



Alpena Township

Map 2.1

Percent of Population 65 Years and Older
(male and female)



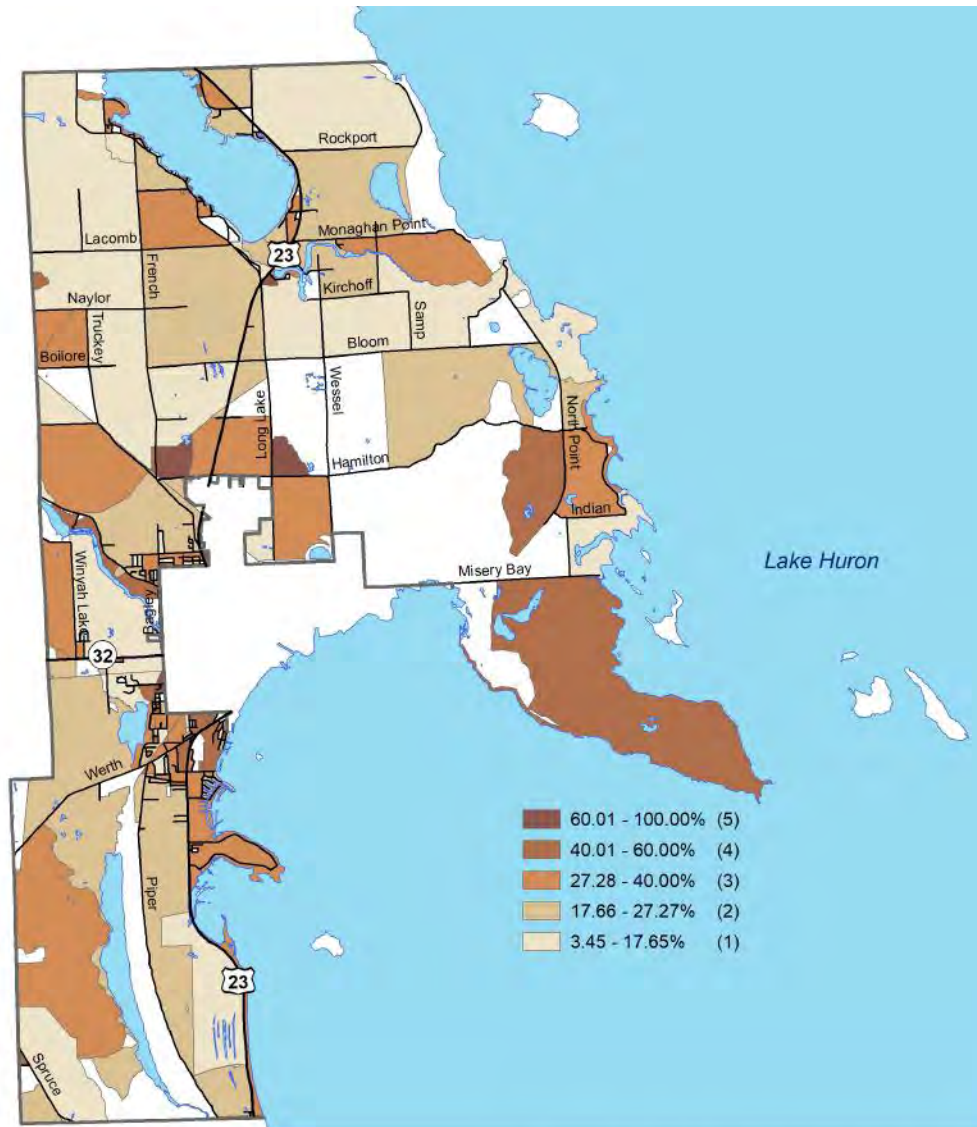
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.2

Percent of Households with People Living Alone



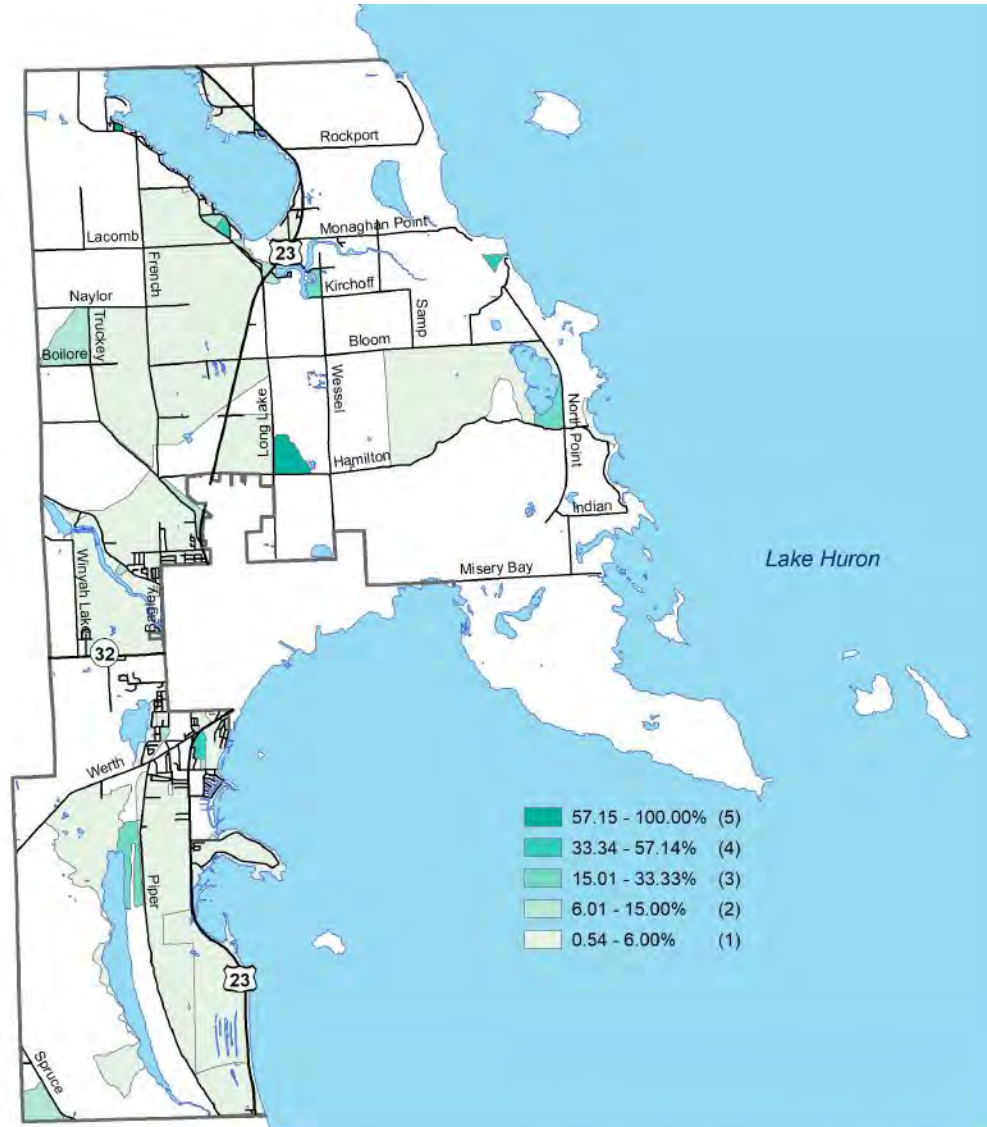
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.3

Percent of Non-white Population



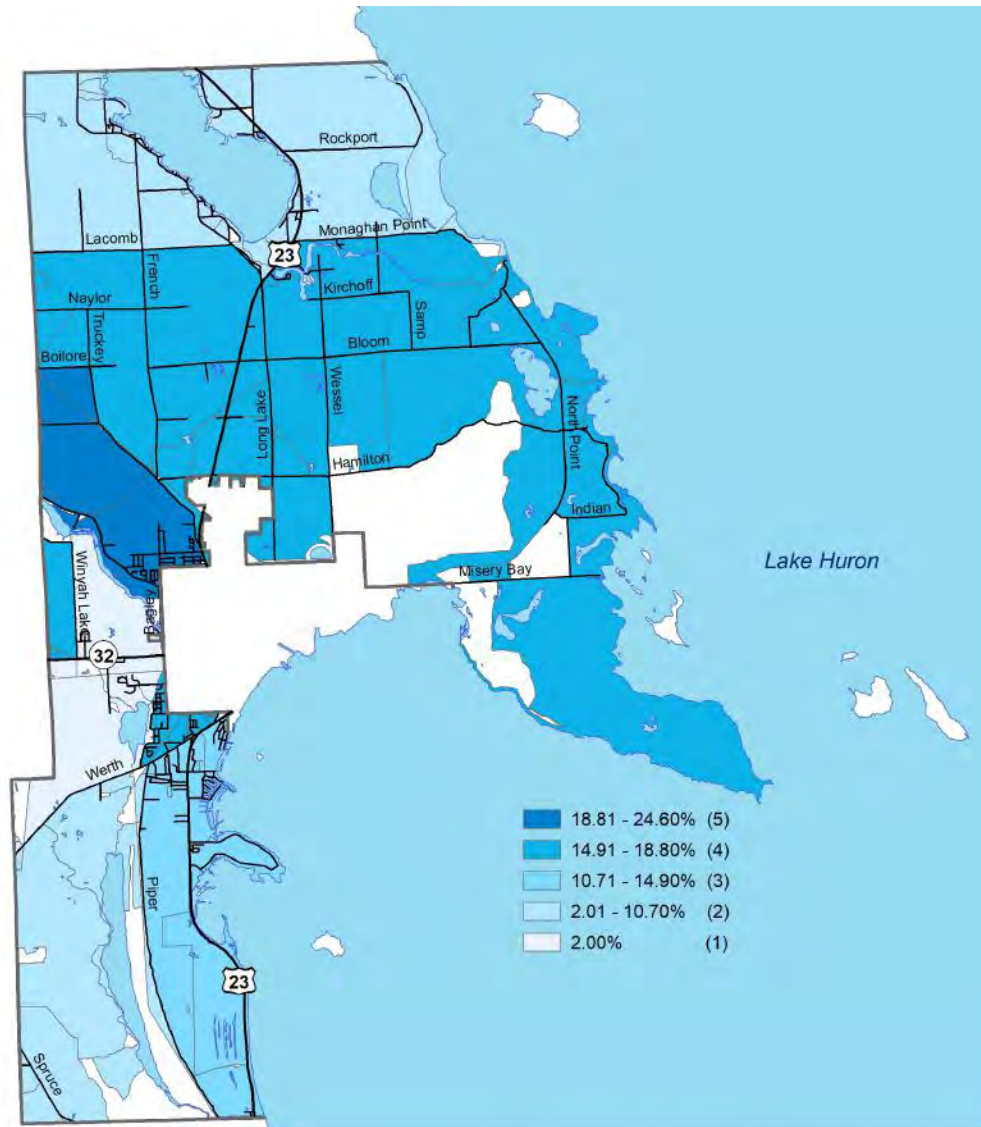
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles

Alpena Township

Map 2.4

Percent of Households Living Below the Poverty Threshold



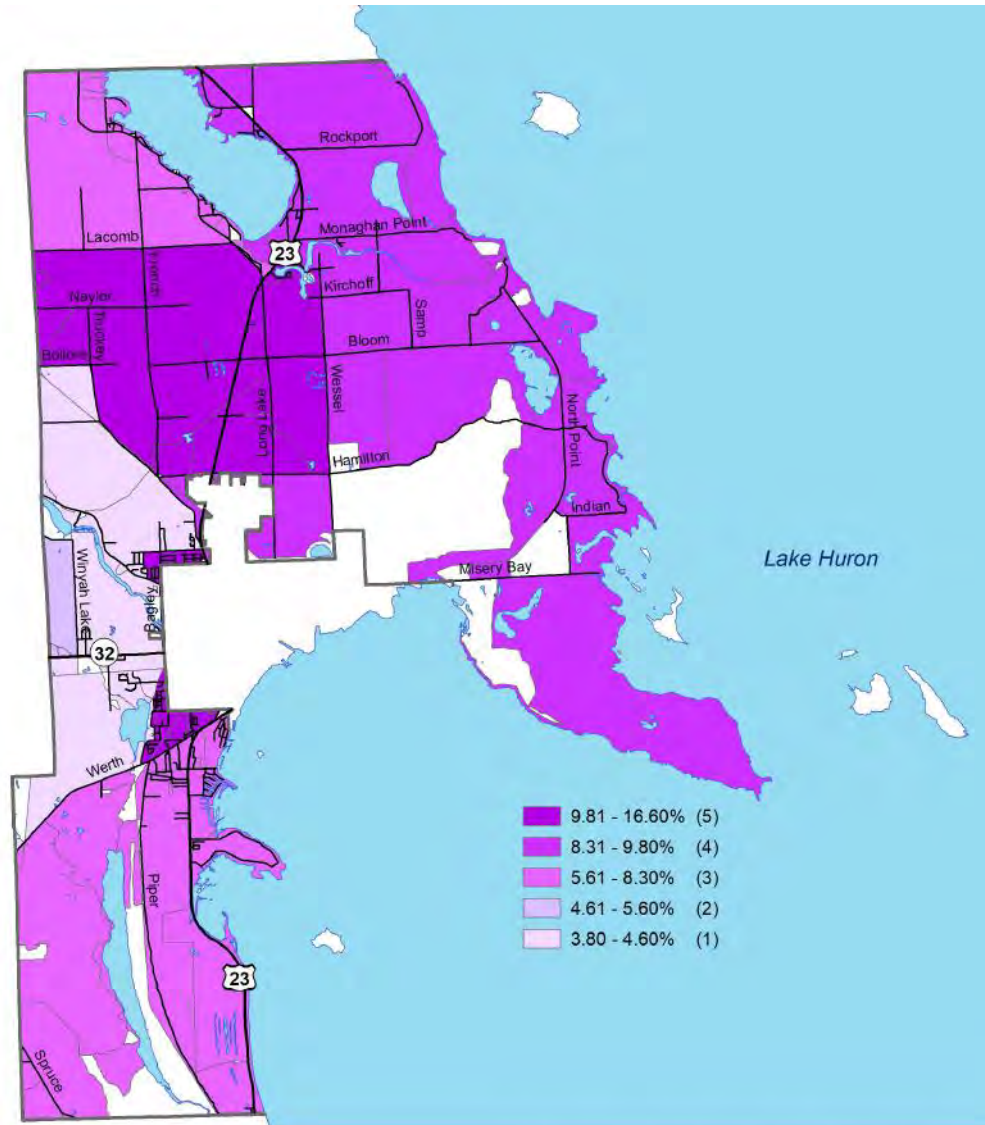
Data Sources:
 NEMCOG,
 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
 0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.5

Percent of Population 25 Years and Older with Less than a High School Education



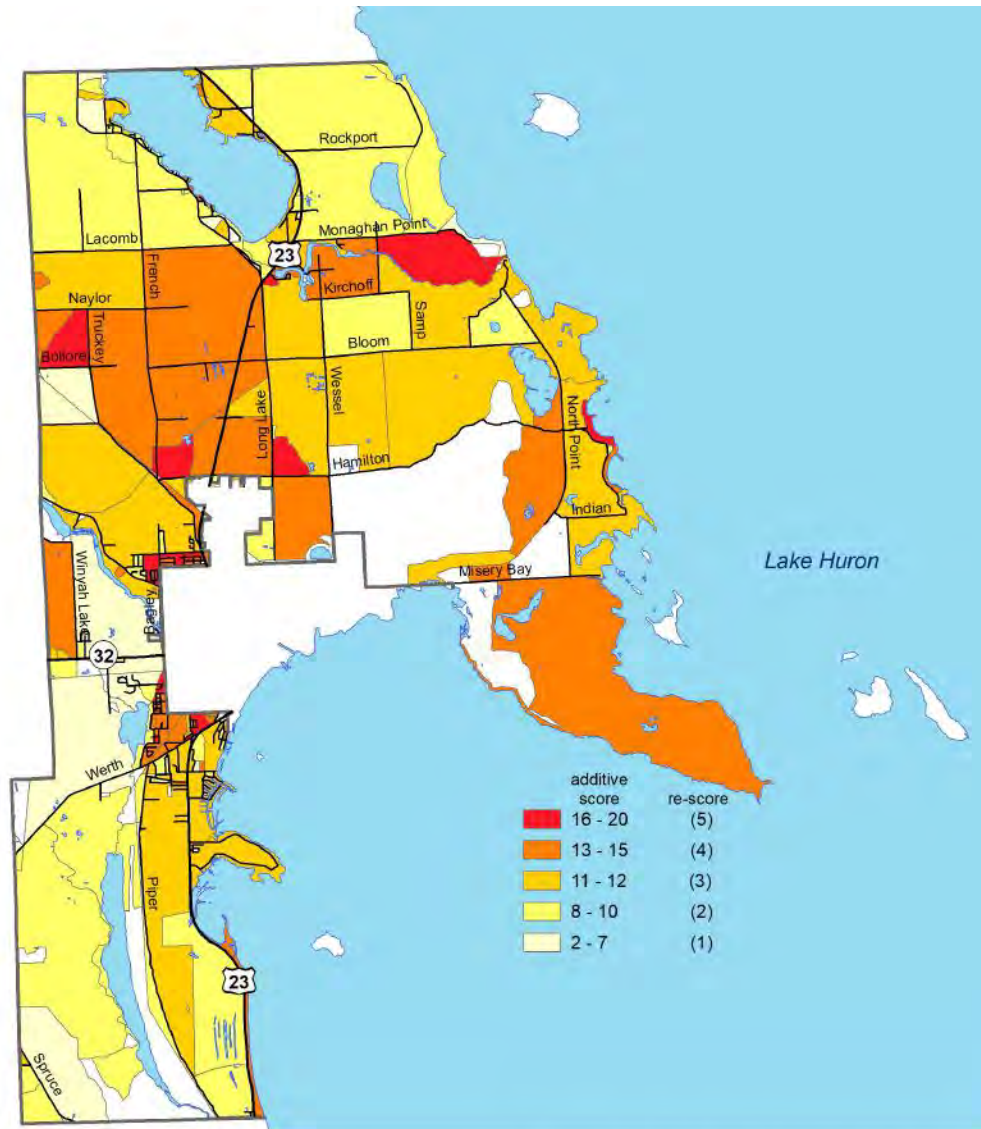
Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.6

Relative Sensitivity of Populations to Extreme Heat Events



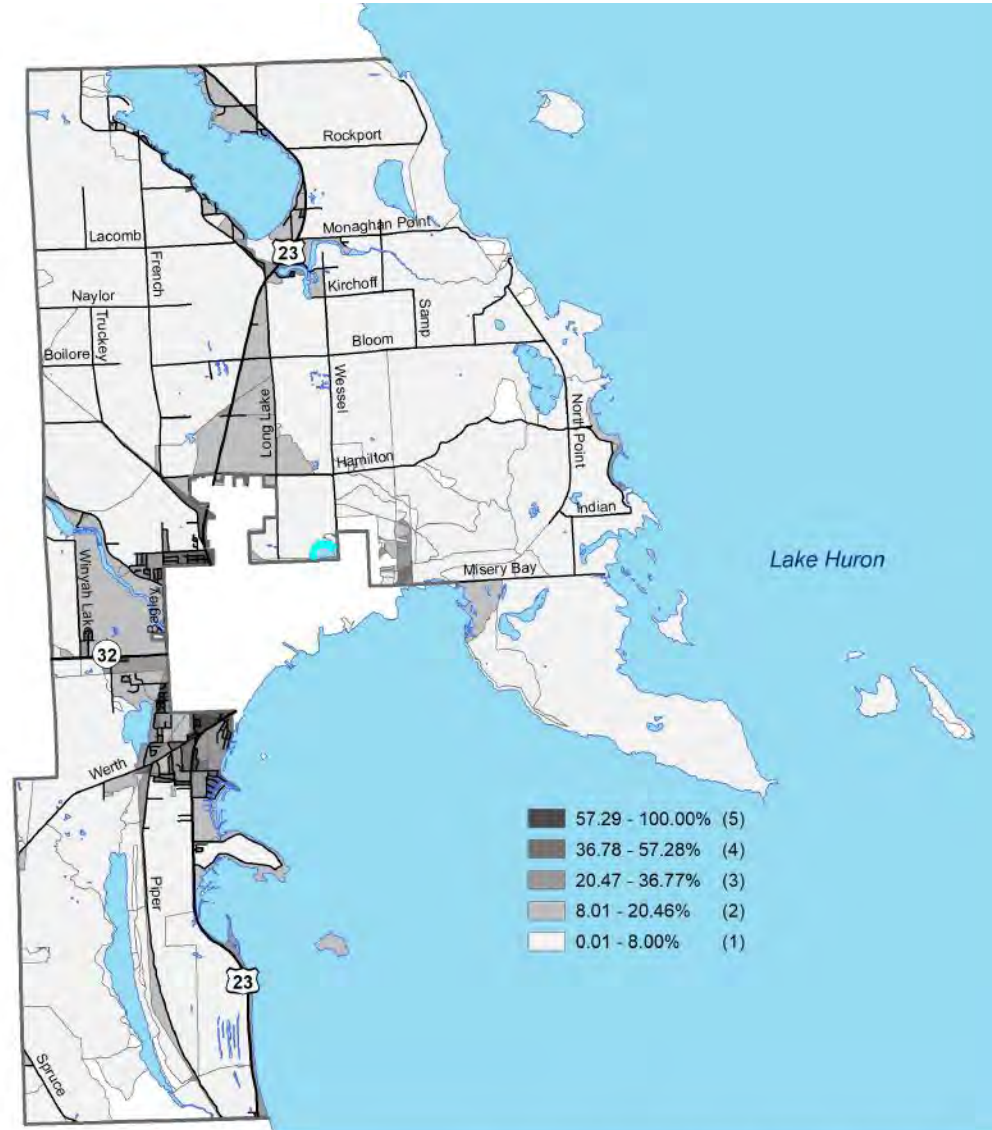
Data Sources:
 NEMCOG,
 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library

Prepared May 2020 by LIAA for the Alpena Community. N
 0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.7

Percent Impervious Surface



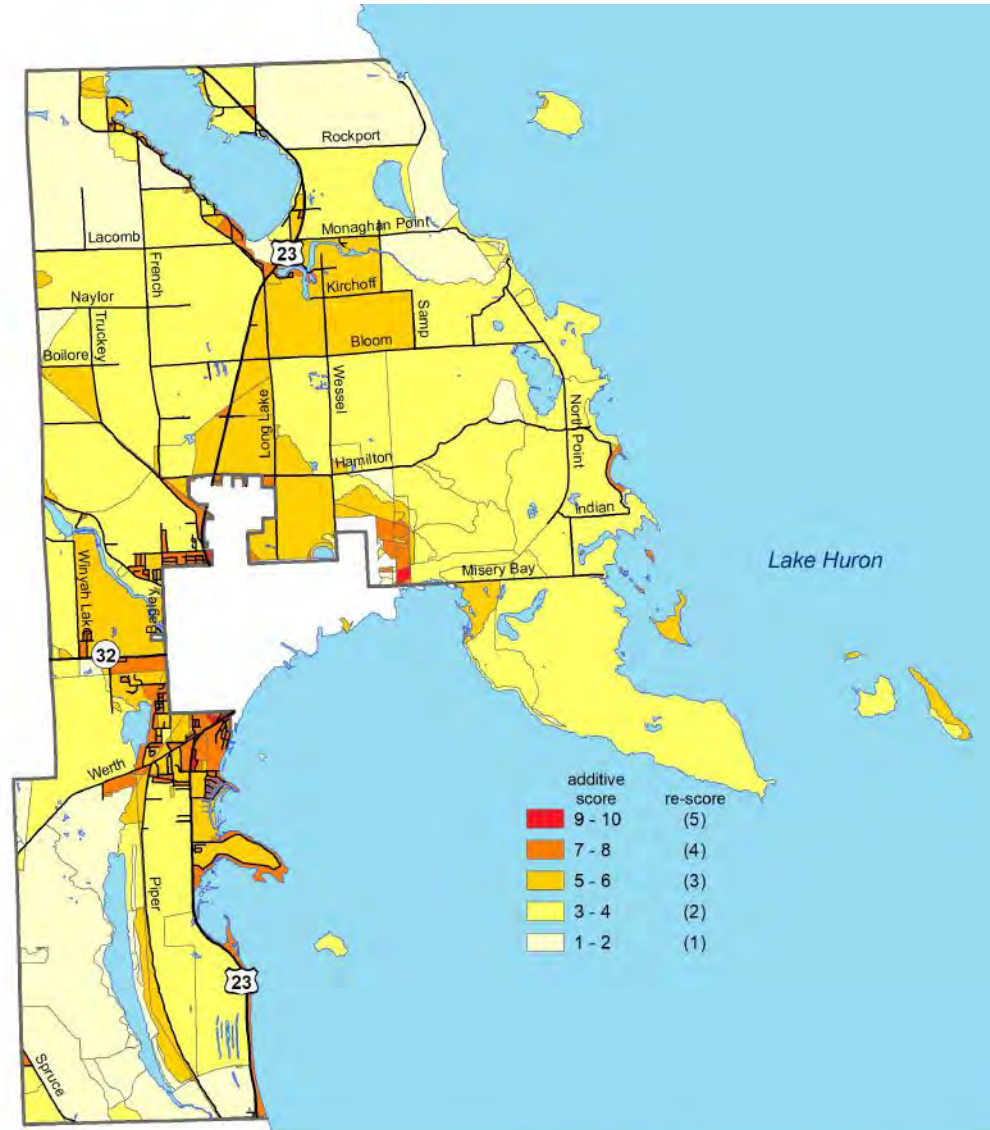
Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.9

Relative Exposure of Populations to Extreme Heat Events

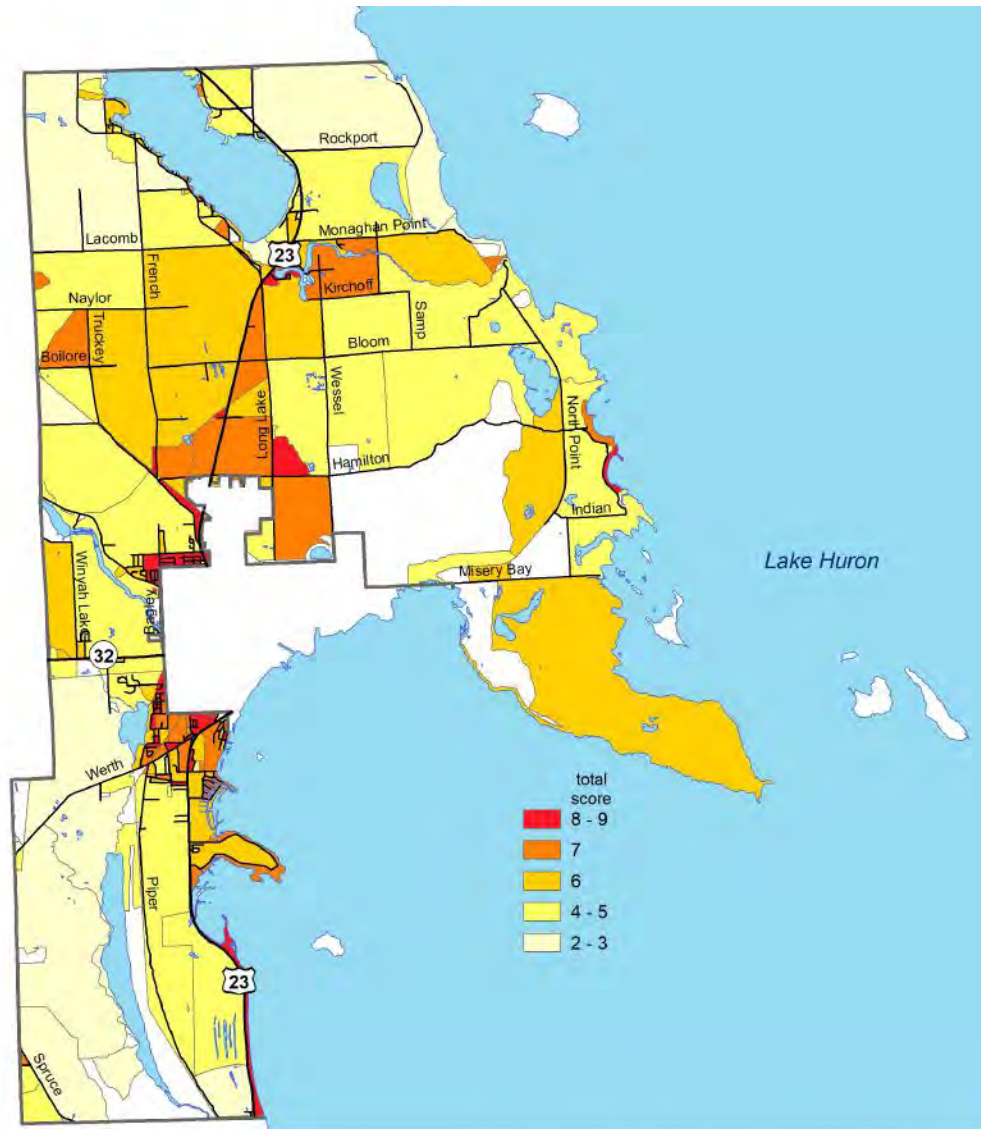


Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles

Alpena Township

Map 2.10
Population Vulnerable to Extreme Heat Events

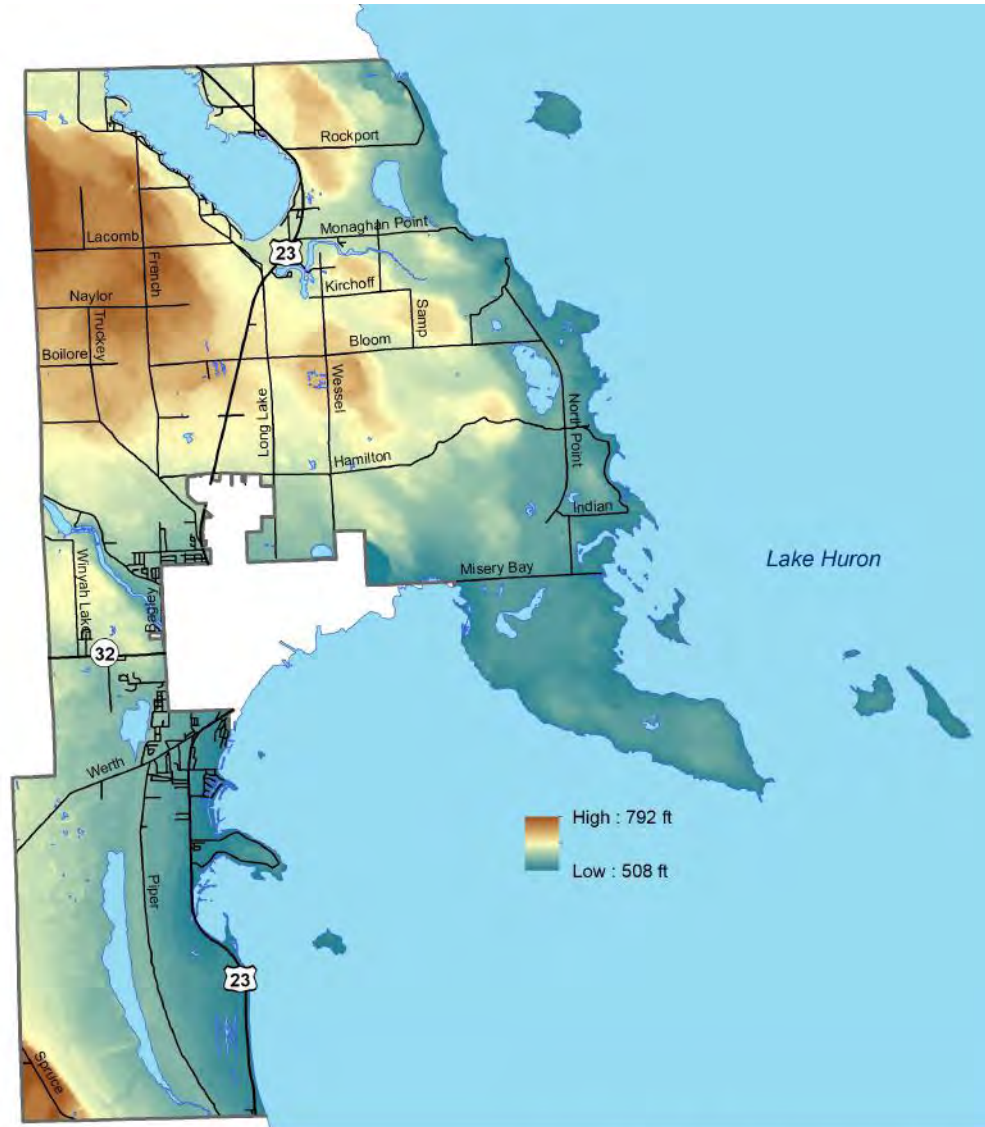


Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.11
Digital Elevation Model

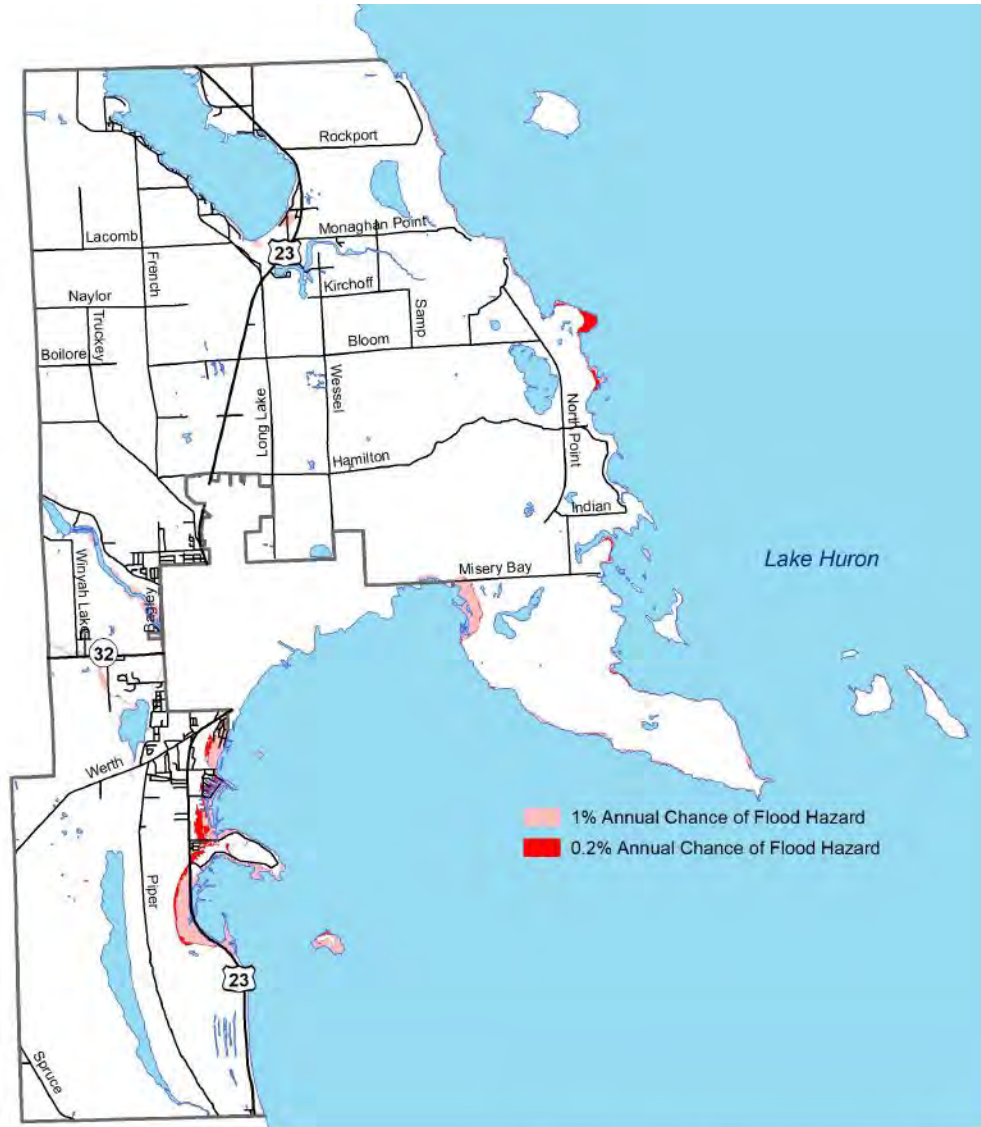


Data Sources:
NEMCOG, USDA Geospatial Data Gateway,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.12
FEMA Flood Zones



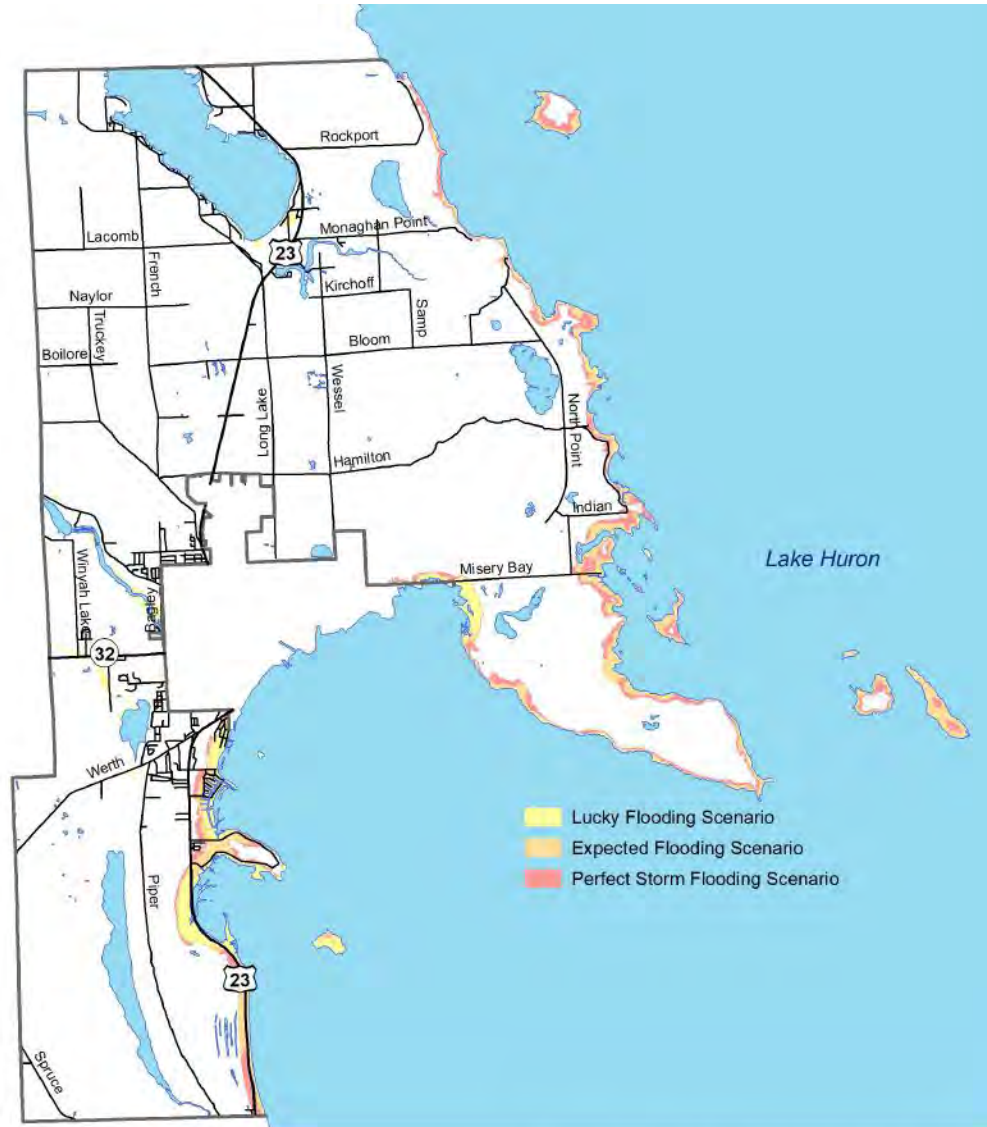
Data Sources:
NEMCOG, FEMA,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.13

Future Climate Scenarios



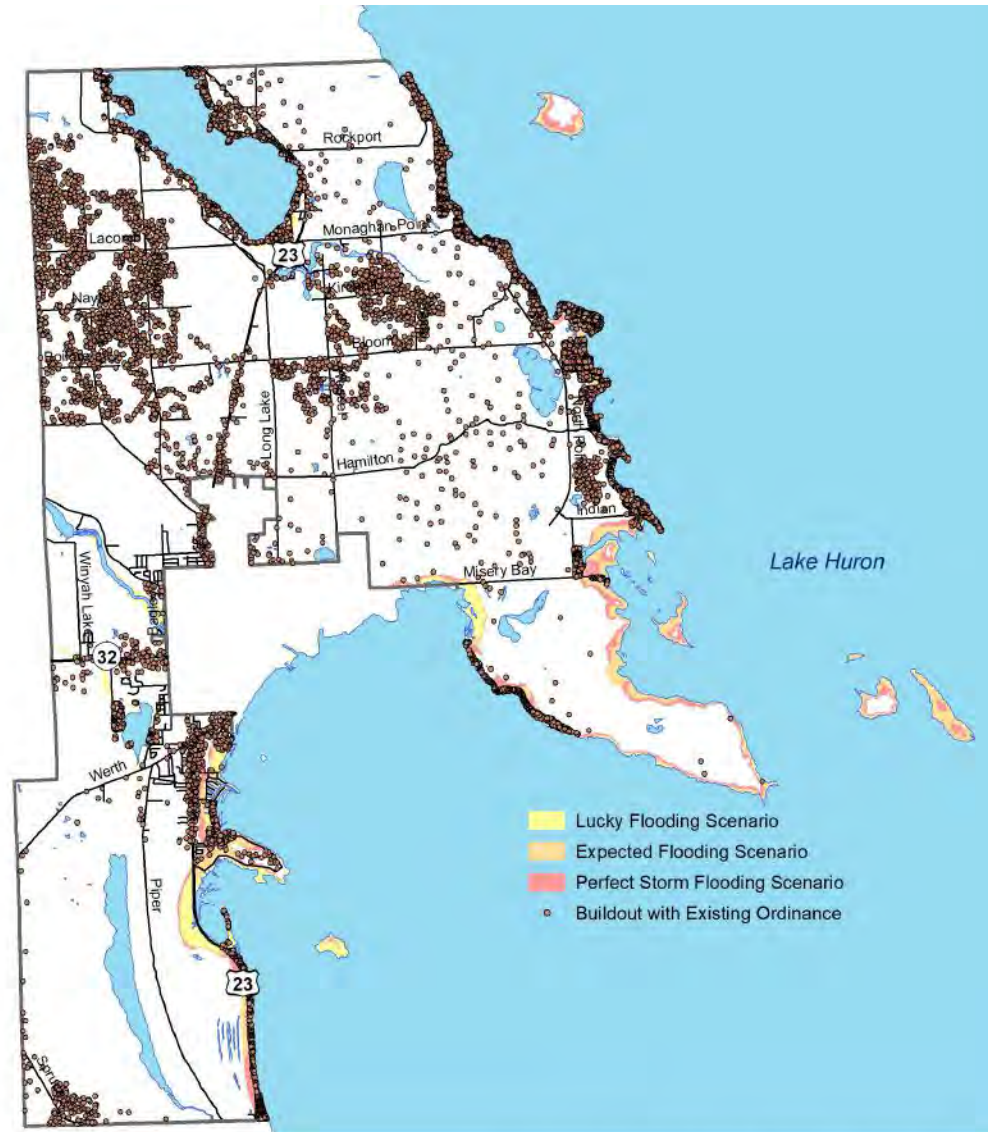
Data Sources:
NEMCOG, U.M.,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles

Alpena Township

Map 2.14

Future Climate Scenarios with Buildout According to Current Zoning



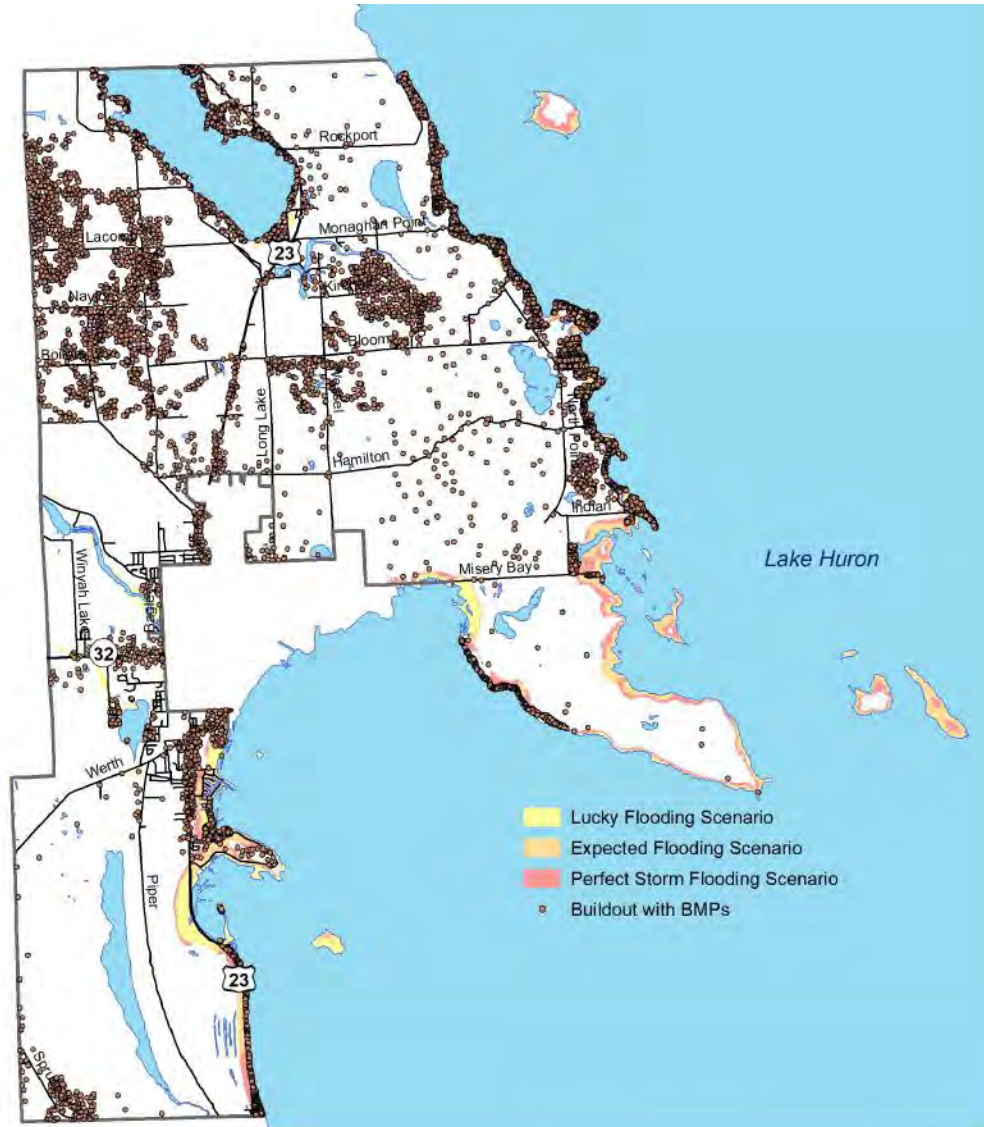
Data Sources:
NEMCOG, U.M.,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

Alpena Township

Map 2.15

Future Climate Scenarios with Buildout According to BMPs

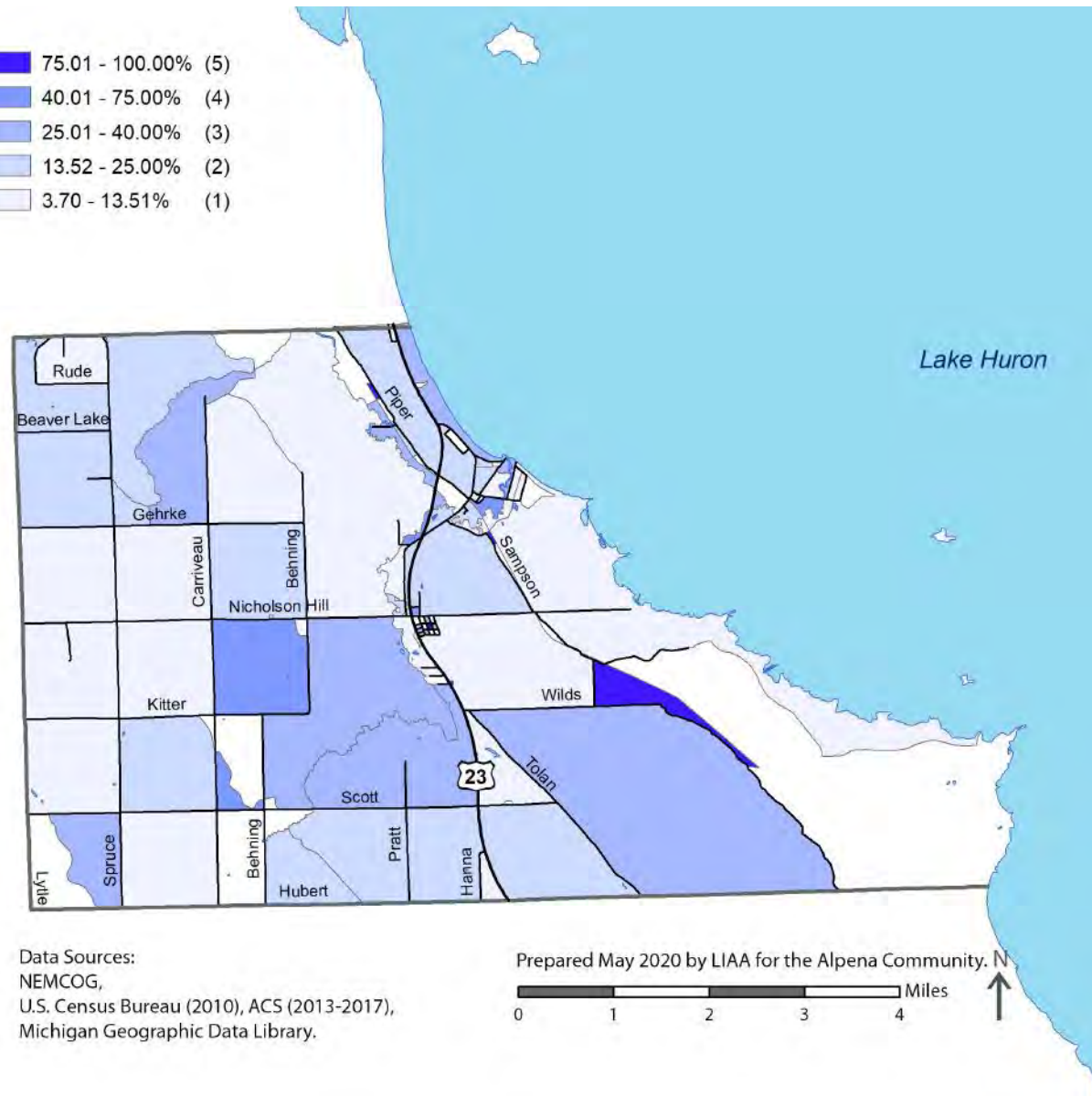


Data Sources:
NEMCOG, U.M.,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1.5 3 4.5 6 Miles ↑

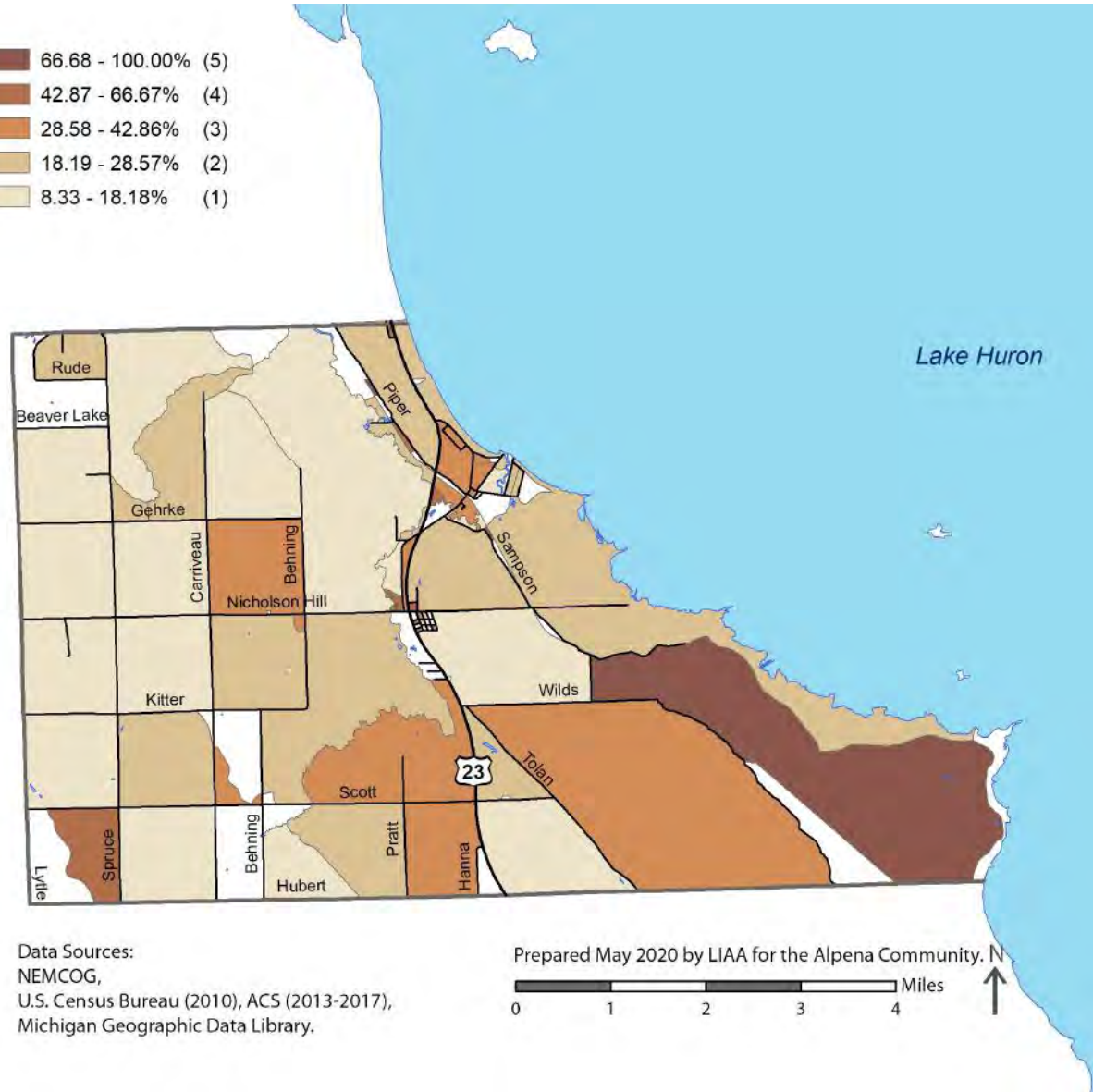
Sanborn Township

Map 3.1
Percent of Population 65
Years and Older (male
and female)



Sanborn Township

Map 3.2
Percent of Households
with People Living
Alone

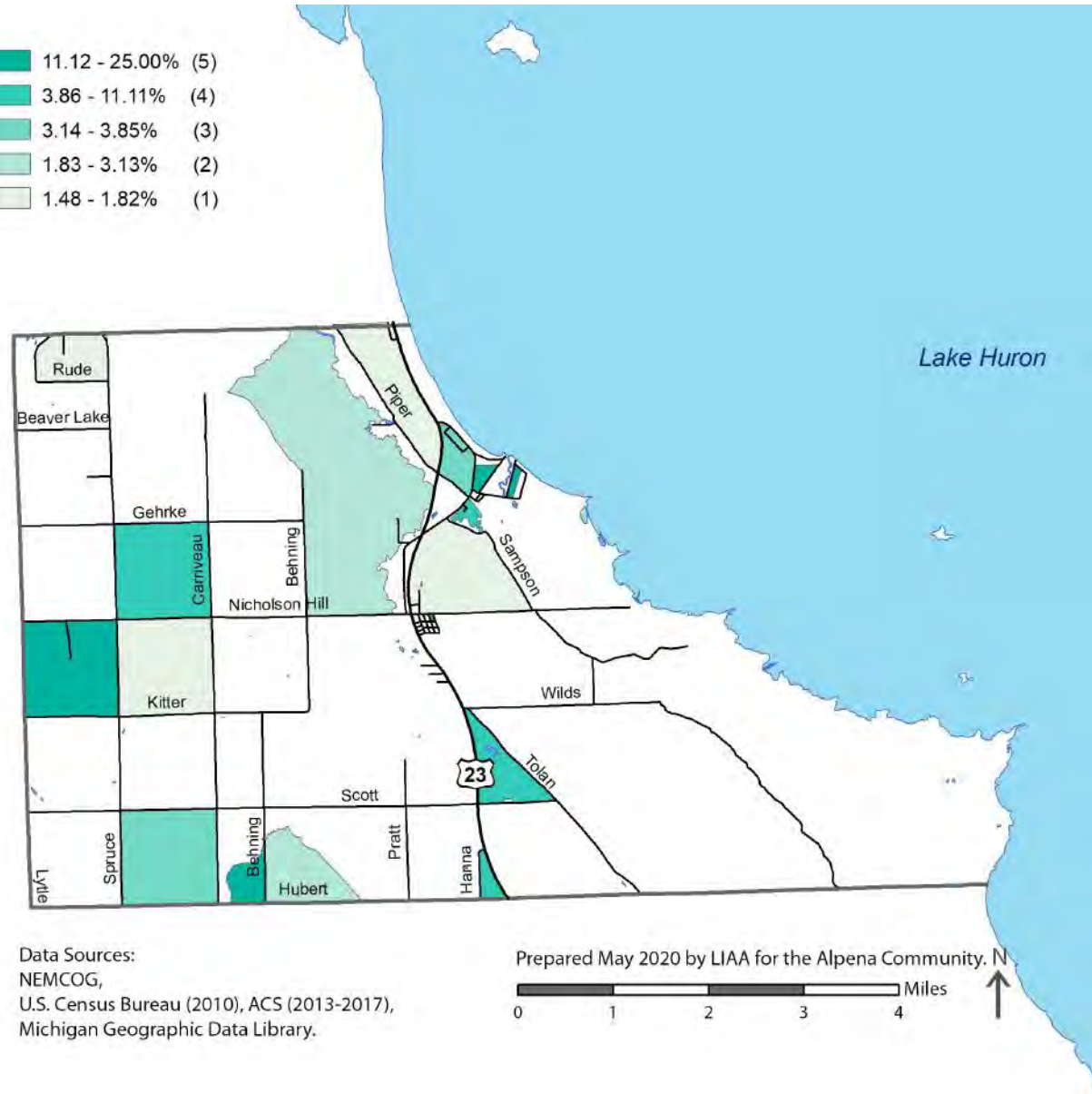


Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1 2 3 4 Miles ↑

Sanborn Township

Map 3.3
Percent of Non-white
Population

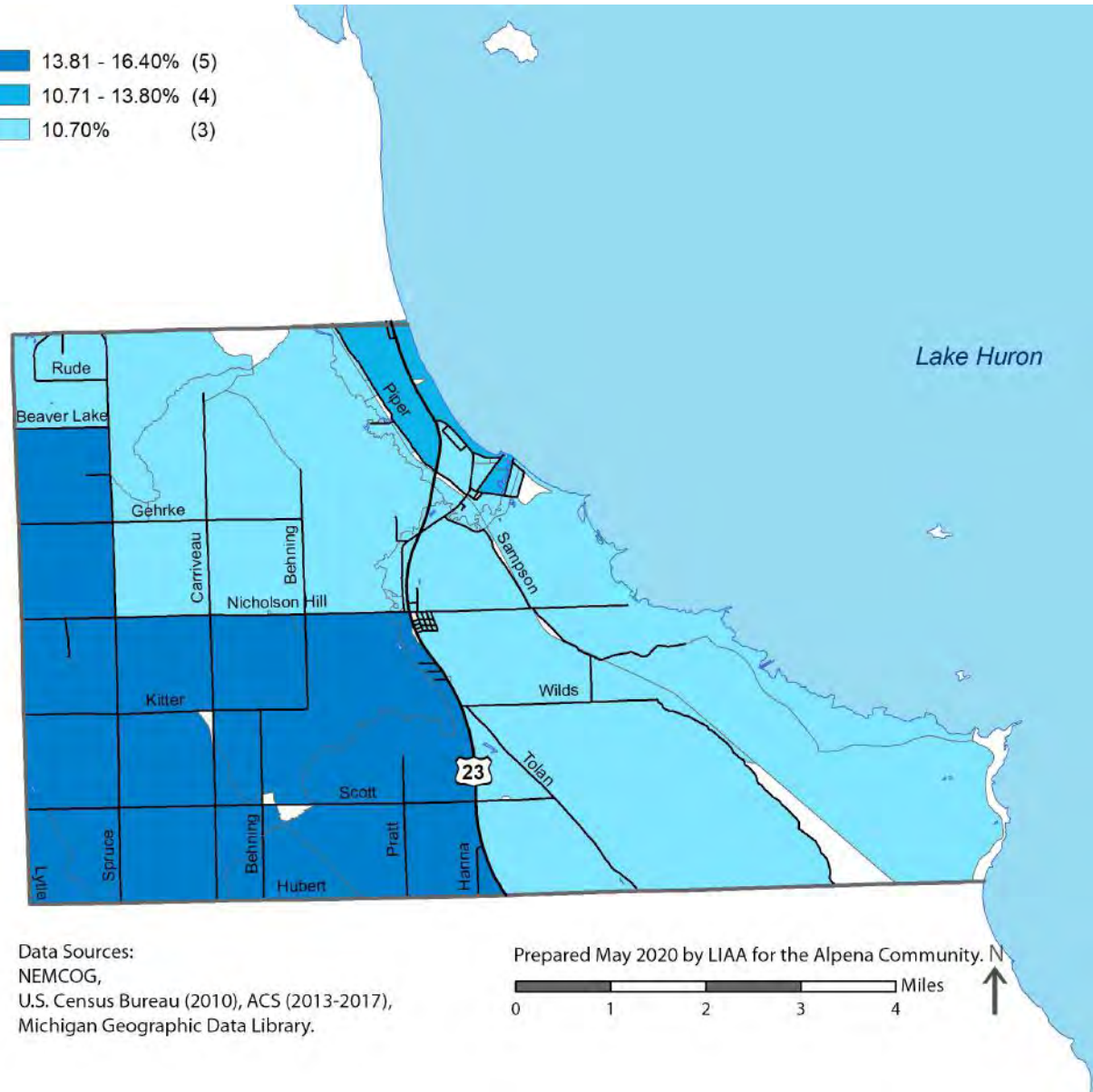
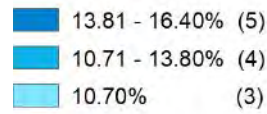


Data Sources:
 NEMCOG,
 U.S. Census Bureau (2010), ACS (2013-2017),
 Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
 0 1 2 3 4 Miles

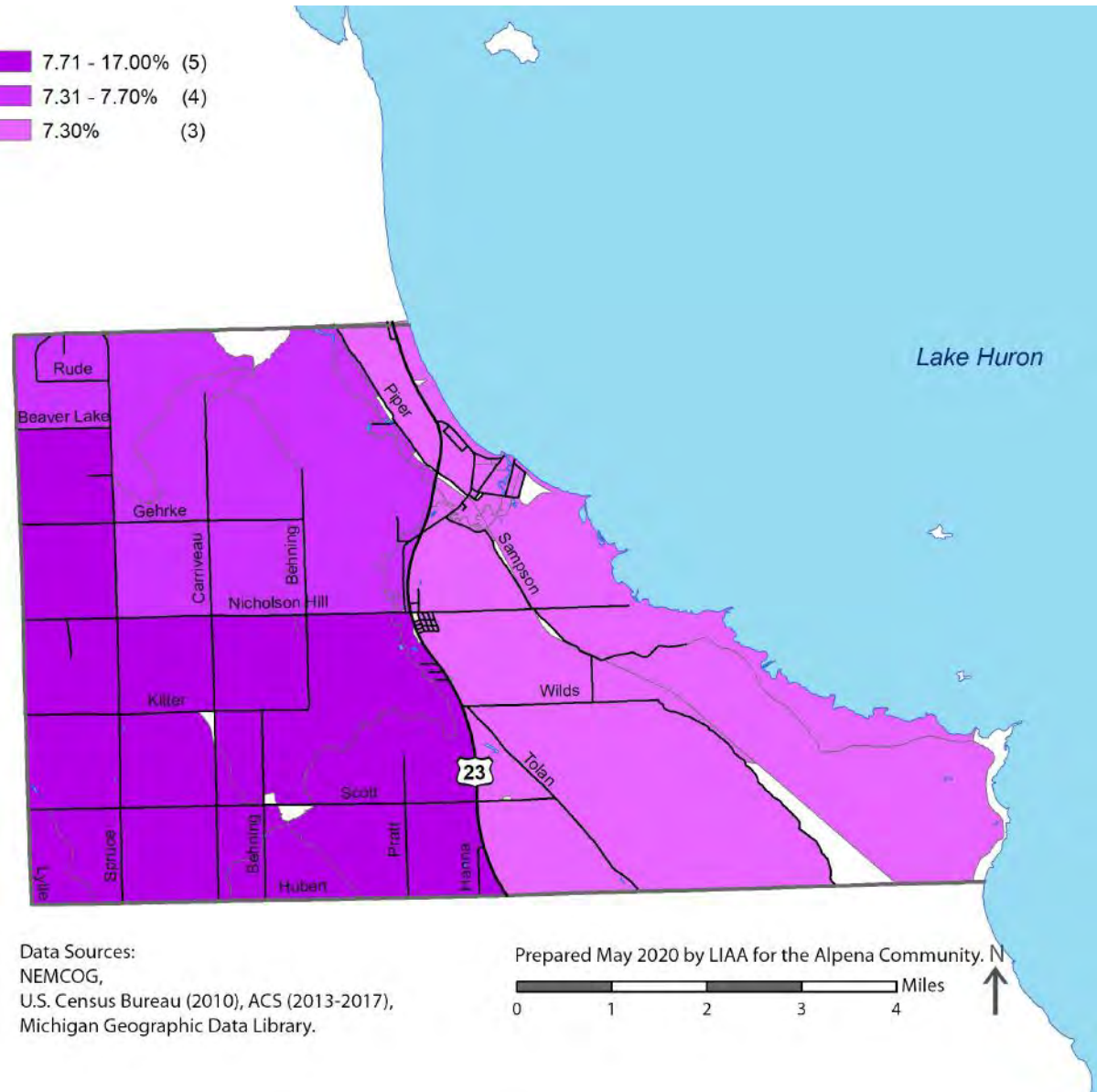
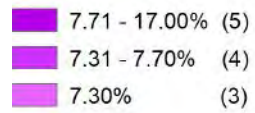
Sanborn Township

Map 3.4
Percent of
Households Living
Below the Poverty
Threshold



Sanborn Township

Map 3.5
Percent of Population 25
Years and Older with
Less than a High School
Education

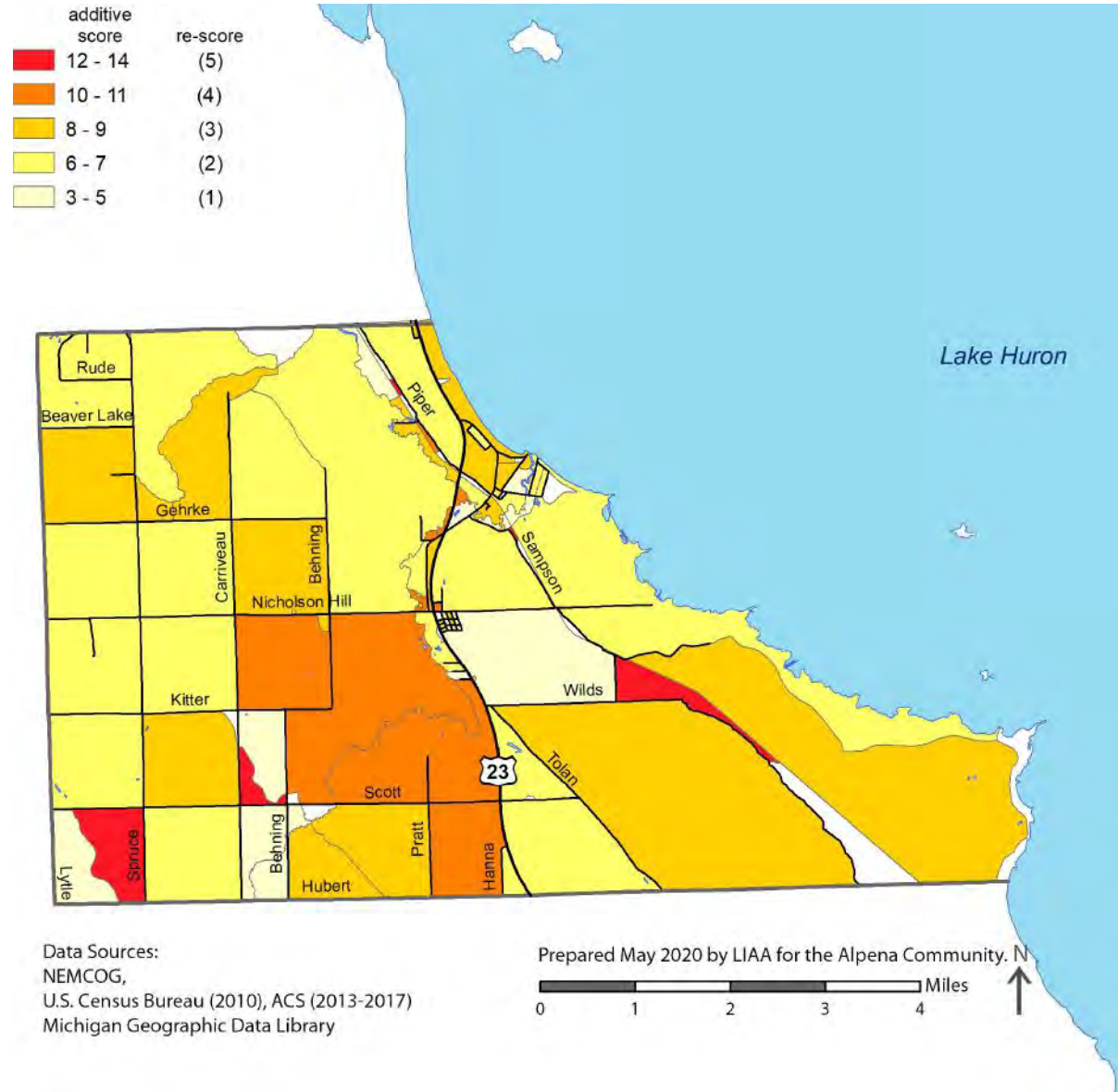


Data Sources:
NEMCOG,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1 2 3 4 Miles

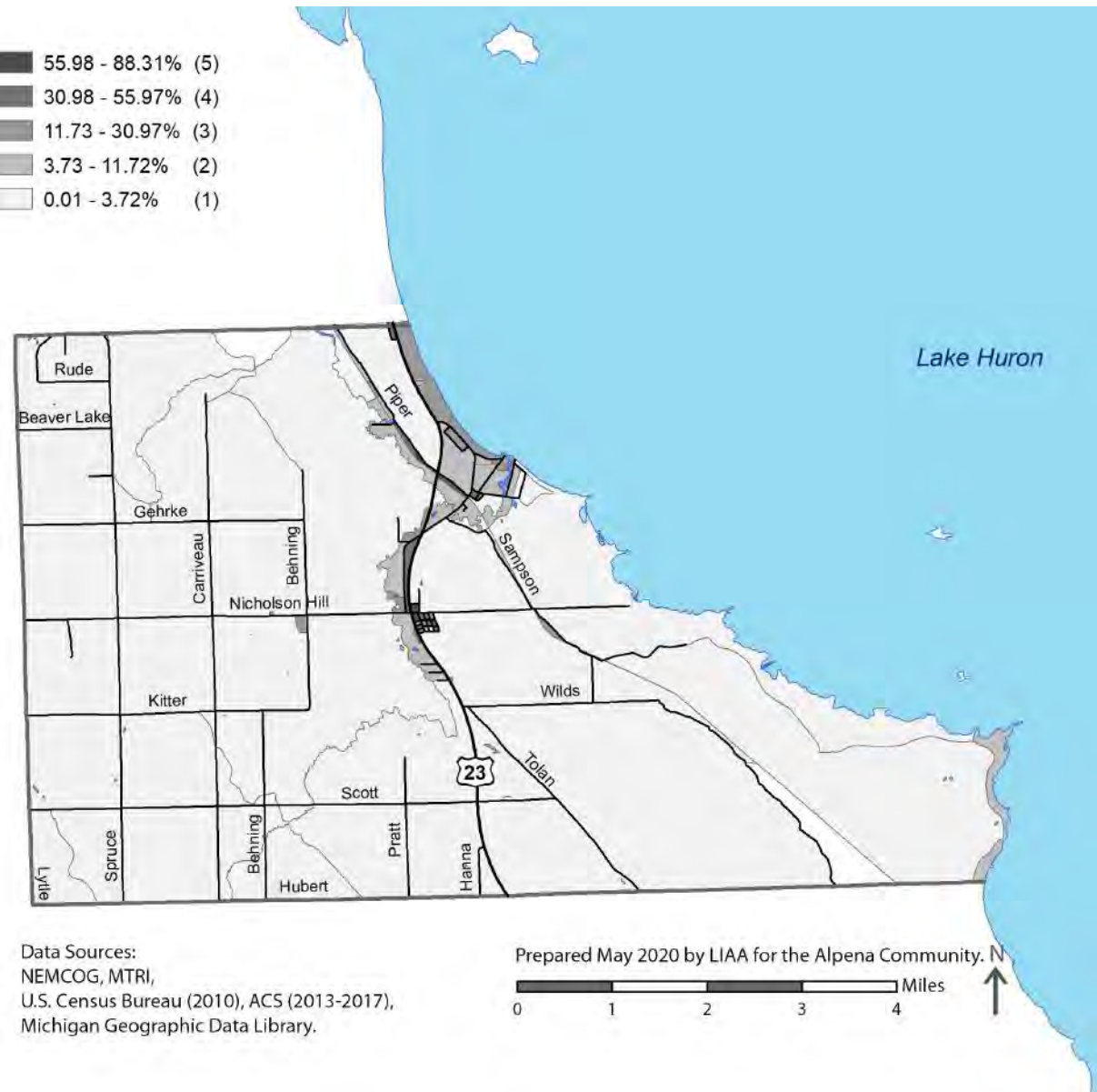
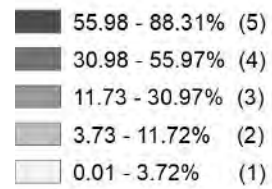
Sanborn Township

Map 3.6
Relative Sensitivity of
Populations to
Extreme Heat Events



Sanborn Township

Map 3.7
Percent Impervious Surface

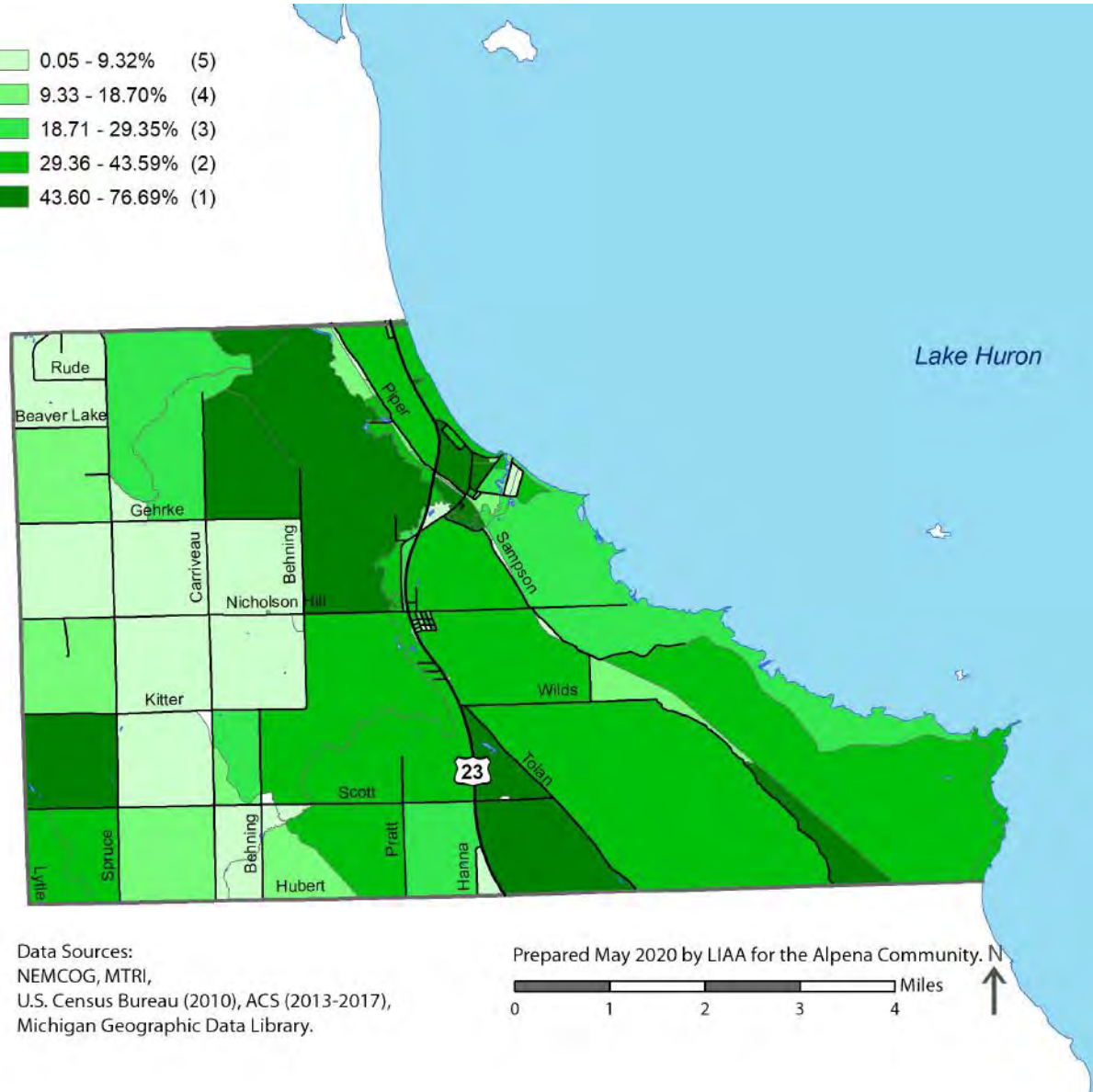


Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1 2 3 4 Miles

Sanborn Township

Map 3.8
Percent Tree Canopy

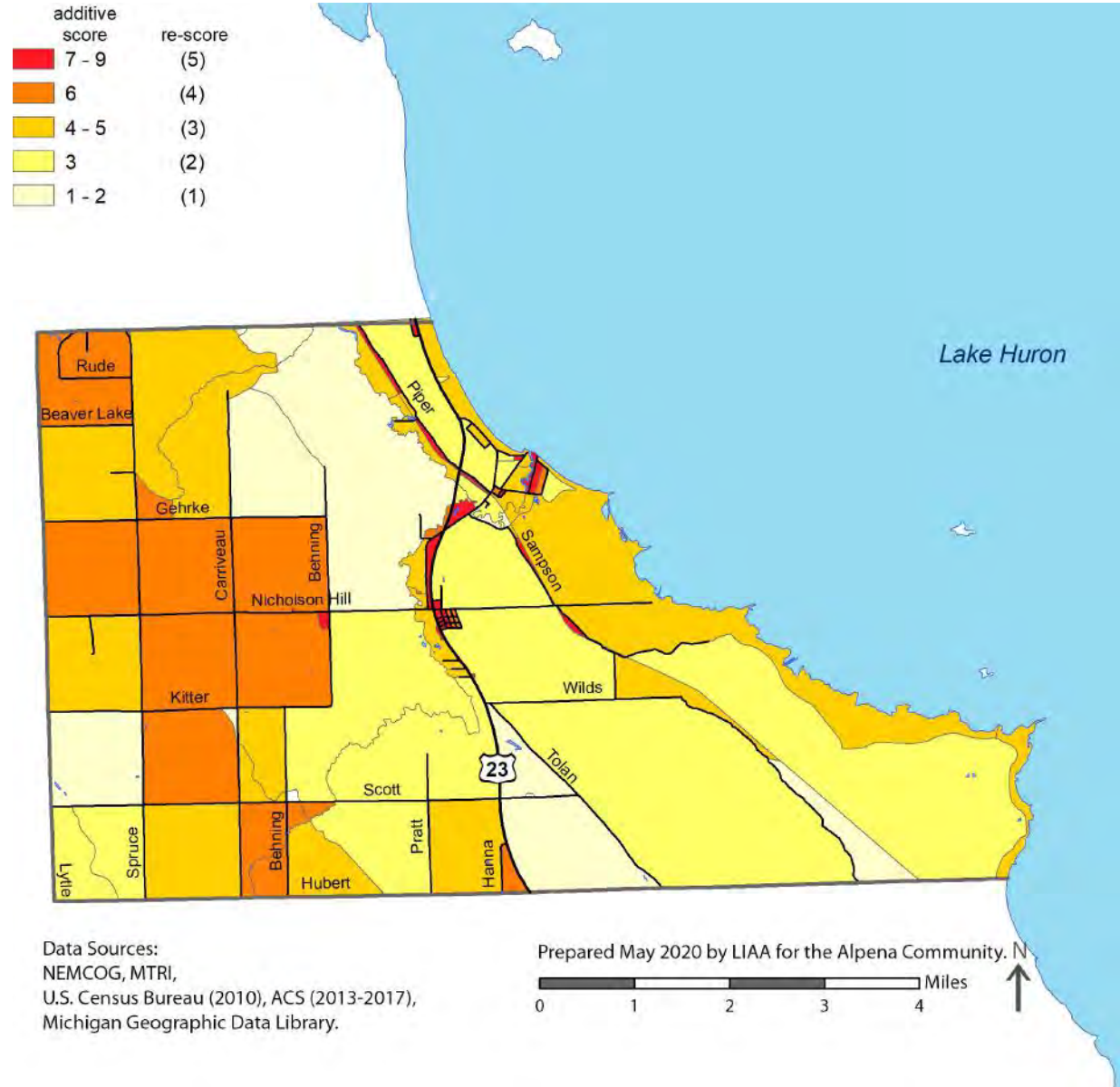


Data Sources:
NEMCOG, MTRI,
U.S. Census Bureau (2010), ACS (2013-2017),
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N
0 1 2 3 4 Miles

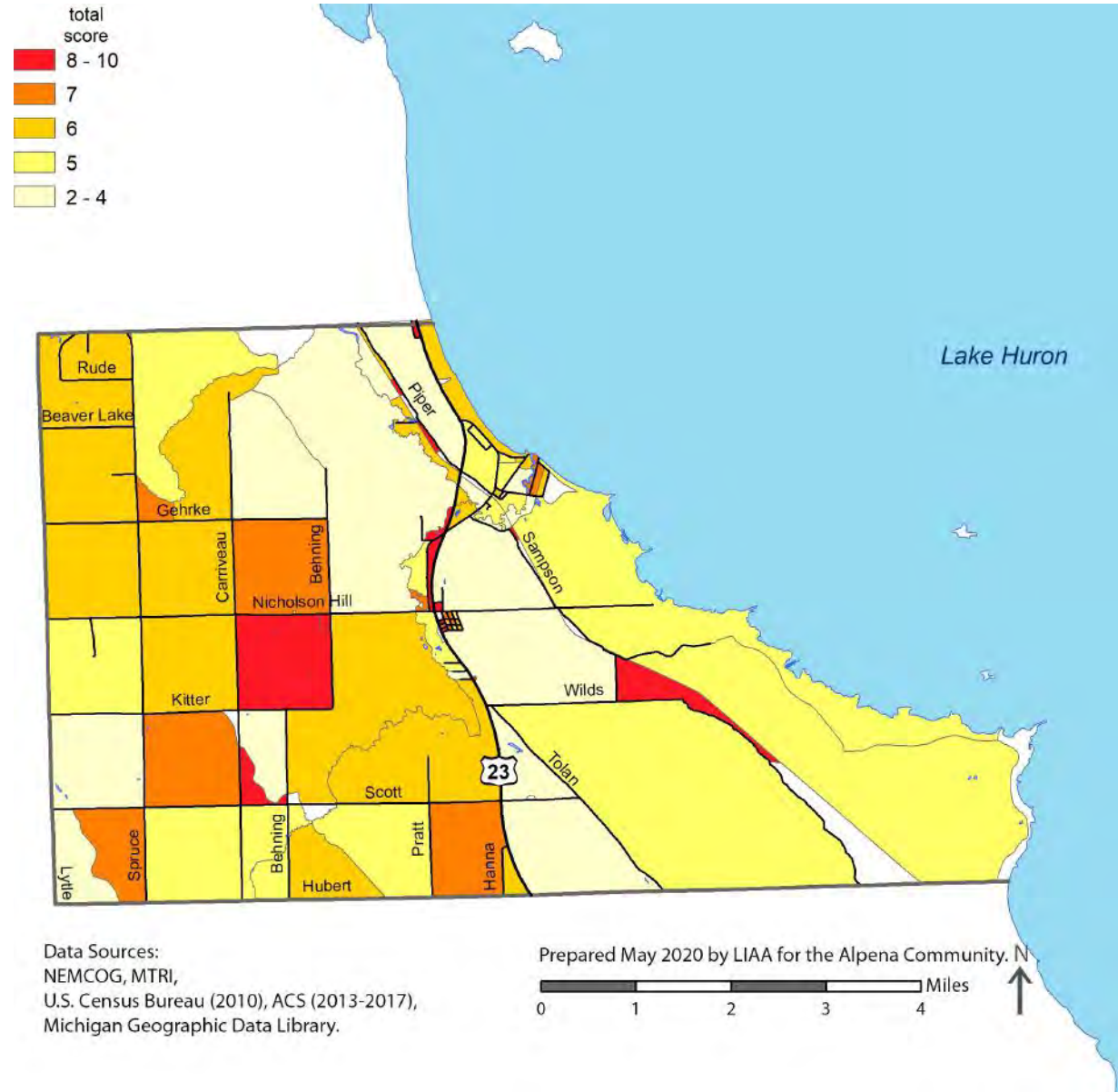
Sanborn Township

Map 3.9
Relative Exposure of
Populations to Extreme
Heat Events



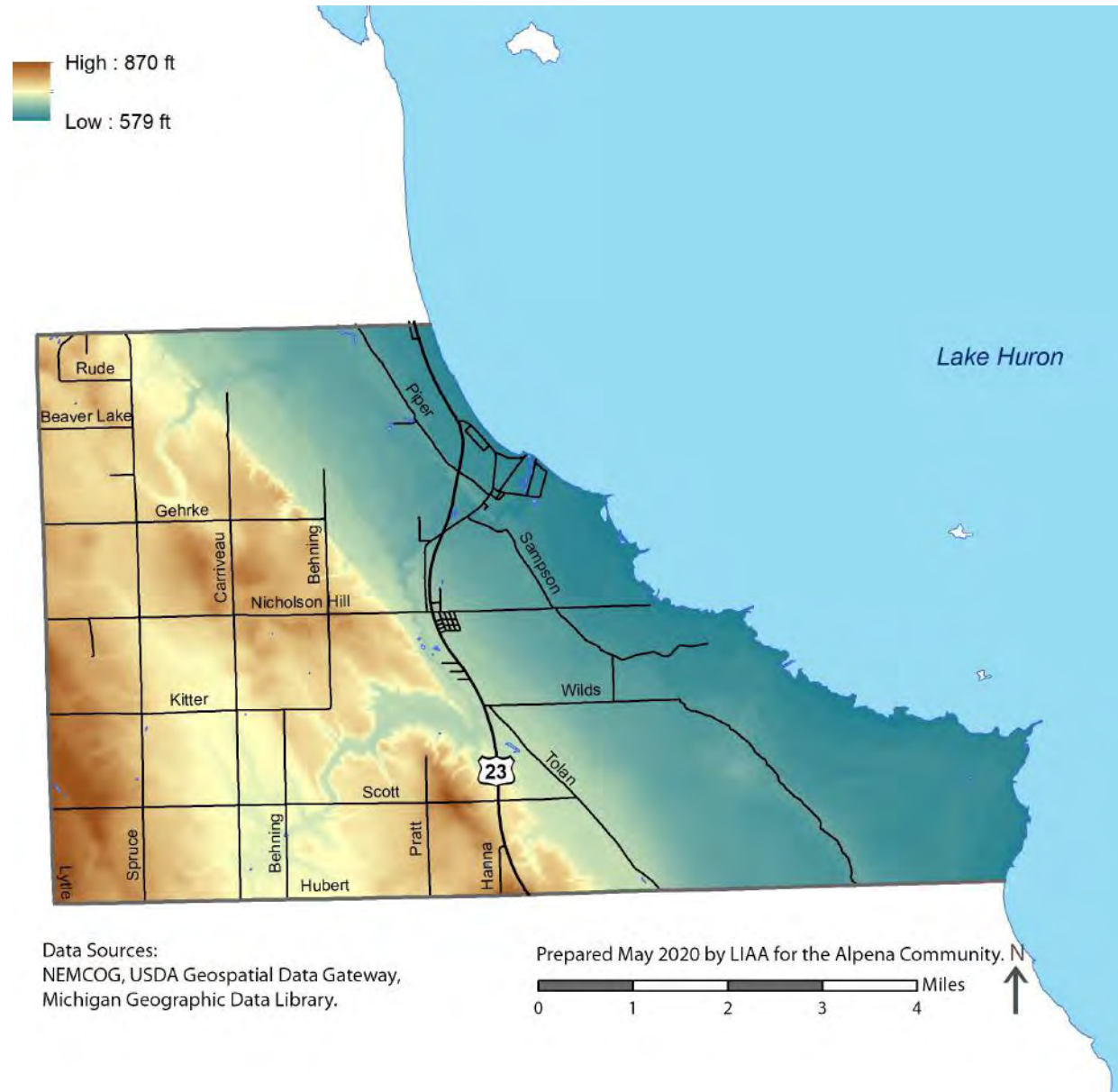
Sanborn Township

Map 3.10
Population
Vulnerable to
Extreme Heat
Events



Sanborn Township

Map 3.11
Digital Elevation Model



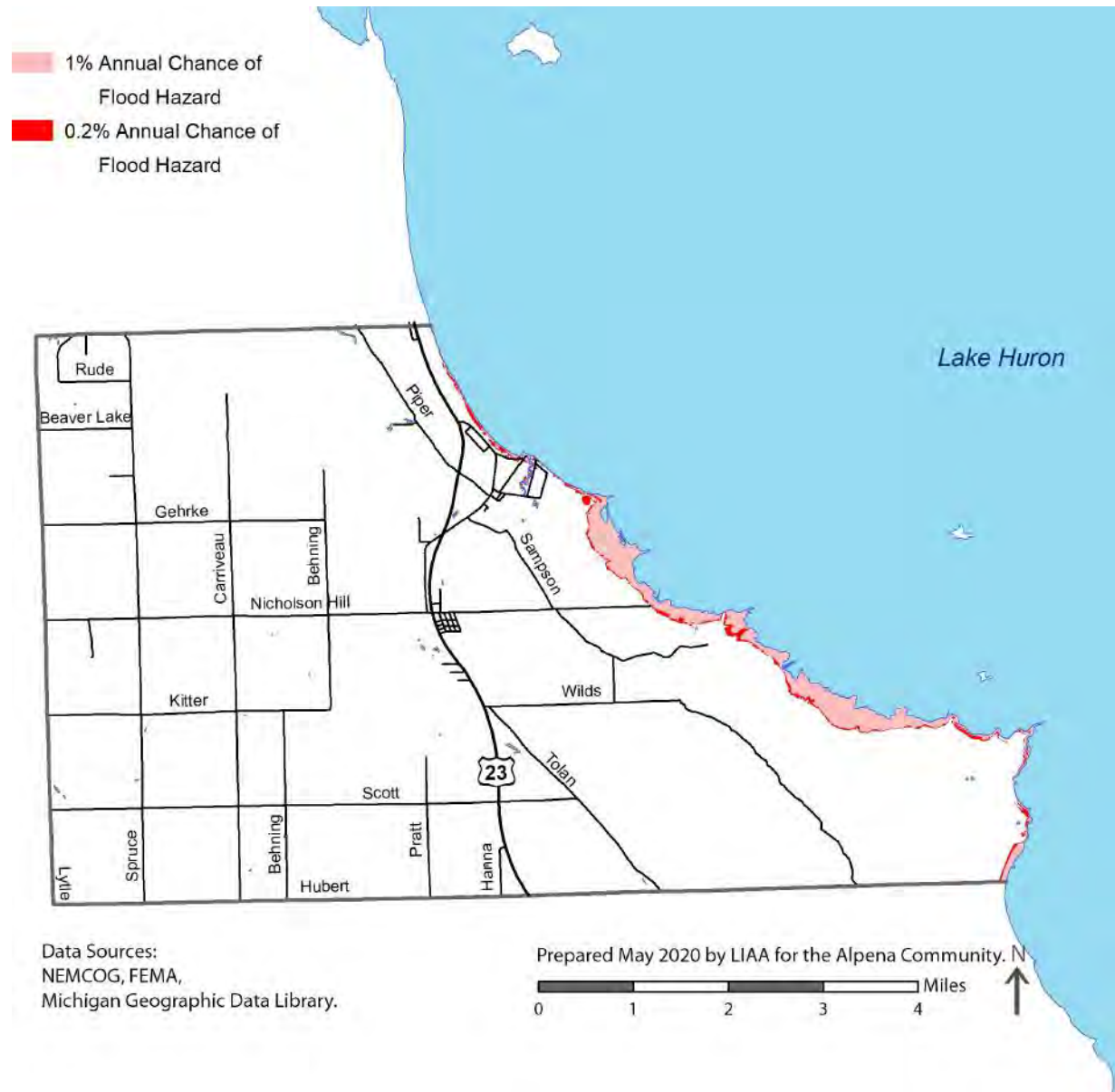
Data Sources:
NEMCOG, USDA Geospatial Data Gateway,
Michigan Geographic Data Library.

Prepared May 2020 by LIAA for the Alpena Community. N



Sanborn Township

Map 3.12
FEMA Flood Zones



Sanborn Township

Map 3.13
Future Climate
Scenarios

