

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 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.

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.

Vulnerability = Sensitivity + Exposure

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 13: Relationship Between Natural Hazards, Built Environment & Legal System

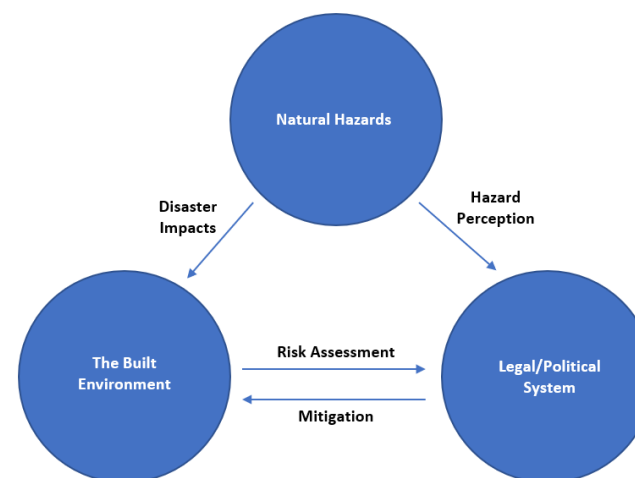


Figure from Disasters and Democracy (Platt, 1999)



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

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.fdoi.org/>[Online 10 June 2009]



Table 16. Needs of Stakeholders and Participants in Disaster Recover

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

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

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

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

To conduct the heat sensitivity assessment of Port Austin, 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. Maps depicting the locations of Port Austin’s vulnerable populations can be found in Appendix G.

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 (Map G.5) 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). Map G.6 depicts 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 township (see Map G.7).

Two socioeconomic factors associated with increased heat-related morbidity and mortality are the percentage of the people living in poverty 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 Port Austin (see Map G.8).

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 Port Austin (see Map G.9).

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.

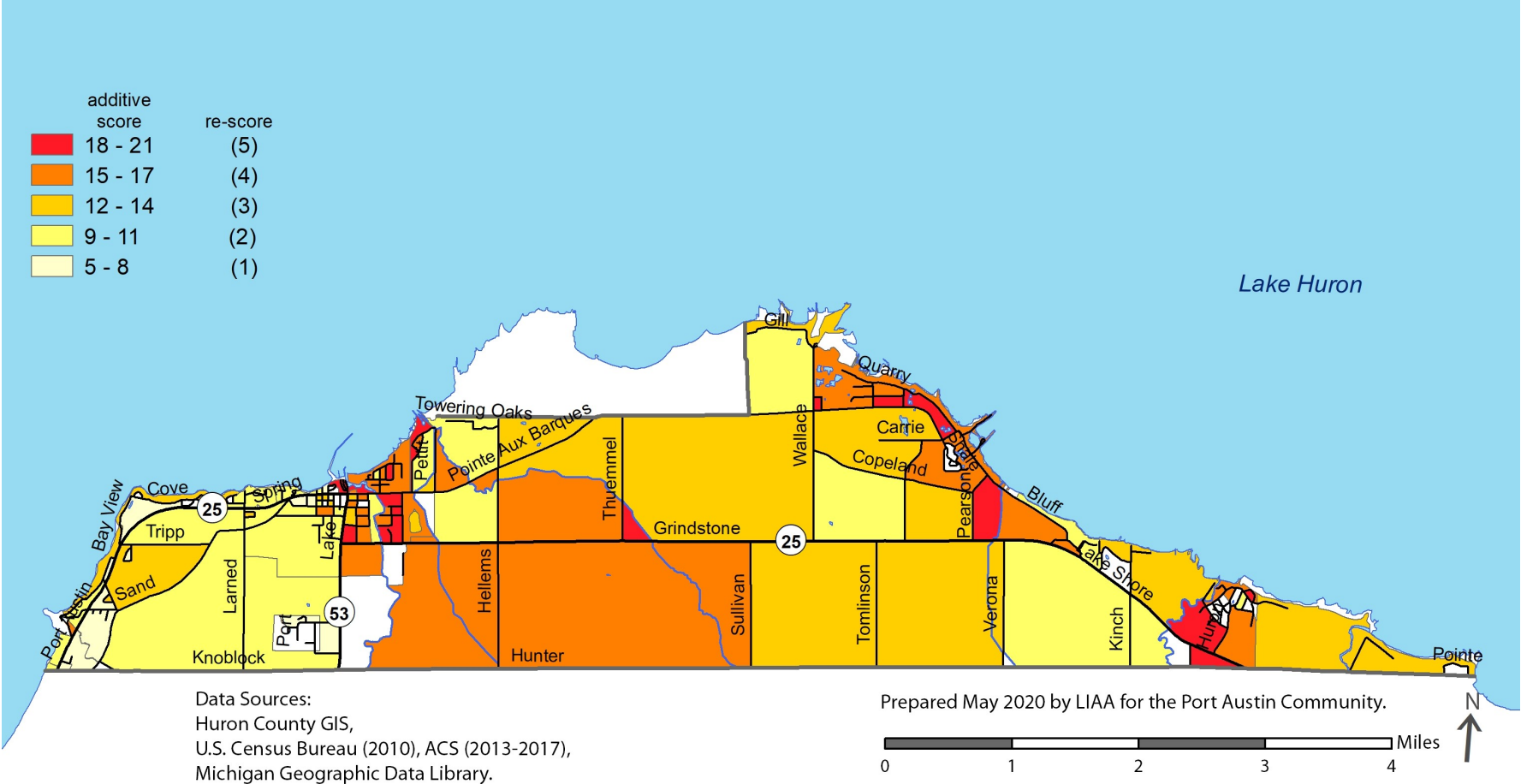
The Port Austin Sensitivity of Populations to Extreme Heat Events Map (Map 6) provides a reasonably detailed map of locations where the highest percentages of at-risk residents live. This does not mean these community residents are in immediate danger. Rather, the map provides planning officials a new 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.


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

⁴⁹Currierp 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.



Map 6. Relative Sensitivity of Populations 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 considered 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

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.

Four Phases of Emergency 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 postdisaster period necessary to return vital life-support systems to minimum operational levels and continuing to provide support until the

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



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 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 (Map G.10). 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 (Map G.11) and scored using a similar five-category process. On Map G.11, 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 Relative Environmental Exposure to Extreme Heat Events Map (Map 7), which provides a reliable depiction of where the Urban Heat Island Effect would be most or least intense during a heat wave. Officials in Port Austin can use this map to better assess where new vegetation and tree canopy would be helpful to reduce the heat impact.

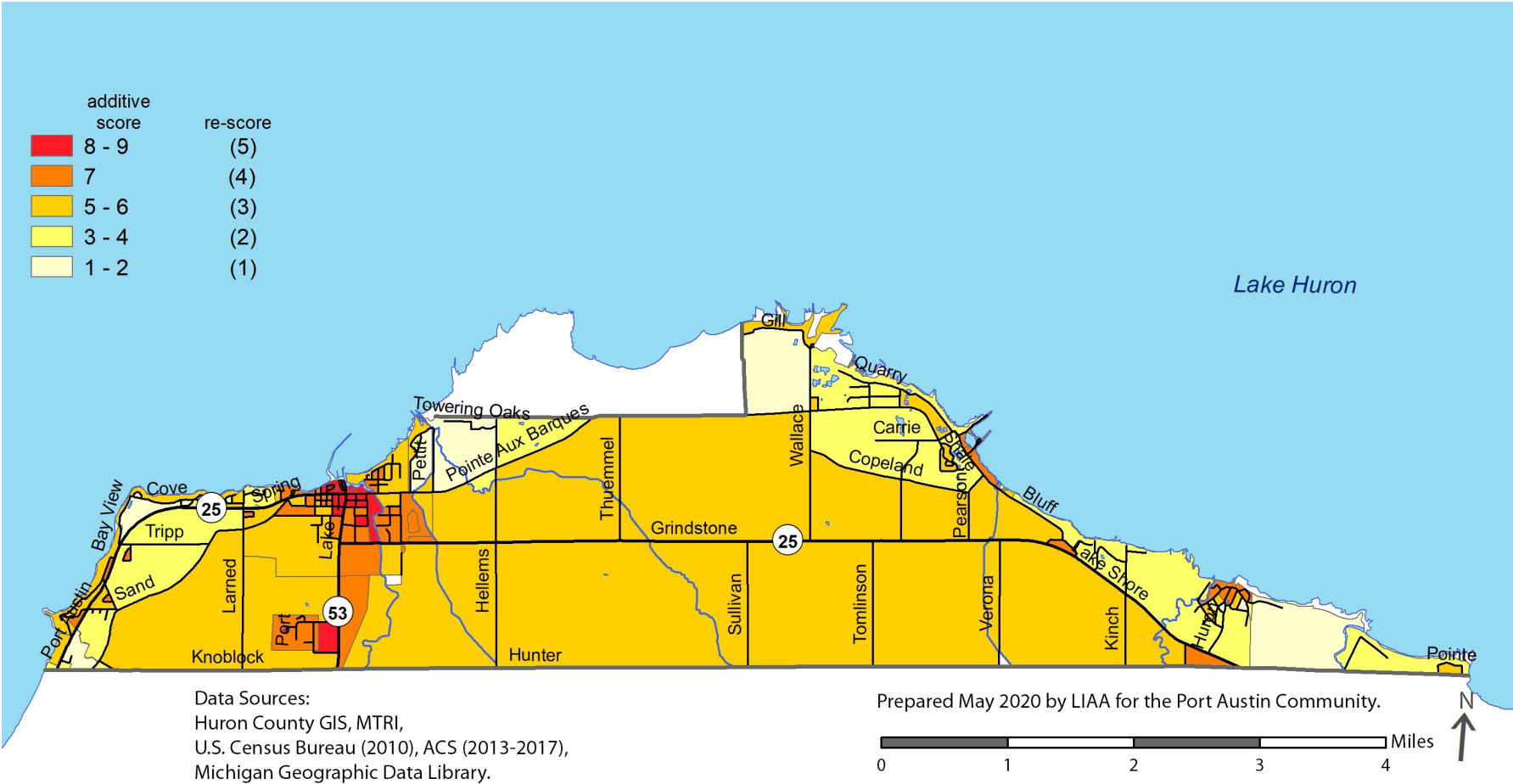
⁵¹Basu and Samet. (2002) Relation between Elevated Ambient Temperature and Mortality: A Review from the Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD.

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.

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



Map 7. Relative Environmental Exposure to Extreme Heat Events

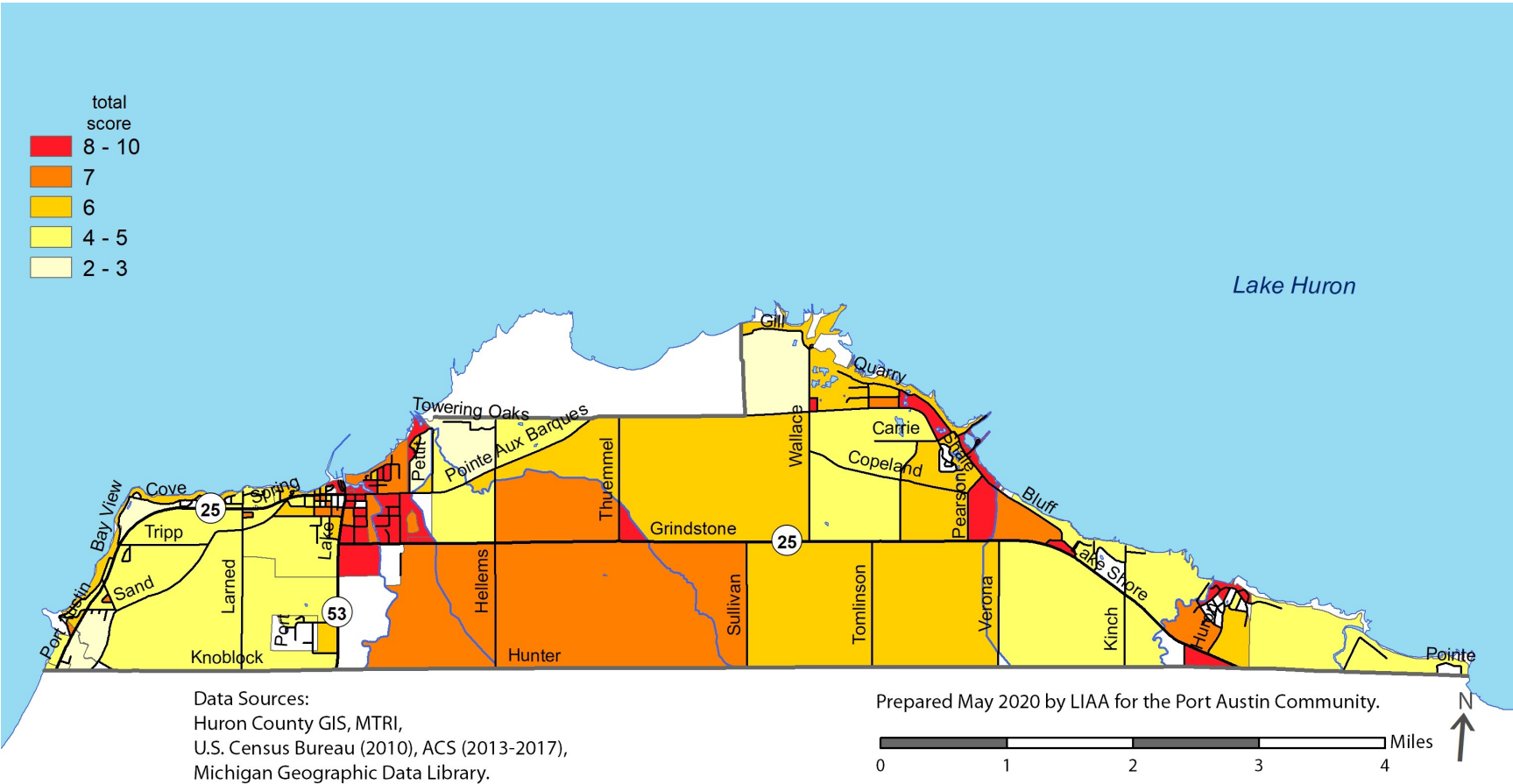




Composite Heat Vulnerability Map

The Port Austin Heat Vulnerability Map is a simple additive combination of the overall sensitivity map and the overall exposures map (see Map 8). 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 8-10 (red) have residential populations that may be particularly vulnerable to extreme heat events.

Map 8. Composite Heat Vulnerability





Heavy Rain and Flooding

Climate scientists say that Port Austin and east 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, community planners evaluate potential exposures as well as sensitivity to flooding. 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 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 Map (Map G.4) offers a useful view of the topography of Port Austin, 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.

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 Port Austin 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 analysis 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. Map 9 shows the estimated land areas that would be affected by waves and flooding under these three climate futures.

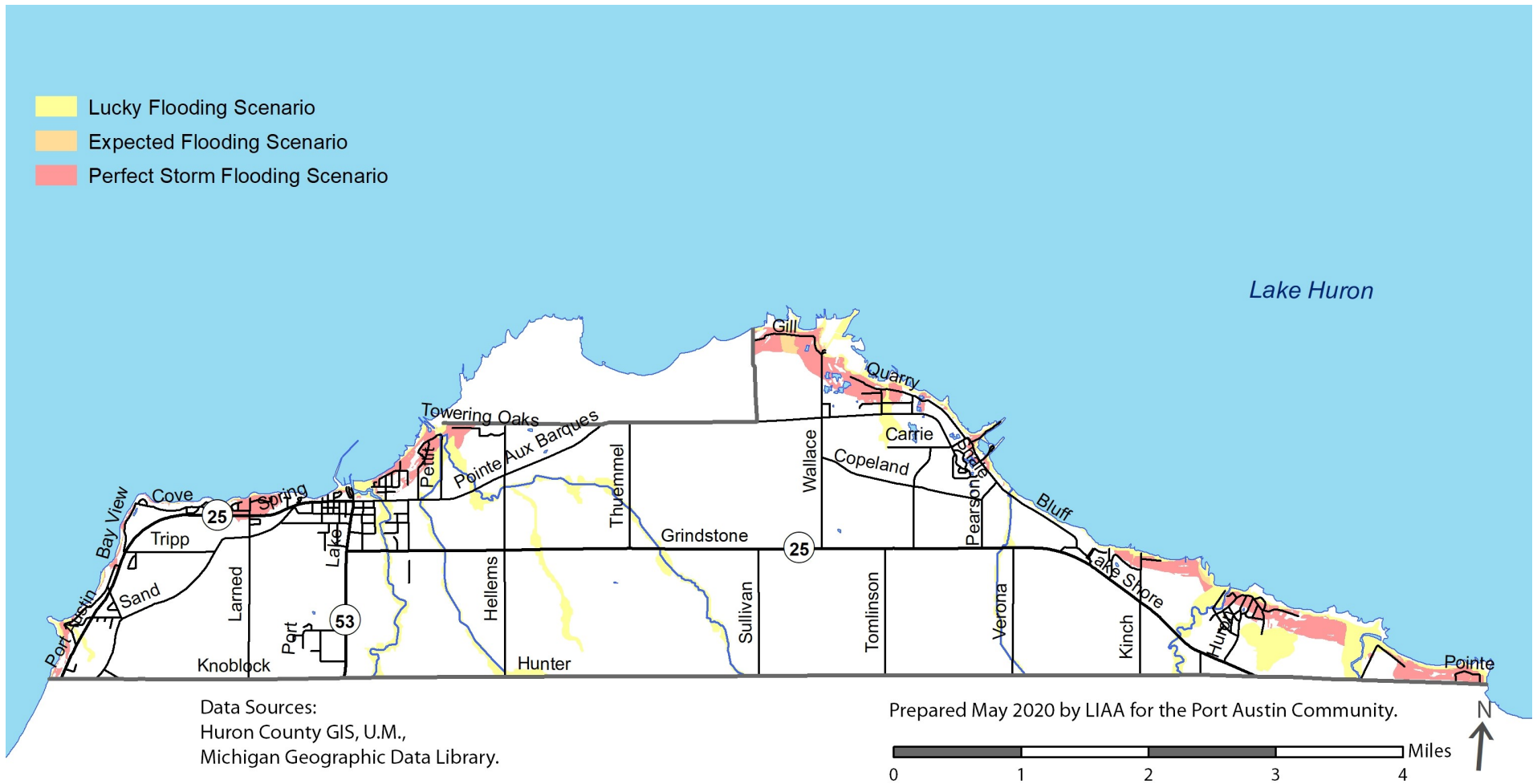
“Lucky” Future. Under the Lucky Climate Future, Great Lakes water levels will stay relatively low. Although there will be wave and wind action, major storm events and wave impacts will not encroach on properties landward of current beaches. A Lucky Future projection, indicating the land areas that would be affected by high-energy waves along the shoreline and/or adjacent riverine flooding under these conditions, is shown in green on Map 9.

“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 Federal Emergency Management Agency’s (FEMA) ongoing Great Lakes Coast Flood Study. 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 purple on Map 9.

“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 on Map 9.



Map 9. Port Austin Flooding Scenarios





Management Options

The management options used for this scenario-based planning analysis are designed to represent feasible arrays of options a community might reasonably address, ranging from making no changes to current programs to adopting “best management practices” (BMPs) designed to mitigate potential harms from flooding conditions. Each of the following descriptions outline the key assumptions made in defining each of the management options compared to the others.

Current Practices. Under this option, the assumption is made that the Port Austin Community will continue to manage land in the same manner it currently employs, in accordance with adopted plans, zoning ordinances, and relevant local ordinances.

Buildout According to Current Zoning. Under this option, the community will experience a full buildout of residential development according to its existing zoning code. Additional homes are built in areas at the base flood elevation and are at risk for flooding. See Map G.12 for a visual of where these potential development areas are located. This is not an exact picture of the development capacity in the community; rather, this work equates to an estimate of where development may possibly occur under current zoning, with additional land set aside for open space, driveways, streets and yards. The dots on the map do not represent actual physical locations of structures. Rather, the dots are randomly placed by the CommunityViz software to provide a quick visual representation of the potential for additional buildout in Port Austin under current zoning. A greater number of dots in an area indicates a greater potential for buildout in that area.

Built-Out According to Best Management Practices (BMPs) . Under this option, the Port Austin Community will adopt and implement Best Management Practices to preserve natural resources and protect private property, and then experience full development under the revised zoning provisions.

For this study, only a handful of best management practices are modeled, as described below. The selected BMPs were chosen because each can have a significant spatial effect and a policy or regulatory effect that can be achieved through a zoning ordinance. These BMPs are easily modeled using Community Viz software. The intent of including this management option is to present several amendments that could be adopted that may influence the impact on land use and the environment in the community (see Map G.13).

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

Each management option can be combined with each of the three Climate Futures 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 Township 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 Port Austin. Land-use impacts include the acreage, parcels, structures and critical facilities that would be at risk under different Climate Futures for each management option. Environmental conditions include the acreage of wetlands, impervious surfaces, and high-risk erosion areas impacted in each Climate Future for each management option.

Land Use Results

Total Acres

The total acres of land impacted by flooding increases from the Lucky Climate Future to the Perfect Storm Climate Future. The number of acres impacted increases the most between the Expected and Perfect Storm forecasts (a 88% increase in land area). Between the Lucky and Expected scenarios, the total acres increases only slightly. Table 17 shows the total acres of land impacted under each future flood forecast in Port Austin Township.

Table 17. Total Land Acres Impacted by Flooding

	Lucky	Expected	Perfect Storm
Port Austin	117	124	233



Parcels

As Table 18 shows, between 130 and 388 parcels are impacted depending on the severity of the Climate Future in Port Austin Township. Map 9 illustrates the extent of inundation for each Climate Future.

Table 18. Total Number of Parcels Impacted by Flooding, by Zoning District

Use Type	Lucky	Expected	Perfect Storm
Residential	105	108	339
Non-Residential	25	25	49
Total	130	133	388

Structures

Up to 388 structures may be impacted in the Township depending on the severity of the Climate Future experienced. Table 19 summarizes the total number of structures impacted under the varying Climate Futures.

Table 19. Number of Structures Impacted by Flooding

	Lucky	Expected	Perfect Storm
Current Development	130	133	388
Build-out According to Current Zoning Ordinance (Additional Structures Impacted)	+1,011	+1,026	+1,310
Build-out According to Best Management Practices (Additional Structures Impacted)	+144	+147	+60



Financial Impacts in Each of the Flooding Scenarios

Tables 20 and 21 show the potential negative financial impacts that the various flooding scenarios may present to the Port Austin community. Shown in Table 20, the Township currently generates \$2.5 million in tax revenue. The remainder of the table illustrates how implementing best management practices, namely including 50-foot buffers from flood-prone areas, can reduce the proportion of tax revenue lost in the case of a particular flood scenario. For example, if a Perfect Storm flood scenario in which the community is completely built out according to its current zoning, around 45% of the municipality’s tax revenue would be lost. However, if built out according to BMP’s the Township would only lose 26% of its tax revenue. The same pattern reveals itself in regard to potential property damage costs. The additional projected damages during a Perfect Storm event are \$41.69 million if the community is built out according to current zoning, compared to a much lesser \$7.35 million if the community implements best practices. Both of these tables serve to highlight the financial implications for different zoning and flood management practices in Port Austin Township.

Table 20. Tax Revenue of Affected Properties

Use Type	Total	Lucky	Expected	Perfect Storm
Tax Revenue	\$2.5 million	\$232,820	\$242,579	\$750,521
Build-out According to Current Zoning Ordinance (Potential Additional Tax Revenue Impacted)	\$15.11 million	\$3.78 million	\$3.85 million	\$6.77 million
Build-out According to Best Management Practices (Potential Additional Tax Revenue Impacted)	\$7.35 million	\$860,558	\$890,766	\$1.91 million

Table 21. Potential Property Damages for Different Flooding Scenarios

Use Type	Lucky	Expected	Perfect Storm
Damages	\$2.55 million	\$2.65 million	\$6.11 million
Build-out According to Current Zoning Ordinance (Additional Damages, average)	\$7.42 million	\$8 million	\$41.69 million
Build-out According to Best Management Practices (Additional Damages, average)	\$1.19 million	\$1.85 million	\$7.35 million