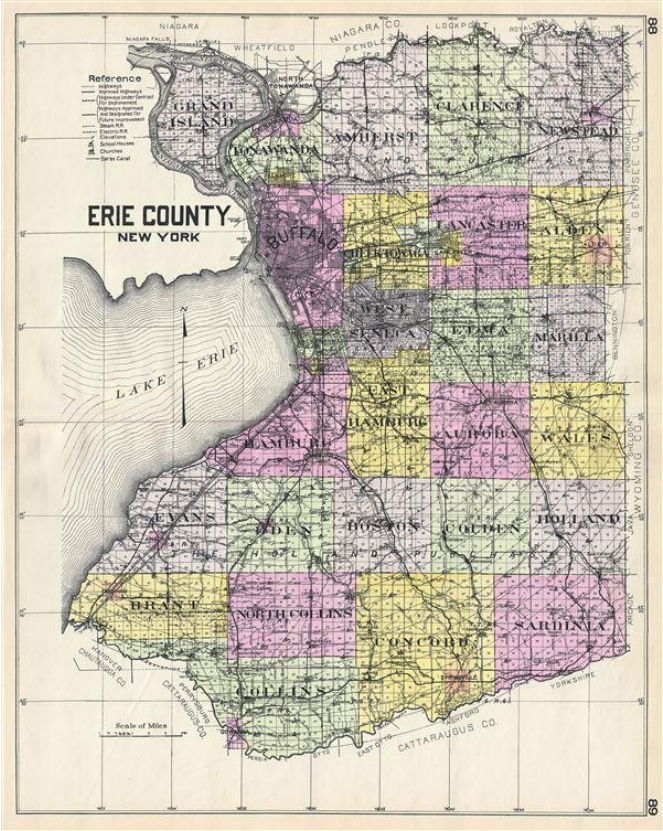
Erie County Climate Vulnerability Assessment

DRAFT Climate Hazards Summary Report

August 16, 2020



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Cover page: The image shows a historic map of Erie County from 1912 (Image Credit: Everts, 1912). This project takes into account peer-reviewed climate projections and literature, existing data, and maps in order to assess Erie County's Vulnerability to changes in the dynamics of physical, chemical and biological processes due to climate change across the region.

This project has been funded in part by the Climate Smart Community Grant Program, Title 15 of the Environmental Protection Fund through the NYS Department of Environmental Conservation.

Abstract

Erie County, NY is in the process of developing a Climate Vulnerability Assessment (CVA) of its jurisdictional responsibilities. The overall objective is to assess the climate related hazards most pertinent to Erie County, identify gaps in the County's capacity to mitigate and address the identified threats, as well as show where the County is doing well in climate preparedness to allocate resources more efficiently. In an important first step, the particular climate hazards and threats that the assessment will focus on need to be identified. While there may be multiple climate-related hazards that Erie County may face, some hazards are more impactful and/or are more readily addressed by Erie Count than others. A literature review identified hazards related to temperature (air quality, extreme heat etc.), precipitation (flooding, ice jams and water quality issues from pollutants associated with agricultural runoff/sewer overflows and erosion-based nutrient injections etc.), wind (coastal erosion, property/infrastructure damage), vector-borne diseases (malaria, Lyme's disease etc.), and invasive species/Harmful Algal Blooms (changes in species' distribution, increased incidence of occurrence etc.) as the primary focus areas for the CVA process. These hazards will be incorporated into the next steps in the vulnerability framework, which include spatially mapping these threats, performing a sensitivity analysis to identify the most sensitive populations, infrastructure and other sectors; and evaluating the adaptive capacity of Erie County to respond and recover from these threats.

Executive Summary

With the impacts of global climate change already becoming evident locally and across the globe (Erie County, 2019a; Environmental Law & Policy Center, 2019; Rosenzweig et al, 2011), it is the responsibility of governments and communities to work proactively to prevent, mitigate, and offset the coming impacts. The government of Erie County, NY has been awarded funds through the New York State Department of Environmental Conservation's Climate Smart Communities program (NYS, 2019) to conduct a Climate Vulnerability Assessment of its operations. Erie County has contracted a team at the University at Buffalo (UB) to conduct this assessment. This team includes faculty from the Departments of Environment and Sustainability as well as Geography, and a doctoral student also from the Geography Department. In addition, staff at Erie County's Department of Environment and Planning are overseeing and coordinating this effort.

First, a literature review has been conducted. The review included climate hazards, as well as issues of social vulnerability and resilience. Based on the literature review and input from internal stakeholders at Erie County and external stakeholders such as the Erie County Community Climate Change Task Force (C3TF), several focus hazards were selected. Selected hazards aligned with previous guidance documents (Erie County, 2019a; Erie County 2019b; URS, 2015; BNW, 2014 etc.) as well as in consideration of what Erie County as a governmental entity can feasibly influence under its jurisdiction. Selected focus hazards include temperature, precipitation, vector-borne diseases, and invasive species/Harmful Algal Blooms. Each hazard will be analyzed to identify the projected impacts that the changing climate will bring with respect to that specific threat. In most cases, the hazards will be geospatially analyzed in order to identify the geographic and temporal scale of the threat. Hazards not analyzed geospatially will be assessed through additional literature review to ensure all pertinent information is reflected in the final Climate Vulnerability Assessment.

Once the climate hazards have been investigated and spatially mapped, they will be cross referenced with Erie County's sensitive populations, infrastructure, and ecosystems under the County's jurisdiction in what is called sensitivity analysis. Sensitivity analysis identifies the extent to which vulnerable populations and infrastructure are potentially impacted by their exposure. In this case, that exposure is in reference to climate-related hazards (City of Rochester, 2018, Colburn et al, 2016; Kumar et al, 2016; Shen, Fen & Peng, 2016). The final step is to evaluate the County's adaptive capacity to climate change-related impacts. Adaptive capacity is the innate resilience of social institutions such as county governance to impacts, both over the short and long term. This resilience is due to proactive planning and/or the production of innovative responses from government and partners both prior to and after a disaster/impact (Gupta, et al., 2010). Collectively, this information will be incorporated into the final report that will conclude the Climate Vulnerability Assessment for Erie County, NY.

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INTRODUCTION

Erie County: Erie County, NY, sits entirely within the Lake Erie-Niagara River watershed (BNW, 2014) and consists of 44 municipalities – 25 towns, 16 villages, and 3 cities (Erie County, 2019a). Geographically, the County consists of about 1,277 square miles, 17.5% of that is open water; and there are 77 miles of shoreline between Lake Erie and the Niagara River (URS, 2015). As the 8th most populous county in New York, Erie County government manages extensive infrastructure, including sewers, roadways, and buildings. The County manages over 1,100 miles of sewers, 6 Water Resource Recovery Facilities (WRRF), 5 Excess Flow Management Facilities, and over 90 pumping stations (Erie County, 2019a). Collectively, more than 16 billion gallons of sewage passes through the County's jurisdiction, with 10 billion gallons directly treated and 6 billion passed through to another municipality's WRRFs (Erie County, 2019a). The County manages a substantial portfolio of buildings (more than 220) and fleet vehicles (1,195) (Erie County, 2019a). Additionally, with 1,187 centerline miles of roadways and 290 bridges, the County has the largest system of county-owned roadways in the State (Erie County, 2019a). Collectively, this amounts to a significant responsibility for the County, all of which is subject to a variety of climate-related impacts. Erie County's Department of Environment and Planning (EC DEP) has been proactively working to reduce, mitigate and offset its internal operations GHG emissions and climate impact, as described in its "Climate Action & Sustainability Plan" (Erie County, 2019a).

In addition to the responsibilities related to infrastructure, Erie County government has important roles for emergency, social and health services, and is the leading provider of services for vulnerable populations. Erie County oversees multiple departments relevant to these services, including Departments of Homeland Security and Emergency Services, Health, Labor Relations, Mental Health, Senior Services, Social Services, and Veterans Services, Commission on the Status of Women, and Offices for Consumer Protection, Medicaid Inspector General, People with Disabilities, and Public Advocacy,. With almost 25% of the County's population of minority status, 1 in 5 people in the county considered "vulnerable" (populations that are more likely to experience negative impacts from a given hazard, such as those that are below 5 years of age and above 65 years of age, as defined in the Multijurisdictional Natural Hazard Mitigation Plan Update) (URS, 2015), a 7% foreign-born population, and a 14.9% poverty rate (Data USA, 2020), the County has both critical relationships with and understanding of vulnerable populations, and therefore has a unique role in addressing new threats posed by climate change.

Global Climate Change*:* Rising greenhouse gas emissions are resulting in unprecedented global environmental change (Environmental Law & Policy Center, 2019, Rosenzweig et al, 2011), including changes in temperature and precipitation (Climate Connect, 2020; IPCC, 2013). These climatic changes have been induced by rampant human emissions of greenhouse gases such as carbon dioxide. These emissions result from the combustion of fossil fuels and other human activities. Although greenhouse gases are necessary to make Earth habitable, the increased concentration of these gases in our atmosphere traps a greater amount of heat than what would occur naturally, leading to increases in average temperature across the globe and a variety of other changes in climate trends. **While human civilization has existed for about 10,000 years, and our species, *Homo sapiens,* has existed for about 300,000 years, under our current trajectory temperatures on earth may increase to those that have not been seen for 20 million years** (**Figure 1).**

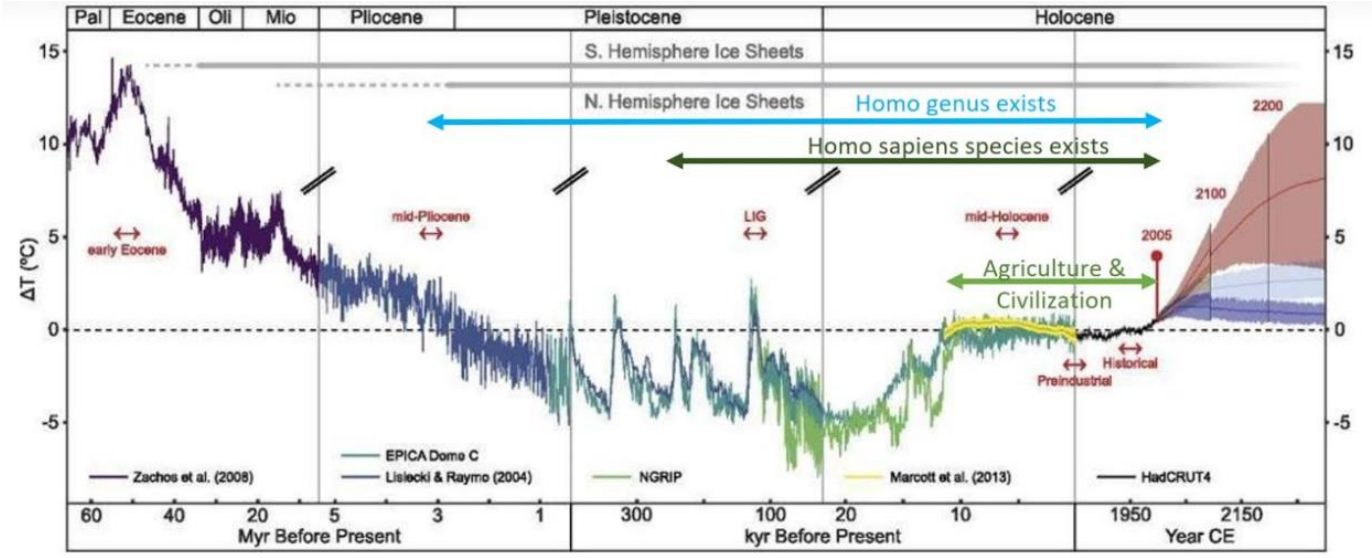

Figure 1: Trends in temperature over the past 65 million years, and projected trends in temperature over the next 200 years.

This includes shifts in the climatic zones that plants and wildlife have evolved with and are adapted to, as shown by **Figure 2** and **Figure 3**. In **Figure 2**, the growing zones mapped by the Arbor Day Foundation show a comparison between the years 1990 and 2015, clearly showing a change in the delineated growing zones. In this analysis, the growing zones that are suited for cold-loving plants have been shifting northward as average temperatures rise. In Parker and Abatzoglou, 2016; future projections were mapped, and this additional analysis further illustrated the northwards shift of climatic growing zones (**Figure 3**). For more background information on climate science, please refer to the Climate Health Connect's "Climate Change 101: Climate Science Basics" report (https://climatehealthconnect.org/wp-content/uploads/2016/09/Climate101.pdf) (Climate Health Connect, 2020).

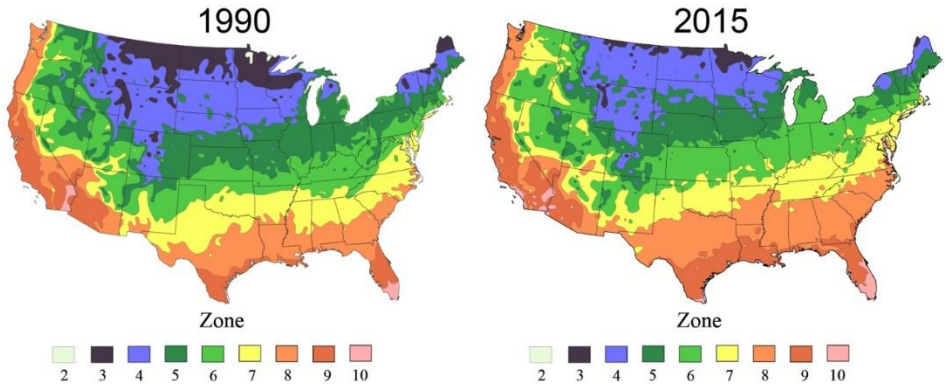

Figure 2: Arbor Day Foundation comparison of temporal changes in growing zones from 1990 to 2015. (Arbor Day Foundation, 2020)

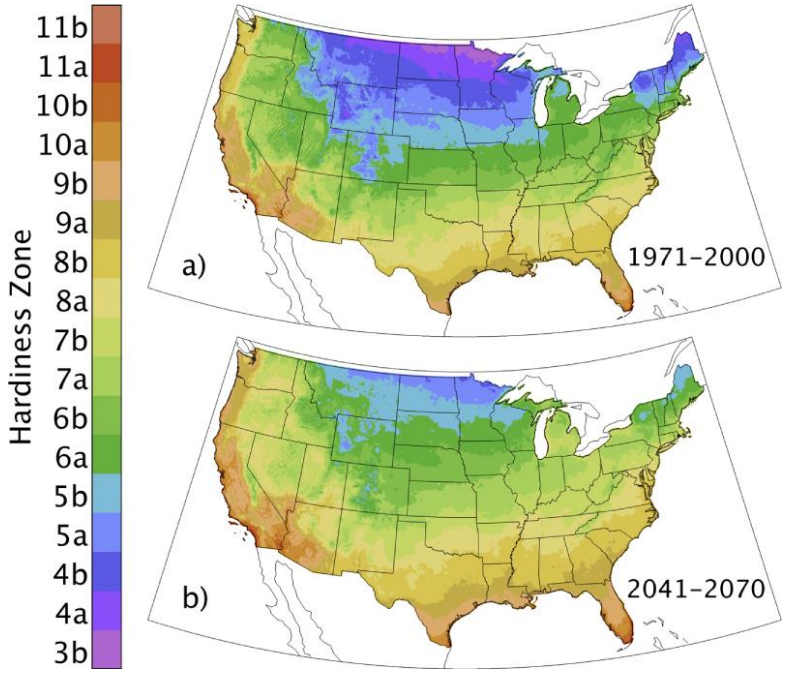

Figure 3: Future projections showing continued northward shift of colder hardiness zones (Parker and Abatzoglou, 2016)

Climate Change in Western NY: Human-made emissions of carbon dioxide and other greenhouse gases are causing warming that is not typical of the historical record. These emissions are likely to result in negative impacts to the western New York region. Increases in average annual temperature, frequency of extreme heat and precipitation events, and alterations of habitat suitability will all bring potentially negative changes to the region. For a detailed information on climate change science and how climate change may impact New York State specifically, refer to "Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State" (Rosenzweig et al, 2011). Data showing historical atmospheric concentration of carbon dioxide (**Figure 4**) (Our World in Data, 2020), and an increase in Erie County's historically observed versus projected temperature (**Figure 5**) (US Climate Resilience Toolkit, 2020) help to visualize these changes. Even under emissions scenarios that assume humans greatly reduce GHG emissions, the challenge to Erie County to protect life and property in our community, and especially to protect vulnerable populations, is significant.

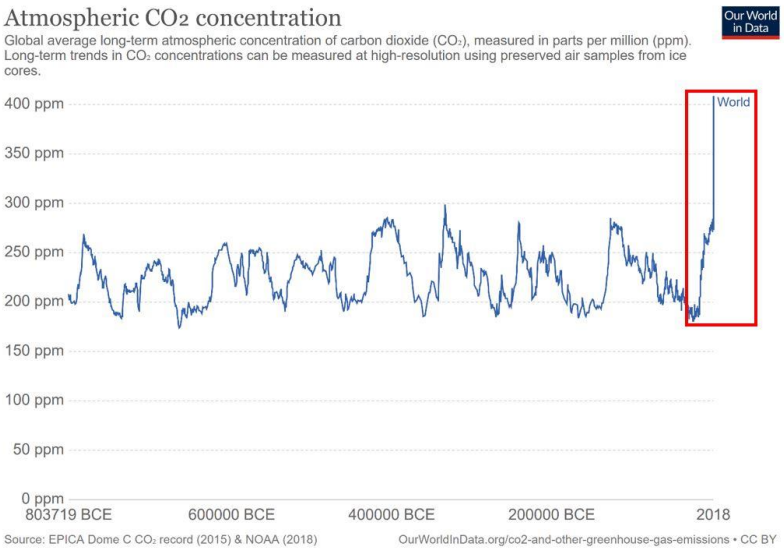

Figure 4: Chart showing measured atmospheric concentration of carbon dioxide over past 800,000+ years. Note nonlinearity of recent increase in concentration outlined in red box (Our World in Data, 2020).

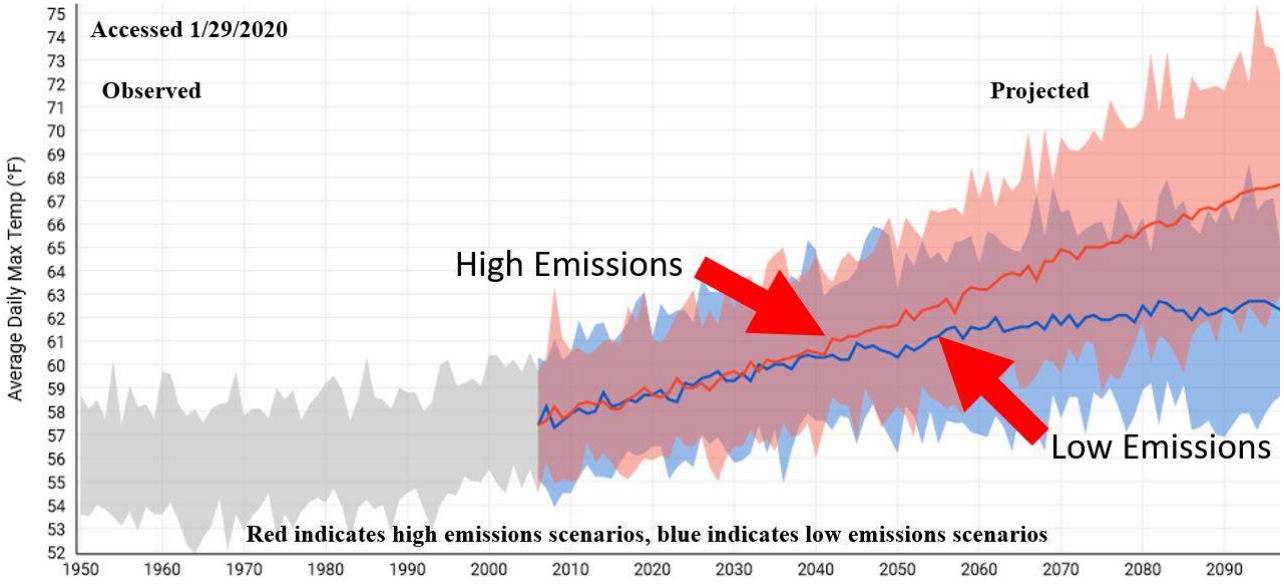

Figure 5: Observed and projected average daily maximum temperature for Erie County, NY (1950 – 2100). Low emissions scenario is shown in blue and high emissions scenario is shown in red (US Climate Resilience Toolkit, 2020).

Climate Change and Extreme Weather Events: While no single weather event is standalone evidence of a changing climate, longer-term trends in frequency and intensity of extreme events inform potential climate change impacts. Trends in temperature change impact the hydrological cycle and can lead to extended periods of drought intermingled with extreme precipitation. For instance, elevated temperatures reduce winter snowpack, which reduces soil moisture, potentially leading to drought conditions (Frumhoff et al, 2007). It may be counterintuitive, but these same changes can also lead to extremes in precipitation, and New York State has seen an increase in extreme precipitation events in recent years (Figure 4) (New York State, 2014). Extreme snowfall is projected to increase in the northeast US as well, something that may be particularly relevant to the Erie County region given the proximity to Lake Erie. As ice cover on the Great Lakes diminishes, the warmer water makes it more likely to drive lake-effect snow, resulting in periods of extreme snowfall. This is evident in current trends in lake-effect snowfall around the Great Lakes basin (Easterling et al, 2017). These extremes take place as warmer air drives moisture off of waterbodies and mixes in the atmosphere, ultimately producing precipitation. Our changing climate can release a vast amount of moisture in a short period of time, especially if the right atmospheric conditions exist (Environmental Law and Policy Center, 2019; Rosenzweig 2011).

Extreme Weather Events in Western New York: New York state is no stranger to extreme events, including flooding, snowstorms, extreme heat and high wind events. Some important past extreme weather events in our area include:

- **The 2009 historic flooding in the Village of Gowanda.** Flooding of Thatcher Brook occurred when extreme precipitation from the collision of two storms dropped a massive amount of water on the Cattaraugus Creek watershed. The flooding left one dead, destroyed the Village hospital and resulted in $1-2 million in damages to the community where at least 25% of the homes in the Village of Gowanda were impacted (Olean Times Herald, 2020; Szabo et al, 2010).

- **The November 2014 winter storm.** A lake effect storm, given the code name Knife by local governments and known colloquially as “Snowvember”, hit the greater Buffalo region and lasted from November 17 to 19. Nearly 7 feet of snow fell in this time on a large portion of the County, resulting in stranded commuters, property damage, and the loss of 13 lives (National Weather Service, 2020) (**Figure 6**).

- **A record-breaking heat wave in July, 2020.** During this heat wave, WNY temperatures soared into the 90+ degree range for multiple consecutive days, breaking weather records for Buffalo, NY for both duration of these temperatures as well as the hottest day on record for July 9th at 98 degrees Fahrenheit. This record was the 2nd hottest of any day in Buffalo as well (Buffalo News, 2020).

- **A July 16, 2020 tornado.** A severe storm resulted in a tornado touching down in Chautauqua County, NY. This tornado destroyed a family barn, causing hundreds of thousands of dollars of damage to the Dewettville property (WIVB4, 2020). Extreme winds associated with thunderstorms have been increasing in Erie County, a potential link to climate-related changes (Vermette, 2017).

Figure 6: Image of the November 2014 winter storm "Wall of Snow" approaching Buffalo in 2014 (NOAA, 2014)

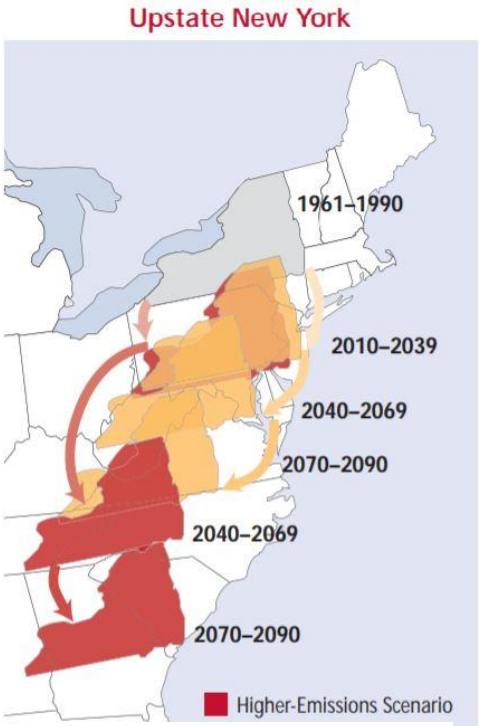

Figure 7: Graphical depiction of NY's "Migrating Climate" (Frumhoff et al, 2007)

As our climate shifts, and potentially "migrates", western NY is predicted to experience more extreme weather events, including possible extremes not historically witnessed before **(Figure 7**). Under certain emissions scenarios, New York State's climate may change to resemble the climates that are typically experienced in the southeast United States. This potentially means longer summers and shorter winters. Given the extremes already experienced in recent years, in a warming world these events are expected to occur more frequently, with increased severity and duration. Extremes in temperature (**Figure 8**) (Frumhoff et al, 2007) and precipitation (**Figure 9**) (New York State, 2014) are often cited as common hazards we may face. However, these changes in temperature and precipitation can lead to other, less-direct threats that may be less obvious.

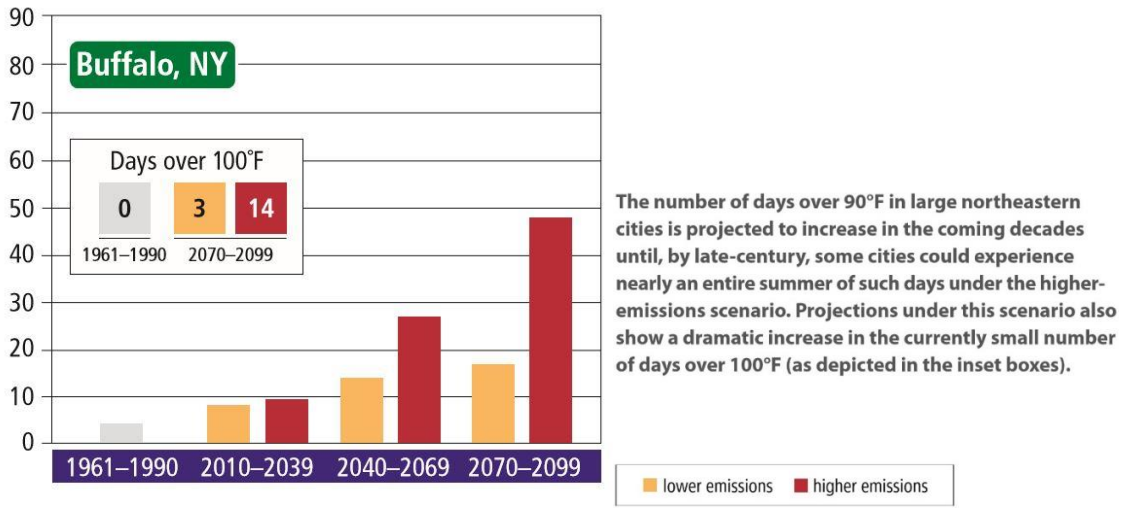

Figure 8: Extreme heat projections (days over 100°F) for Buffalo, NY (Frumhoff et al, 2007).

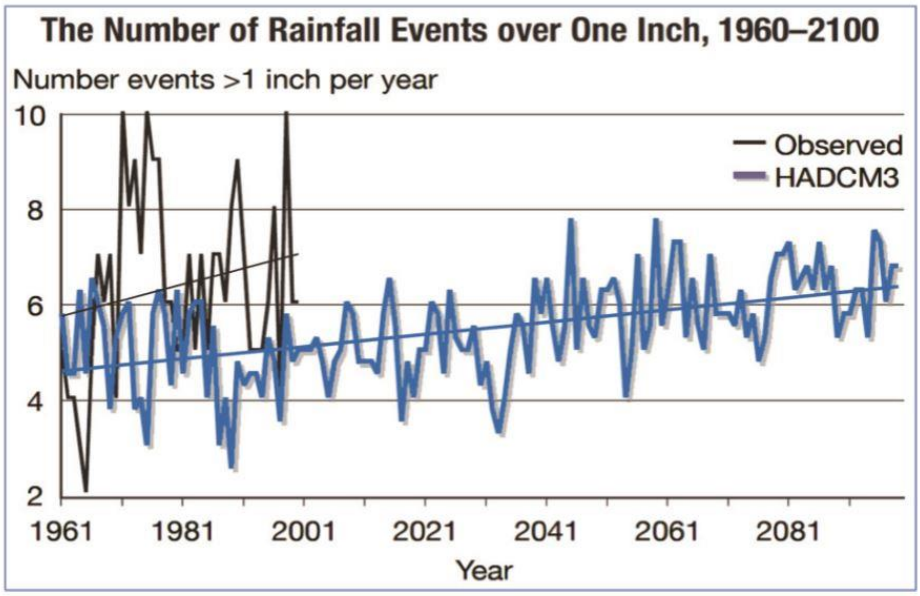

Figure 4. The observed number of rainfall events exceeding one inch from 1960 to 2000 in New York is shown by the black line, and the projected number of such events, using the HadCM3 global climate model, is show by the blue line. These results are broadly consistent with those of the other 15 global climate models used by ClimAID for a high greenhouse gas emission scenario.

Figure 9: Extreme precipitation projections for New York State (New York State, 2014)

In western New York and beyond, the simultaneous convergence of multiple climate change impacts could lead to synergistic effects that amplify the already dangerous changes we may face (Climate Central, 2020). For example, increased incidence of extreme precipitation events can lead to erosion of streambanks. This erosion results in direct loss of arable soil in agricultural land and potential damage to public property. Additionally, the soil lost from riparian zones causes sedimentation in waterways, and

eventual deposition into lakes. This increase in turbidity negatively impacts aquatic ecological communities and delivers nutrients in the form of phosphorous and nitrogen (naturally present in soils) that can cause excessive growth of aquatic macrophytes and harmful algal blooms (HABs). These algal blooms can cause toxic effects on wildlife and pets, as well as humans, and are a major cause for concern in NYS and abroad (New York State, 2019). Harmful algal blooms are also linked to increases in temperature, so climate-related increases in water temperature are a contributing factor in HAB extent, severity, and duration. This combination of extremes in precipitation and increases in temperature may elevate the extent and severity of HABs, impacting water quality for wildlife as well as drinking water supplies (Griffith and Gobler, 2019; Gobler, 2019). Understanding these impacts on municipal governments is critical to ensuring that impacts to public health and safety, damage to infrastructure, and environmental impacts are all kept to a minimum.

The Climate Vulnerability Assessment: Recently, the Erie County Department of Environment and Planning received funding from the New York State Department of Environmental Conservation to conduct a Climate Vulnerability Assessment (CVA) under the State's "Climate Smart Communities" program (New York State, 2018; New York State, 2020). This summary report on Erie County's Climate Vulnerability Assessment (CVA) will aid Erie County in determining climate vulnerability, social vulnerability, and adaptive capacity as it relates to the areas that are under County jurisdiction. Identifying the County's strengths and weaknesses will help guide decision making and planning efforts to prevent or mitigate the impacts that climate change may bring. This assessment will investigate the direct impacts of anticipated climate hazards on Erie County. Additionally, the issues related to climate migration, environmental justice and vulnerabilities to western NY's supply chains will also be incorporated into the assessment. Each are briefly described below.

The Erie County region has recently been described as a potential "climate oasis" (Aldia Environmental, 2020; NBC News, 2020). In general, this is due to the region's proximity to immense freshwater resources found in the Great Lakes and relative mild temperatures that may provide greater ecosystem and economic resilience compared to other regions. However, the issue is complex. The Great Lakes are a massive resource of freshwater, but they are not unlimited. Indeed, these resources have already been strained for decades due to pollution and human development (Environmental Law & Policy Center, 2019), and the additional stressor of climate change may further exacerbate the problem. Combine the existing degradation of these resources with an influx of "climate refugees" or "climate immigrants" from more severely impacted regions, and the resources may not be as rich as once thought. Also, potential changes in temperature across the region are likely to cause negative impacts for residents. Although current residents of Erie County may be used to the frigid temperatures of the winter months, climate refugees coming from warmer locations will be less adapted to this environment. And current residents are likely less prepared for potentially warmer temperatures and more frequent heat waves that are predicted during the summer. For example, Buffalo, NY has one of the oldest housing stocks in the country and many homes lack air conditioning. This makes our region more vulnerable to increasing temperatures than southern regions, and there is also potential for unanticipated extremes beyond modeled projections as climate change progresses.

Because climate change will not affect everyone equally, issues of equity and environmental justice are critical when assessing the impacts of climate hazards. One of the issues with the notion of WNY potentially becoming a "climate oasis" is that it tends to overlook issues of historical gentrification of the cities in Erie County, and risks creating "climate gentrification" as more and more people move to this

region and property values go up. This in turn makes it more difficult for those of lower economic status to own homes and thrive in these higher cost situations. Currently, home values are rising faster in Buffalo than anywhere else in the country, including New York City (Bloomberg News, 2020). Additionally, the most vulnerable among us - the old, young, impoverished, and ethnic minority populations - have historically faced the brunt of the impacts from disasters (Andrew et al, 2008; Peek, 2008, Bolin, 2007; Fothergill & Peek, 2004; Cutter et al, 2003) and it behooves us to consider these populations and the impacts they face as we develop an assessment of Erie County's climate vulnerabilities.

Should the WNY region avoid the worst of direct climate-related impacts, there remains the risk of climate impacts elsewhere on the globe impacting the residents of Erie County, and Erie County as a governmental entity. For example, although the direct impacts of the 2012 Hurricane Sandy in New York State largely centered around the New York City area, there were disruptions in the supply chain here in western New York as a result. Additional risks in supply disruption and municipal financing may be associated with agriculture, water scarcity, and famine in other parts of the world that are far removed from WNY but may impact the region all the same. The risk that climate change has on supply chains is well known to the business community. This awareness is borne out in reports from Business for Social Responsibility, where they explicitly recommend that businesses identify and mitigate issues with climate hazards in their suppliers (Wei and Chase, 2018). Other industry-specific news articles identify climate change as one of several key drivers of potential global supply chain disruptions, listed along with COVID-19 and terrorism (MH&L, 2020). The heightened risk is a cause for concern for the shipping industry, as efforts to get the business community to understand and address these concerns shows (BSR, 2020; MIT Management, 2020). Clearly, we do not live in a vacuum and what impacts humanity elsewhere may very well impact us from thousands of miles away.

IDENTIFYING CLIMATE THREATS TO OUR REGION

This section of the report is focused on assessing Erie County's exposure to a variety of climate-related hazards to identify a few specific hazards that will be analyzed further in this assessment. This is the initial step in the process of developing a Climate Vulnerability Assessment (CVA) for the region. The process of identifying climate threats to Erie County consisted of a thorough literature review of existing climate-related guidance documents for the region, climate related reports, and published scientific literature. Our review of scientific publications particularly focused on literature and data that is based on future climate projections for our region, as opposed to historical data trends. This is due to increasing evidence that environmental change may bring about non-linear, and sometime unexpected alterations in climate (Our World in Data, 2020; Burke et al, 2018; Franzke, 2014; IPCC, 2013). The broad list of potential threats under consideration for further assessment were then refined, focusing on threats that particularly impact Erie County's jurisdictional responsibilities, which will ultimately enable the County to take meaningful steps toward addressing vulnerabilities to these threats in future projects.

The process of identification began with a review of four important climate mitigation guidance documents that illustrate the approaches and methods that Erie County is currently considering, employing, or planning to implement related to climate change, which offer important insights for how

the County is currently thinking about climate and its potential impacts. These documents are listed and summarized below:

- the Climate Action and Sustainability Plan (CASP) (Erie County, 2019a),
- the Multijurisdictional Natural Hazard Mitigation Plan Update (MNHMP) (URS, 2015),
- the Healthy Niagara-Niagara River Management Plan Phase I (BNW, 2014) and
- the Regional Niagara River Lake Erie Watershed Management Plan Phase II (Erie County, 2019b).

In the CASP document (Erie County, 2019a), several sections are devoted to describing and evaluating the impacts, as well as mitigation efforts, that relate to Erie County's governmental activities. The Plan consists of in-depth reviews of the County's infrastructure and associated climate-related impacts and an inventory of their carbon emissions; transportation-related emissions and how to reduce the carbon footprint of county-owned vehicles as well as employee's commutes; waste management and recycling program; County-owned buildings and energy consumption; management of County-owned lands; issues related to stormwater, flooding, and water conservation; how to leverage the County's purchasing power effectively. Finally, a detailed plan on how to achieve the GHG reduction goals outlined in the CASP is included (Erie County, 2019a).

The MNHMP (URS, 2015) describes a total of 14 goals that aim to reduce losses (economic as well as related to personal injury and property damage) from natural hazards. These three goals include these ones that are overlapping with the objectives of this study:

1. improving Best Management Practices (BMPs) to encourage development that is less prone to damage from disasters,
2. capacity building for disaster preparation and response, and
3. overall reducing damage and/or losses from a variety of natural hazards (extreme temperatures, high wind events, winter storms, erosion, flooding, ice jams, earthquakes, mass wasting or landslides, fire), damage to critical infrastructure and facilities, and damage from human activities.

To support these goals, the MNHMP (URS, 2015) detailed a considerable list of actions that may be used (the value and appropriateness of the action depends on local conditions) to achieve the goals outlined above.

The Healthy Niagara – Niagara River Watershed Management Plan Phase 1 (BNW, 2014) and Regional Niagara River Lake Erie Watershed Management Plan Phase 2 (Erie County, 2019b) were authored by a collaborative effort between the Erie County Department of Environment and Planning, Buffalo Niagara Riverkeeper and the Lake Erie Watershed Protection Alliance (LEWPA). They are a treasure trove of information on the myriad natural features in the region and the threats that they face. The Plans also provide an analysis and assessment of these threats, that culminate in 25 Key Findings, as well as subsequent recommendations. The full list of recommendations can be viewed at www.erie.gov/wmp, and relevant examples are outlined in the next section.

These documents are thorough and exhaustive in nature, representing the County's concerted effort to understand and assess the natural history of the region, mitigate or lessen the impacts that the County may have on the environment, and plan for climate-related disasters.

In addition to the four documents mentioned above, many other resources were reviewed as part of our literature review including articles, reports and other documents that focus on a portfolio of potential

threats to our region. These include biophysical threats such as temperature (heat-related mortality and disease, air quality degradation), precipitation (ice jams, flooding, erosion, runoff, snowfall), wind (seiche events, lakeshore flooding and erosion, treefalls), vector-borne diseases (Lyme Disease, Malaria), invasive species (zebra mussel, hemlock woolly adelgid), harmful algal blooms (HABs). Social and economic threats were also assessed via literature on social vulnerability to disasters (risk to minority communities/the economically disadvantaged, children, and the elderly), and impacts to regional and local economies (such as changes to the quality and length of the winter recreation season). Guidance documents such as the Great Lakes Climate Change Report (Environmental Law & Policy Center, 2019), New York State Climate Hazards Profile (Tuzzo et al, 2018), One Region Forward (University at Buffalo Regional Institute, 2014), ClimAID (Rosenzweig et al, 2011), Cleveland, Ohio Climate Hazard and Social Vulnerability Assessment (Esselman et al, 2018), Erie County Natural Resources Inventory (Erie County, 2020), LiveWell Erie (Erie County, 2019c), Initiatives for a Smart Economy 2.0, Focus on Inclusion (Erie County, 2017), Western New York Regional Sustainability Plan (Regional Planning Consortium, 2013), and Resilient Buffalo Niagara (Grover et al, 2014) among others, were also reviewed.

Existing guidance on the topic found in the MNHMP (URS, 2015) highlights multiple hazards that the region may face. These hazards are linked as well as unrelated to climate change; and include natural hazards such as winter storms, earthquakes, severe storms, ice storm events, tornados, landslides, wildfires, ice jams, floods, extreme temperatures, and wave action; as well as man-made hazards such as terrorism, hazardous materials (fixed sites and transit of), fire, transportation accidents, structural collapse, explosions, oil spills, and epidemics (URS, 2015).

An additional concept utilized in the threat assessment process can be found in the PEOPLES Resilience Framework (Renschler et al., 2010; Renschler, 2013; Renschler, 2015; Cimellaro et al., 2016). The PEOPLES Framework features seven interrelated dimensions, across a variety of scales, that are useful for taking a holistic approach towards assessing a system's resilience and sustainability in the face of disruption. The seven dimensions and a brief description of each are provided in **Figure 10** below (Renschler, et al., 2010). This concept was developed by Dr. Chris Renschler from the University at Buffalo, in conjunction with other scientists as funded by the National Institute of Standards and Technology's Engineering Laboratory (Renschler et al., 2010). The PEOPLES Resilience Framework has been shown to be very useful in assessing the functionality of a given system based on perturbations from events such as climate-related natural disasters that change the functionality of services an individual, a neighborhood or a county relies on. Utilizing the PEOPLES Resilience Framework is therefore inclusive and comprehensive in nature and makes sure that the investigators and users of the method take into account a wide range of stakeholder interests and ask relevant questions. This is especially important as our assessment seeks to consider the unequal impacts of climate threats on underrepresented communities in our region.

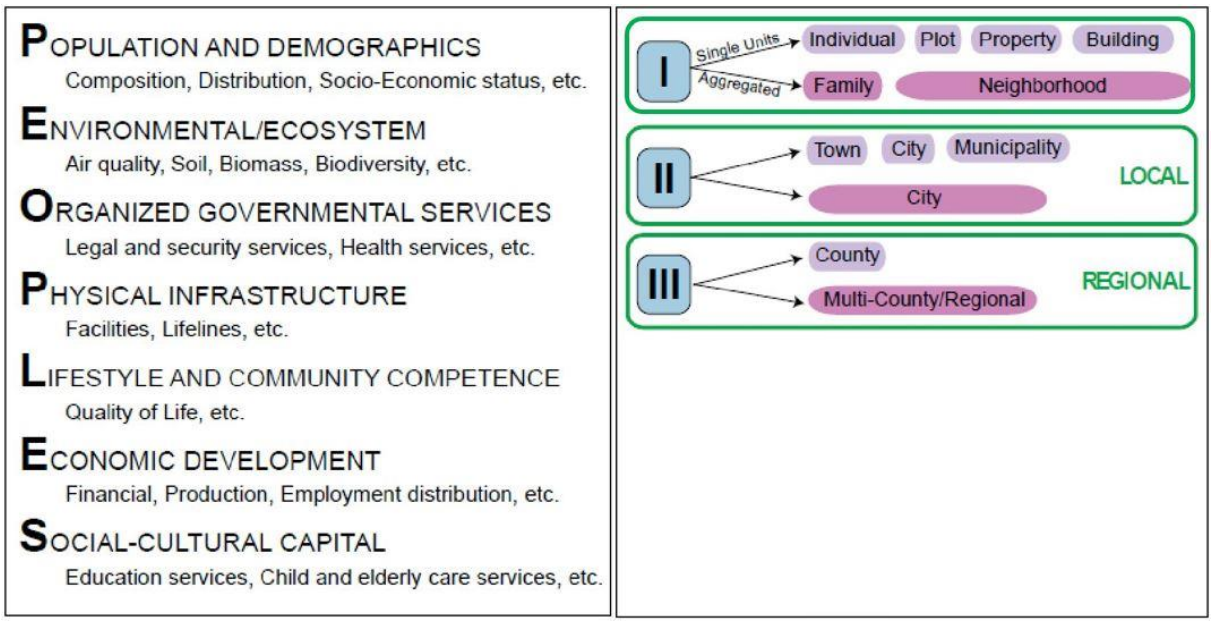

Figure 10: PEOPLES Resilience Framework (Renschler, et al., 2020)

Using the PEOPLES framework to guide our thinking, the CVA team reviewed the potential threats that had been previously identified in the literature. This process is illustrated in **Figure 11**, where the hazards related to changes in temperature and precipitation in the region are compared with the variable scales and dimensions of the PEOPLES Framework. In this example, climate hazards are shown to differentially impact populations based at the individual, neighborhood, business, and municipal (Erie County) level. The threats under consideration were further refined based on the likely frequency and duration of the threat's occurrence and impact, the jurisdictional ability of Erie County to impact the threat, and the overall impact that the threat has on the County (**Figure 11, Figure 12**).

	Vulnerable Populations	Temperature Effects	Precipitation Effects
	**Individuals**, disadvantaged and low income populations (**P E O P L E S**)	Impact to health and finances from air quality impacts and utility costs	Risk to individual health from flooding or heavy snow
	**Neighborhoods**, disadvantaged and low income populations, proximity to risk areas (**P E O P L E S**)	Disadvantaged neighborhoods lack access to warming/cooling stations	Disadvantaged neighborhoods lack disaster preparedness and are slow to recover
	**Businesses,** large shopping centers, small shops, home businesses (**P E O P L E S**)	Cost of heating and cooling	Damage to physical infrastructure of businesses
	**Erie County,** jurisdictional responsibilities – roads, sewers, social support network (**P E O P L E S**)	Extremes in temperature impact County infrastructure, stress budget, and social services	Flooding and snow can impact sewer infrastructure, social services

Figure 11: Consideration of populations vulnerable to two climate-related impacts with the various dimensions of the PEOPLES Resiliency Framework

RESULTS

Based on our review, five hazard categories were selected to investigate further, pending stakeholder review and County confirmation. These categories are:

1. temperature (extreme heat/cold),
2. precipitation (extreme precipitation events and flooding),
3. wind,
4. vector-borne disease (VBD), and
5. invasive species & Harmful Algae Blooms (HAB).

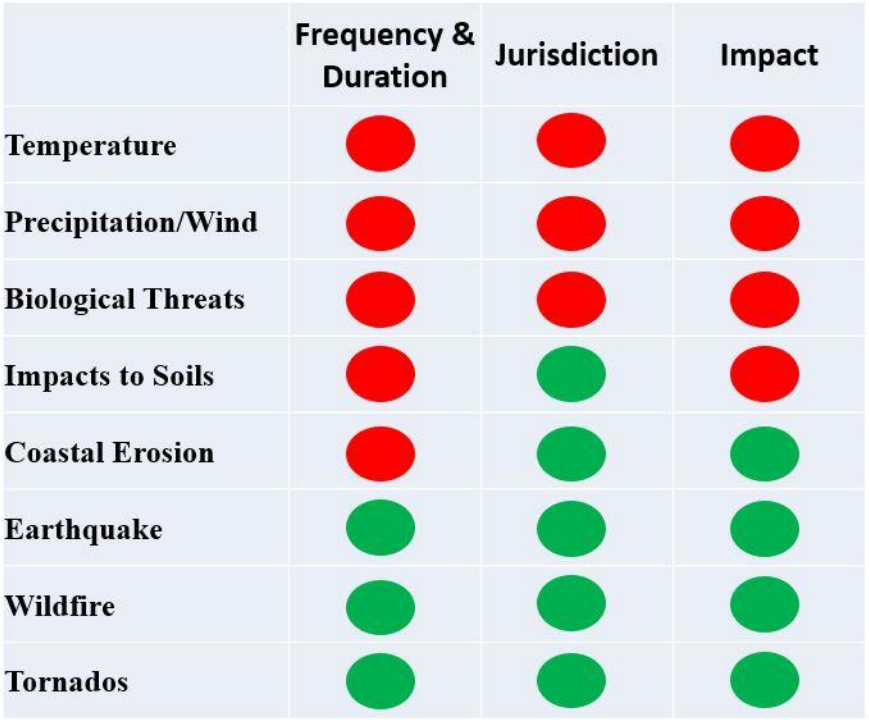

Figure 12: Matrix created using MJHR-identified threats to aid in selecting focus threats for the CVA process. In this decision-making process, green = lower and red = higher.

***Note that certain threats may include multiple subcategories: extreme heat or extreme cold, air quality impacts (temperature); extreme rain events, windstorms associated with thunderstorm events, prolonged drought, or snowstorms (precipitation); and vector-borne diseases, invasive species, and harmful algal blooms (biological threats). While coastal erosion, earthquakes, wildfire and tornados may have impacts, these impacts are of low frequency, localized and are outside the scope of this study.**

The hazards were chosen based on the potential frequency and duration of an event in that category, its relevance to Erie County jurisdiction, as well as the severity of potential impacts of the event (**Figure 12)**. For example, while earthquakes have occurred in the region, they are uncommon and rarely result in

major damage; while flooding does occur with greater frequency and can result in major damage (as described above, regarding Gowanda in 2009). Each of the 5 chosen categories, as they relate to Erie County are briefly described below.

Temperature analysis of the northeast US, western New York, and the Greater Buffalo and Erie County region all point to an upward trend for average temperature. Since 1990, vegetative growing zones have shifted northward and the trend is projected to continue (**Figure 2 & Figure 3**) (Parker and Abatzoglou, 2016; Arbor Day Foundation, 2015; Frumhoff et al, 2007). While increases in temperature and carbon dioxide may increase plant productivity in some instances, overall the increase in temperature is expected to negatively impact crop yields and health of livestock, and may also result in an increase in pressure on agriculture from noxious weeds and insect pests (Walthall et al, 2013). Observed and projected changes in average daily maximum temperature modeled by the US Climate Resilience Toolkit (toolkit.climate.gov/) have an upward trend, whether the low emissions scenario or high emissions scenario is considered (**Figure 4**) (US Climate Resilience Toolkit, 2020). In Buffalo, NY, temperature extremes such as the number of days over 100 degrees Fahrenheit are expected to increase from 0 to between 3 and 14 days (**Figure 8**) (Frumhoff et al, 2007). Climate-related changes in temperature may also impact the formation and break up of ice jams (Das et al, 2017). Ice jams occur when ice builds up in a waterway, damming the water behind the buildup. This in turn creates a dangerous situation, as a substantial volume of water may accrue behind the ice jam and a melting event can release that water creating a flash flood (URS, 2015). Wind can be a contributing factor to development of ice jams. Changes in temperature can also negatively impact air quality when extreme heat events create high levels of ozone. This can be a public health concern in regions not previously experienced in dealing with such events (**Figure 8, Figure 12, Figure 14**) (APHA, 2020; Hamstead et al., 2018; Jacob and Winner, 2009).

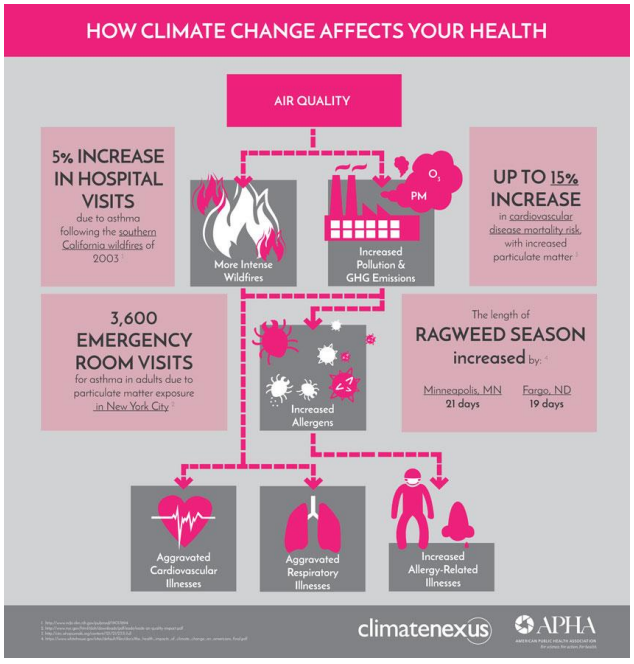

Figure 13: How air quality degradation (from wildfires, allergens, temperature etc.) attributed to climate change can impact your health (APHA, 2020)

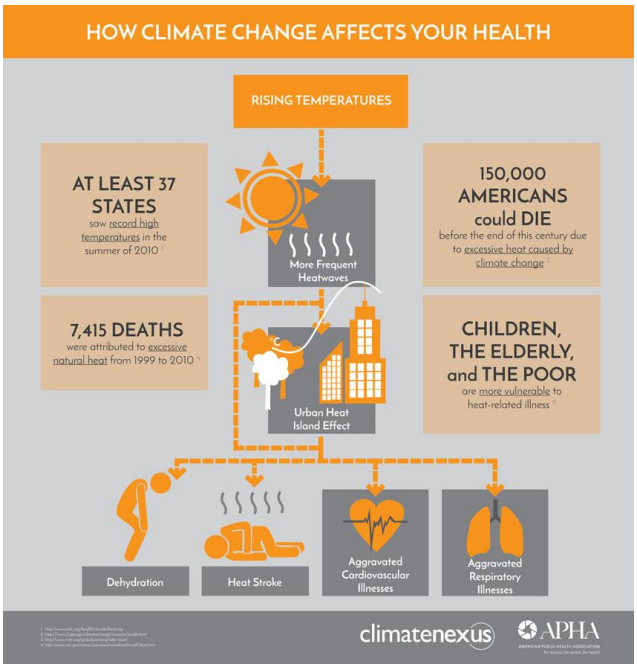

Figure 14: How climate change-related changes to temperature affect your health (APHA, 2020).

Precipitation patterns have changed in New York State. The number of rainfall events that produce precipitation in excess of 1 inch have increased over the past 50 years and the events that produced more than 2 inches of precipitation has had the highest frequency in the past 10 years, this is expected to increase further over the next several decades (**Figure 9**) (Frankson et al, 2017; NYS Environmental Protection Bureau, 2014). Annual precipitation is expected to increase by 5-15% in the region, with less precipitation in winter and spring and more precipitation in fall and summer (Easterling, et. al., 2017). Snowfall will also be impacted. While the overall amount of winter precipitation isn't expected to decline, the timing and intensity of storms may change. Erie County is expected to see a decrease in precipitation overall in December, winter storms are projected to produce more rain than snow, and when it does snow the intensity of snowfall may be more severe with short durations of heavy snow (Notaro & Lorenz, 2013). Heavier, more intense, precipitation can lead to increased physical and chemical weathering (Chapin et. al., 2002). Physical weathering will take place from increases in freeze-thaw or wet-dry events, which creates and widens physical cracks in substrates such as bedrock, concrete, and pavement. Additionally, heavy rain can lead to saturated soils and splash effects that may exacerbate erosion. Increases in precipitation may also exacerbate chemical weathering through elevated acidity stemming from the dissolution of carbon dioxide in rainwater – creating a weak, albeit still acidic, carbonic acid. These impacts combined with increases in temperature can also lead to higher rates in chemical reactions which in turn increases chemical weathering. Alterations in precipitation patterns may negatively impact the agricultural community in Erie County. As variability increases, more arid conditions may reduce crop yields and extremes in precipitation may increase rates of erosion and directly lead to loss of prime farm soils (Walthall et al, 2013). Precipitation can also interact with wind. Over the past 20 years, there has been a significant increase in wind associated with thunderstorms (**Figure 15**), illustrating the interrelated impacts that climate change may bring (Vermette, 2017). From

the Erie County perspective, these potential changes can mean challenges in managing stormwater flow, excess inputs to sewer lines (and associated overages of flow that release untreated wastewater into waterways), and damage to infrastructure from physical weathering, chemical weathering, and storm damage. Vulnerable populations may be more at risk through low-income residences located in a floodplain, or through a lack of ability to recover from the financial aspect of flood damage.

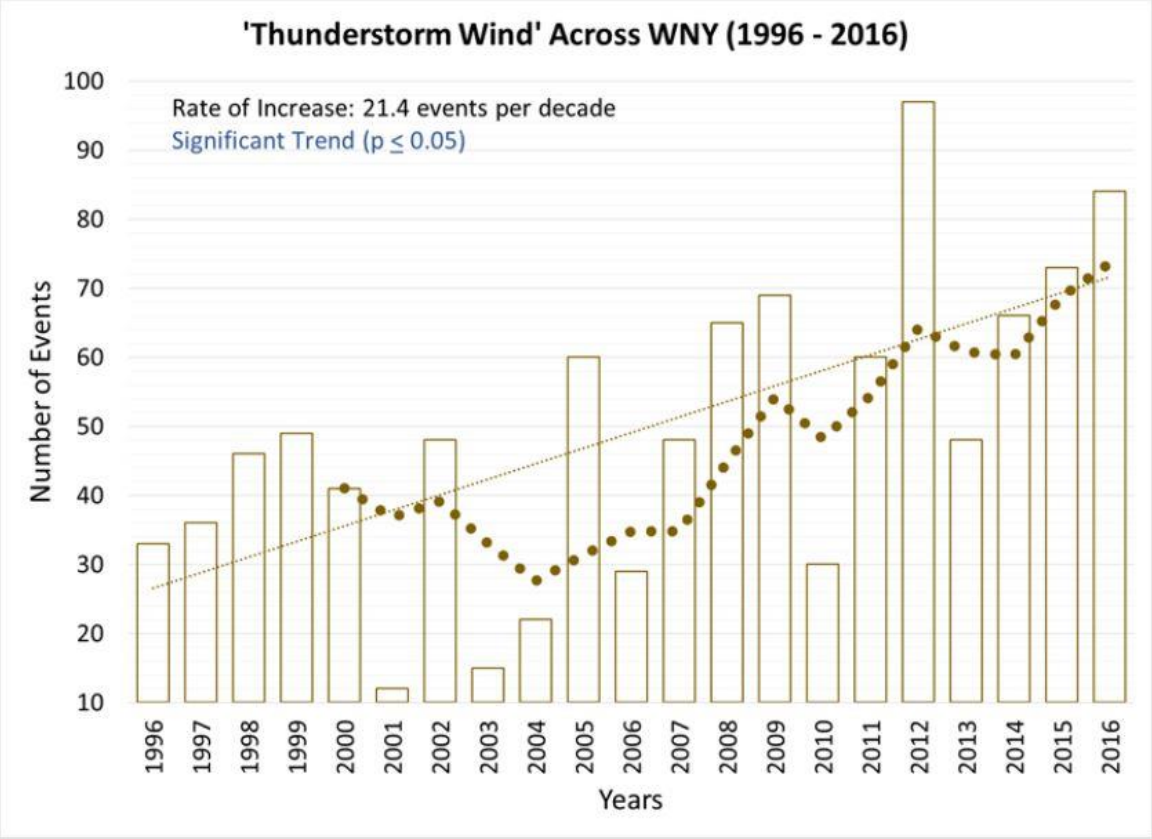

Figure 15: Frequency of thunderstorm wind events reported for WNY (1996-2016) (Vermette, 2017). Data for this chart was obtained from NOAA's Storm Events Database. Here, 'thunderstorm winds' are defined as winds arising from convection (occurring within 30 minutes of observed or detected lightning) with speeds of at least 58 mph, or winds of any speed producing a fatality, injury, or damage).

Wind, according to the MJHR (2015 the entirety of Erie County within an "extreme wind hazard area", and that historically this hazard has cost the region millions in property damage and crop failure (URS, 2015). Additional literature on the topic suggests that climate change may have profound impacts on wind currents surrounding large bodies of water like Lake Erie (Desai et al, 2009), as well as an increase in annual-mean wind speed values in the future (Eichelberger et al, 2008). This may also lead to changes in ice jam formation and break up while the Lake still has ice formation in the winter, although more modeling is needed to assess this factor (Das et al, 2017). Increases in extreme wind events can exacerbate the damage that has historically been done when these events occur (such as ice jams),

leading to additional property damage, crop failure, and potentially wind-related erosion. In regard to extreme wind events such as tornados, western NY has not had the number of events that other regions of the country have. However, a review of the tornado occurrences between 1950 and 2020 indicates that these storms are increasing in frequency – at least over the long term. The period spanning 1950 to 1990 had 8 tornado events, while the period between 1990 and 2020 had 14. Extreme wind can also lead to lakeshore flooding from seiche events, which for Lake Erie are waves resulting from oscillations in lake levels due to atmospheric events. In the Great Lakes, this is largely due to a rapid alteration of barometric pressure gradients resulting in higher wind speeds (URS, 2015). A review of the last 20 years of data indicates that a seiche event occurs on average once every year, with property damage occurring in 11 of those 20 events (NOAA, 2020). In the CVA process, wind will be incorporated into both temperature and precipitation-related analyses, as it is a key factor in both extreme temperature and precipitation (e.g., thunderstorms, **Figure 15**) related events.

Vector-borne diseases (VBD), such as those related to mosquitos and ticks, can be influenced by changes in climate which can lead to changes in habitat suitability for organisms involved (Brownstein et al., 2005). Alterations in average temperature and rates of precipitation can lead to the ability of these organisms to expand their geographic range and can also lead to changes in their behavior (Tuzzo et al, 2018; Gubler et al., 2001). Overall, this can lead to an increase in tick-borne and mosquito-borne disease in Erie County (APHA, 2020). Expansion of the range of the Asian tiger mosquito (*Aedes albopictus*), a species associated with multiple diseases (chikungunya, dengue, West Nile virus etc.) may occur in the Erie County region over the next several decades (Rochlin et al., 2013; Alto & Juliano, 2001), and research on ticks point towards a range of biogeographical factors associated with population increases (Khatchikian et al., 2013).

Invasive species refers to any organism that is found outside of its natural range, and that causes negative impacts to ecological relationships, human economies and public health (WNY PRSIM, 2020). This issue is increasingly recognized as a serious threat, and the same alterations of climate and habitat that may result in range expansions in VBDs pose the same risks regarding invasive species (Tuzzo et al, 2018), which in turn translates to an exacerbated level of negative impact to terrestrial and aquatic ecosystems (Hellman et al, 2008; Rahel and Olden, 2008; Mainka and Howard, 2010). Harmful Algal Blooms (HABs) occur when certain species of aquatic life, such as cyanobacteria, proliferate above their background population levels in freshwater systems such as Lake Erie. These species of cyanobacteria, and others, may create harmful levels of microcystin toxins and other compounds, which can be harmful to human health, pets, and wildlife (NYSDEC, 2019). This issue may also become exacerbated from the impacts of climate change (**Figure 16**) (Griffith and Gobler, 2020; Gobler, 2019).

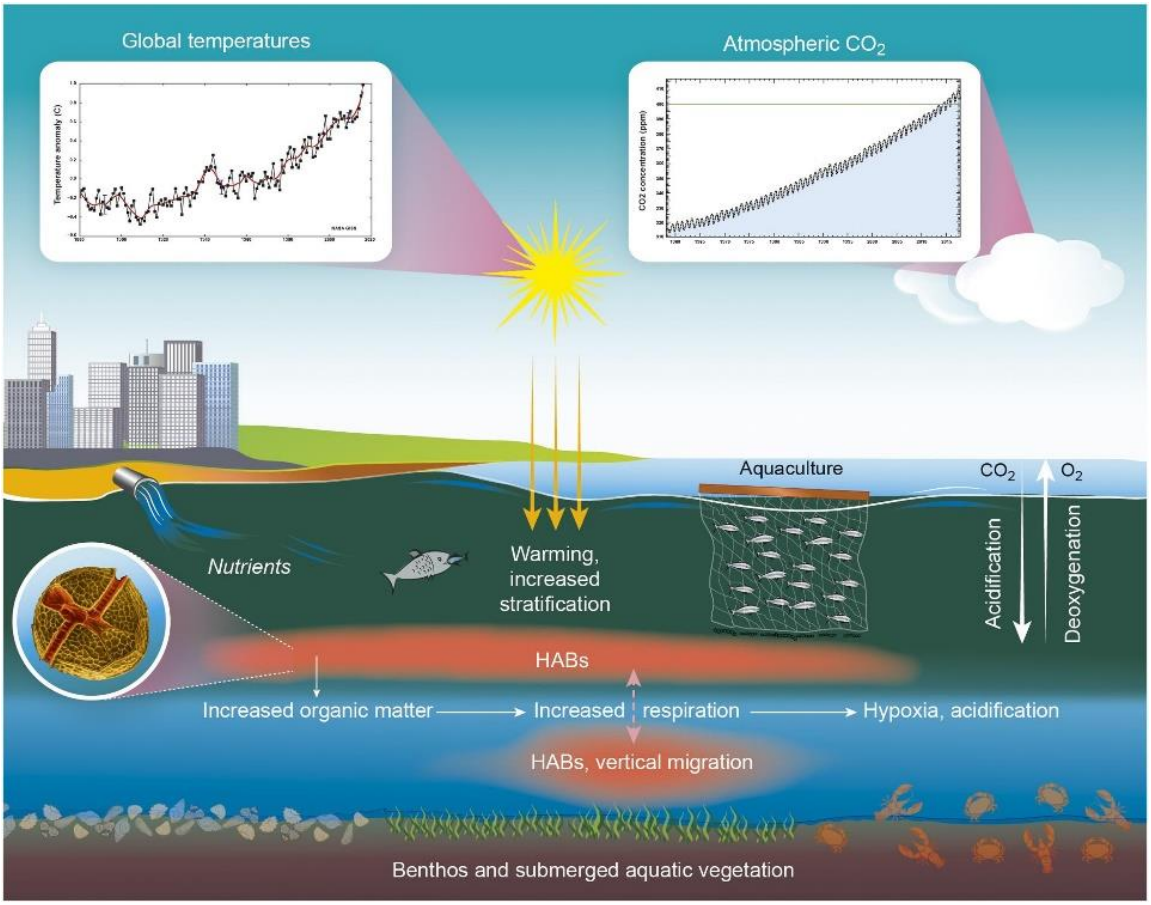

Figure 16: Interaction between climate change impacts and HABs as temperature, carbon dioxide, and nutrients (exacerbated by extremes in precipitation) synergistically react with each other to elevate the frequency, duration, and severity of HABs (Griffith and Gobler, 2020).

NEXT STEPS

The hazards outlined above are not the only threats Erie County may face that are related to climate change. This summary of the Climate Vulnerability Assessment (CVA) for Erie County lists some of the main threats and should be considered as a starting point in analyzing where and to what extent certain hazards may impact the County across time and space. The next step of the CVA includes geospatial analysis of the identified threats, and of what populations and infrastructure are most sensitive to their impacts. This analysis will include the use of the CDC Social Vulnerability Index, which uses a variety of social factors at the census tract level (i.e., economic data and data regarding education, family characteristics, housing, language ability, ethnicity, and vehicle access) to depict the social vulnerability of communities to disasters. The final step will be to assess the adaptive capacity of the County government to be able to address and recover from the identified threats. Currently, University of Buffalo is developing geographic information systems-based (GIS) methodologies to analyze and spatially map these hazards.

Building on previous work by Hamstead et al. (2018) our team is updating a local thermal vulnerability assessment to identify hotspots within the County that are particularly vulnerable to extreme heat and cold conditions. Also, a flood hazard index (FHI) is being developed that compiles metrics from several data sources and creates a numerical index of flood risk that can be spatially mapped to identify areas of concern (Forkuo, 2011; Sanyal & Lu, 2005). The methods used in this study are adapted from these and other literature (Kabenge et al., 2017; Kazakis et al., 2015; Bapalu & Sinha, 2005;), and will include parameters such as elevation/slope, land cover and land use, FEMA-designated flood zones, population density, and tax map parcel density; as well as factoring in climate scenarios produced by the Environmental Protection Agency across two return periods (EPA, 2020). This index is in the process of being improved upon and validated.

To assess the threat of expanded range and subsequent impact from vector-borne diseases and invasive species, this project is investigating the utility of a mapping application created by the United States Fish and Wildlife Service (USFWS). The program is called the "Risk Assessment Mapping Program" (RAMP), and is an application used in ESRI's ArcMap GIS to map invasive species in conjunction with range shifts attributed to climate change (Sanders et al, 2018). In a proof-of-concept phase, this program will be used to assess the potential range expansion of an invasive, disease-causing species of mosquito. The Asian tiger mosquito (*Aedes albopictus*) has been linked to diseases such as chikungunya and West Nile (WNV) and has the potential to spread from southern New York to western New York (Rochlin et al, 2013). If appropriate, RAMP will be used to analyze species of ticks, HABs and certain invasive species (to be decided upon pending appropriate utility of the RAMP program).

Collectively, these various indices and geospatial analyses will be incorporated into the CVA process so that they can be cross referenced with existing Erie County services to identify where the most sensitive populations and infrastructure are located, who the most sensitive populations are (again, to incorporate climate equity in our analysis), what specific hazard(s) may impact them, and the extent of the anticipated impact. This data is then used to inform the assessment of Erie County's adaptive capacity to respond to these hazards. Finally, a set of recommendations for mitigation measures, future planning needs, and other information will be included in the final CVA report, which is projected to be released in early to mid-spring, 2021.

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