CLIMATE CHANGE ADAPTATION IN GREAT LAKES CITIES

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EXECUTIVE SUMMARY

For decision-makers in the cities of Toledo, Dayton, Elyria, and Avon Lake, Ohio, climate change is quickly becoming a planning and policy concern. The latest climate science focusing on the Great Lakes region largely supports these concerns. Climate models predict warmer temperatures, shifting rain and snow patterns, and an increased likelihood of extreme events by the end of the 21st century. Scientists also predict that lake levels will likely be lower, with additional impacts on aquatic species, as well as impacts upon the industries of tourism and trade. The anticipated impacts of climate change will likely not be distributed equally across each city included in this study. However, societies have the capacity to adapt in the face of climatic change and have done so in the past. Researchers have identified a variety of resources, assets, and governance structures that increase the ability and likelihood of successful adaptation—even in the face of significant uncertainty.

In order to anticipate and successfully respond to these impacts, cities in the Great Lakes region need to better understand the opportunities and constraints within their current governance structures to build their adaptive capacity. To evaluate this capacity, we conducted an Integrated Assessment (IA) of the four cities mentioned above in the state of Ohio. Our study takes a broad view of the political, social, and ecological causes, consequences, and potential solutions to climate vulnerability and impact reduction. The results of our study describe the capacities and constraints each city possesses, as well as identifies best practices cities can implement to take advantage of these capacities and overcome constraints.

While each city had specific capacities and constraints based on our analysis, several overarching themes emerged. First, decision-makers in each city expressed interest in adapting to climate change. Leaders within city governments are working to connect issues of sustainability and adaptation to the core mission of their departments, as well as forming policy networks across the city, to accomplish broader adaptation and sustainability goals. Employees throughout each city also demonstrated dedication to improving the vibrancy of the cities within which they work. They displayed a depth of knowledge and creativity in accomplishing department tasks in the face of severe financial constraints. Overall, leadership and the quality of current city employees emerged as key capacities throughout our study.

However, there are significant constraints to adaptation as well. Two broad trends identified are scarce financial resources and limited access to scientific knowledge. Interviewees reported financial resources significantly constrained adaptation and sustainability action. Identifying methods to utilize co-benefits of standard operating procedures and practices to enhance climate adaptation needs, as well as increasing flexibility in funding structures, are strategies that can aid in minimizing this constraint. Moreover, consideration of the potential distribution of impacts from climate change when implementing adaptation and sustainability policies can ensure the most effective, economic and equitable actions are taken. The availability of usable climate knowledge, along with other kinds of knowledge needed to inform decision-making about adaptation, is limited across the four cities. Knowledge in this case includes not only an understanding of anticipated climate change impacts, but also how it interplays with other kinds of knowledge (e.g. socioeconomic, health and ecosystem management related data) that inform cities' decision-making.

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ABSTRACT

Can the cities and people of the Laurentian Great Lakes adapt to climate change while improving economic, social, and ecological resiliency? Answering this question requires understanding how social, economic, political and ecological processes interact over various spatial and temporal scales to shape climate adaptation needs. Climate models project warmer temperatures and shifting precipitation patterns with an increased likelihood of extreme events by the end of the 21st century. To better understand how the Great Lakes region can adapt to climatic impacts, we carried out an Integrated Assessment (IA) of the adaptive capacity of four cities in Ohio (Avon Lake, Dayton, Elyria, and Toledo). In particular, we assessed the various capitals, capacities and constraints in these four cities to respond to climatic impact. Further, using the adaptive capacity wheel, we assessed how institutions of urban governance are likely to constrain or facilitate adaptation in the cities.

To support our IA, we conducted a total of sixty-two interviews with city policy- and decision-makers. Using qualitative coding software, we organized and analyzed our qualitative data to identify leverage points, synergistic projects, and partnerships. Overall we find that each city is experiencing significant financial constraints, limits on the knowledge available, and a diverse perception of risk distribution and priorities related to anticipated climate impacts. Approaches to improve risk management and reduction include broad stakeholder engagement, private-public partnerships, and forming and engaging in regional networks. Using the adaptive capacity wheel to identify institutional constraints and opportunities, our research offers lessons and methods to better understand how governance of climate change adaptation can progress.

INTRODUCTION

For decision-makers in the cities of Toledo, Dayton, Elyria, and Avon Lake, Ohio, climate change is quickly becoming a policy and planning concern. Numerous city employees and elected officials reported being concerned about lake level change, invasive species, heat events, and severe weather. However, they also stressed the difficulty of addressing the effects of climate change on people, ecosystems and infrastructure. Across the four cities, officials were quick to point towards the vast difference climate change represents in the way they make decisions—no longer does the past suggest the future.

The latest climate science focusing on the Great Lakes region largely supports these concerns. Climate models predict warmer temperatures, shifting rain and snow patterns, and an increased likelihood of extreme events by the end of the 21st century (Hinderer, 2010). Scientists also predict lake levels to be significantly lower, with additional impacts on aquatic species, as well as impacts upon the industries of tourism and trade (GLRA, 2000; Pryor, 2012). However, the specific impact climate change will have in the Great Lakes region still remains uncertain. The accuracy of downscaled climate models still remains low and there is much uncertainty about the role mitigation will play in shaping future climate change—a wide-range of future emissions trajectories remains possible as international negotiations over climate change continue. Perhaps most difficult of all, great ambiguity exists around how to best adapt to climate change.

However, societies have the capacity to adapt in the face of climatic change and have done so in the past (Adger, 2003; Adger and Vincent, 2005; Adger et al., 2009; Engle, 2011; Lemos et al., 2013; Smit and Wandel, 2006). The Intergovernmental Panel on Climate Change defines adaptation as an "adjustment in human and natural systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities" and further posits there are at least three forms of adaptation—anticipatory, autonomous, and planned (IPCC, 2007, Glossary). Researchers have identified a variety of resources, assets, and governance structures that increase the ability and likelihood of successful adaptation—even in the face of significant uncertainty. Many have theorized about and explored empirically how these resources and assets build the capacity of different systems to adapt to climate-driven disturbance (Adger and Vincent, 2005; Eakin and Lemos, 2006). Broadly defined, adaptive capacity is the ability of individuals, households, or societies to utilize resources in order to reduce vulnerability or enable livelihoods to change.

While support for climate policy and adaptation has been slow to develop across the US (Lemos and Rood, 2010), there is evidence of growing awareness among the public of climate change as problem and its impacts as a public policy issue. In January 2010, 57% of Americans believed that climate change is occurring; by September of 2012, this number jumped to 70% (Leiserowitz et al, 2012a). In the Great Lakes region, a recent public survey (GLAA-C, 2013) shows that 78% of participants believe that we are in a period of climate change; 47% anticipate climate change will lead to adverse impacts in the Great Lakes Region, and 25% believe that they themselves or their families face risk from climate change impacts. More importantly for this study, a majority (69% and 55% respectively) of respondents believe that local government should take action to protect their community against climate change impacts and that universities are a trusted source of climate change information. These results may indicate the popular support for adaptation is increasing in the region, which may, in turn, support local city authorities' efforts to build adaptive capacity.

For all these reasons, we sought to assess the capacity cities in the Great Lakes region have to adapt to potential climate change. To evaluate the adaptive capacity of cities in the Great Lakes region, we conducted an integrated assessment (IA) of four cities in Ohio: Avon Lake, Dayton, Elyria, and Toledo. An IA combines an analysis of the social, ecological, and governance components of an issue in order to better grasp the causes, effects, and potential solutions of complex, interdependent problems (Sea Grant, 2009). To achieve our IA goals, we first reviewed the literature focusing on adaptation to climate change and, second, collected primary data through in-depth, stakeholder interviews to understand the opportunities and

constraints for each city to respond to climate change impact. We particularly focused on local concerns regarding climate change, current policies to deal with climate change, and the capacity to identify and manage risk to future impacts in light of uncertainty and resource constraints.

The goal of this project is to help cities further increase their capacity to adapt to climate change so that they can minimize tradeoffs, unintended consequences, and maladaptations to climate variability and change and take better advantage of their current strengths and resources to maximize positive synergies between what they currently do and the capacities they need to build. Our ultimate goal is to support our case-study cities to move towards greater resiliency to climate effects. It is our hope that the integrated framing of our research will allow stakeholders and decision-makers to better understand the current capacities, barriers, and potential for adaptation within their cities and the broader region. Further, by identifying strengths and weaknesses in each city, we locate opportunities for the sharing of best practices, experiences, and resources to create a more resilient Great Lakes area.

To accomplish this, we utilize and combine the aforementioned literature on urban climate planning, institutional change, and adaptive capacity. In particularly, we draw upon the adaptive capacity wheel (Gupta et al., 2010), which is an analytical tool to assess the adaptive capacity of institutions. In our study, the decision level of interest is city government. We analyze these results within the context of factors found to be important in facilitating adaptive actions in the broader urban planning and adaptive capacity literatures. In particular, they highlight the importance of policy entrepreneurs connecting adaptation priorities with broader policy priorities, while recognizing the broader context of vulnerability, flexibility, and capacity to implement and administrate policies (Anguelovski and Carmin, 2011; Carmin, Anguelovski, and Roberts, 2012; Eakin and Lemos, 2006; Smit and Wandel, 2006).

We identify institutional mechanisms that governments and policymakers can utilize to implement programs that reduce vulnerability to risks associated with climate change. We recognize that actions taken to address climate impacts have the potential to create tensions or trade-offs with other adaptation initiatives, climate mitigation efforts, sustainability goals, development needs, and overall resiliency (Brown, 2011; Harmin & Gurran, 2009; Luakkonen et al., 2009; Shaw et al., 2007). Additionally, ill thought-out plans can end up becoming maladaptations that in effect increase vulnerability (Barnett & O'Neill, 2010). However, it is also possible that adaptation efforts can have positive synergies with other goals (Lemos et al, 2013). While acknowledging these potential outcomes, we take a systematic and integrative view of city adaptation and resilience that considers the overlapping and interacting nature of stresses and risks, outlined in the following *Research Methods* section.

RESEARCH METHODS

Assessing adaptive capacity is difficult. Most scholars argue that adaptive capacity is a latent quality of a system and observable only when individuals call upon it to actually adapt to a stress (Engle, 2011). Because of this, researchers have identified determinants of adaptive capacity, which describe the assumed preconditions likely to increase the potential of any system to adapt to climate change. Broadly defined, these determinants include: social capital; human capital; financial capital; political capital; institutions and entitlements; and technology and communication (see Table 1). To accomplish our project goals, we conducted 62 interviews with key decision-makers and stakeholders in four Ohioan cities to assess the overall levels of these determinants (often divided into more specific components) in each city. After coding informant interviews and organizing the database in NVivo, we utilized the adaptive capacity wheel (Gupta et al., 2010) to identify current strengths facilitating potential adaptations and weaknesses constraining them. Moreover, we created GIS maps displaying the explicit spatial distribution of climate change exposure and sensitivity in Avon Lake, Dayton, Elyria, and Toledo.

In our interviews, we asked scripted questions, designed to elicit responses, elucidating each city's ability to cope and adapt to climate change. Broadly, the questions we asked centered on the following issues:

- What are opportunities and challenges for Great Lakes cities to respond to climate change?
- What are the main drivers building adaptive capacity across the four identified research sites?
- What have individual research sites done to build adaptive capacity?
- What have the research sites done to build adaptive capacity?
- What policies and projects are being implemented in the four research sites to adapt to climate change?

In order to answer these questions, we first needed to understand the complexities of institutional structures, budgets, networks, and histories, among many other factors, for each city surveyed. We selected cities based on population size and location. Our study consists of a large and small coastal city and a large and small in-land city[1]. We sent letters to 58 cities in the Great Lakes region asking cities to participate in our study. Seven letters were returned expressing willingness to participate; of those willing, we selected four cities in Ohio. Between August and December 2012, we visited each of the cities to carry out our interviews. We identified specific people to interview both through the cities' webpages (e.g. sectors and departments of interest) and through 'snowballing' from one key informant to another. In each city, we interviewed key city officials from different departments and agencies expected to be involved in adaptation planning and action. Additionally, we interviewed individuals not directly associated with the city governments who are involved in projects touching upon adaptation. These interviewees included state and regional government employees and civil society leaders. Each interview lasted roughly sixty minutes and focused on assessing and better understanding opportunities and constraints to building adaptive capacity. We asked interviewees about their perceptions and concerns of climate change, current adaptation or sustainability initiatives within their departments and/or city at-large, current capacities and constraints to respond to projected impacts, and inter-institutional networks and support that could facilitate adequate response to projected impacts. For the purposes of our research, we broadly define support as including perceptions of climate change, leadership taken on the issue, and willingness to adapt.

The recorded interviews were then transcribed over a period of four months. We uploaded these transcripts to NVivo 10 data management software. We removed identifying information from each interview and assigned them a numerical value that corresponded to an identity kept in a secure spreadsheet. Utilizing a codebook we developed, we coded each interview for variables of interest, aligned with the determinants of

[1] This method is consistent with GLAA-C sampling guidelines (see appendix)

adaptive capacity. We controlled for quality by having each member of our research team read every interview, thereby guaranteeing that everyone was individually familiar with each city's capacities and constraints. After completion, we used NVivo 10 software to assist our analysis of results by organizing every data point of relevant information for synthesis into this report. We used this information to support our analysis of how to compose each city's adaptive capacity wheel and recommend pathways each city can take to increase their adaptive capacity and resiliency to climate change.

Finally we created risk indices (vulnerability) maps for each city using geographic information system (GIS). GIS is a tool that enables data to be visualized and analyzed for the purposes of examining spatial relationships, patterns and trends (ESRI, n.d.). In this study, GIS was used to augment the city interview analysis by delving into data to identify areas within each city where populations may be more vulnerable to anticipated climate change impacts and may be targets for program and policy intervention. The maps created can serve as a starting point for expanding decision-maker knowledge and streamlining resource use to areas that may be most at risk.

Data used for analysis included demographic information from the 2010 U.S. Census and 2006-2010 American Community Survey, 100-year flood plain data from FEMA, and a variety of city specific data including boundaries, roadways, rivers, and land use. The demographic data was downloaded according to block group and included percentage of the population below 2010 poverty level, percentage under 5 years of age, percentage over 65 years of age, and percentage minority. These demographics were of particular interest, as research has shown these groups may be most vulnerable to climate change impacts, particularly heat events (USGCRP, 2008). Localized flooding due to increased storm intensity, access to green space, and, in Dayton and Toledo, proximity to high concentrations of vacant land, were expressed as concerns by interviewees. Green spaces help mitigate urban heat island effect, a projected climate impact on urban areas that will likely affect vulnerable populations (Altman, 2012). Citizens living near 100-year flood plains will likely be affected by a great incidence of flooding events (NOAA, 2012). Distance to areas with high vacancy was included in these risk indices because a few public officials in Dayton and Toledo expressed concern about the spread of disease vectors due to waste dumping on vacant property. Block groups and neighborhood boundaries were overlaid to allow for visual reference. In addition to the equally weighted maps included in the appendix, maps with highest risk weighting for proximity to flood plain, proximity to green space, proximity to high vacancy areas, and population demographics are available in appendix.

These data were combined in a weighted calculation to identify areas where the combination of these variables may increase their risk relative to the rest of the city. The weights of individual variables can be adjusted, depending on the primary concern of the city or department using the information.

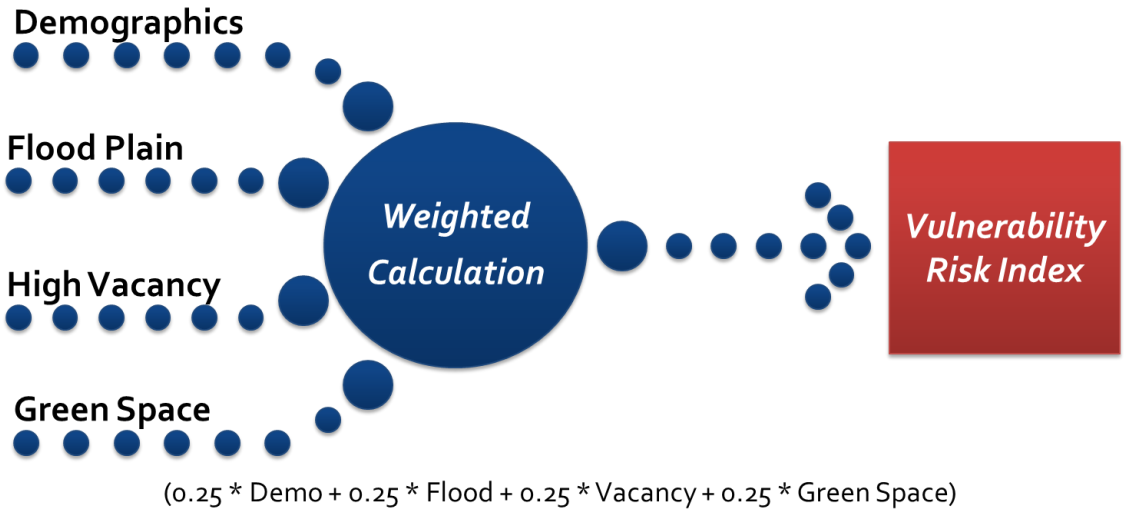

FIGURE 1: REPRESENTATION OF INPUTS INTO GIS WEIGHTED CALCULATION

By bringing together mixed methods and analytic frames, our IA seeks to provide decision-makers and stakeholders in Avon Lake, Dayton, Elyria, and Toledo with information and tools necessary to better adapt to climate change while also recognizing the current successes and strengths of each city.

BACKGROUND

This section is divided into two main parts. The first examines climate change adaptation and city planning from a public governance perspective. The second reviews aspects of climate change and its projections for the Great Lakes region.

CLIMATE GOVERNANCE

JoAnn Carmin and colleagues (Anguelovski & Carmin, 2011; Carmin et al, 2012a; Carmin et al., 2012b) have found that endogenous factors and goals motivate urban adaptation. They argue this is due to the inchoate nature of climate adaptation within planning as early adopters need to innovate by developing their own new planning tools and practices (Anguelovski & Carmin, 2011; Carmin et al, 2012a). They identify three primary endogenous factors for the incorporation of climate adaption into urban governance:

1. The presence of policy entrepreneurs or champions to instigate and inspire a policy shift;
2. How cities learn about local climate impacts and recognizing their vulnerability to future hazards; and
3. A critical internal driver connecting adaptation efforts to broader local priorities and initiatives.

Policy entrepreneurs are individuals that provide clarity to ambiguous, uncertain problems in public policy (Kingdon, 1995; Zahardiadis, 2007). They do so by championing causes and framing solutions so that decision-makers and stakeholders find the issue salient. In Kingdon's (1995) original framing, a policy entrepreneur maneuvers to bring together three separate streams: politics, problems, and policies. By merging these streams, a policy window opens up in which change to policy can occur. In other words, policy entrepreneurs navigate political and policy processes to solve problems. They are dedicated, care deeply about an issue, and are instrumental in instigating policy change. Within the field of climate change adaptation, policy entrepreneurs are instrumental in creating policy windows that facilitate decision-maker action on adaptation.

As cities learn more regarding the projected and actual effects of climate change, it is likely that they will begin adapting to potential stresses and impacts. Anguelovski and Carmin (2011) highlight the example of Durbin, South Africa, where city decision-makers become concerned about climate change only after a vulnerability study was conducted. Hence perception of risk and specific knowledge about when and where it is likely to occur matters in terms of getting decision-makers mobilized to adapt. Lemos, Kirchhoff, and Ramprasad (2012) emphasize, however, that there is a gap between what information producers deem necessary and what information users believe relevant to act. They argue the usability of climate information depends upon users' perceptions of saliency, credibility, accuracy, and timeliness; how new information interacts with existing knowledge systems; and the degree to which information users and producers interact. Climate information alone will not solve the inaction around adaptation (Lemos and Rood 2010; Tribbia and Moser, 2008). Similarly, both the theoretical and empirical literature on climate adaptation points towards the importance of 'boundary organizations', which serve to bridge the gap between researchers and users (Kirchhoff, 2013).

Finally, the ability to align adaptation to broader priorities and policies facilitates the implementation of initiatives reducing vulnerability to climate change. Anguelovski and Carmin (2011) illustrate this point by describing how adapting to climate change in Quito, Ecuador accelerated when policy entrepreneurs demonstrated action would advance the city's reputation as an environmental leader.

Moreover, these three endogenous factors may interact with each other synergistically—once a certain inflection point is achieved, it is possible to imagine positive feedback loops reinforcing adaptation to climate change. For example, as relevant climate information increases, policy entrepreneurs should be better able to

connect climate concerns with local priorities to stimulate climate change adaptations. In turn, these actions are likely to increase learning and knowledge of climate change, which should further increase motivations driving adaptation projects and policies.

Yet as adaptation progresses, scholars have increasingly recognized that specific adaptation actions in a city can potentially interact both positively and negatively with other adaptation goals (Hallegatte, 2008; Kirshen et al, 2008), mitigation plans (Harmin & Gurran, 2009), and broader development goals (Brown, 2011; O'Brien & Leichenko, 2007) in other sectors of the city. Further, unwise or poorly executed adaptations can lead to undesirable effects or maladaptions (Barnett & O'Neill, 2010). This means that even in cases in which the three endogenous factors Anguelovski and Carmin identify are present, it is possible that not every adaptation will be a good one. Understanding how adaptations interact with decision making in other sectors of urban areas is thus important to implementing adaptation options that avoid tradeoffs or negative interactions. Indeed, Viguie and Hallegatte (2012) demonstrate that combining adaptation policies with other urban policies, such as transportation subsidies, can lead to positively synergistic outcomes. An integrated assessment of adaptation action focusing on two Great Lakes cities (Ann Arbor and Grand Rapids, MI) also found several instances where sustainable initiatives may positively build capacity of adaptation (Berquist et al, 2012). Additionally, addressing vulnerability at one scale can interact positively or negatively with the resiliency of other scales. Because of these complex interactions, it is important to better understand political, policy, and decision-making aspects of adaptation initiatives.

TABLE 1: DETERMINANTS OF ADAPTIVE CAPACITY (EAKIN AND LEMOS, 2006)

Determinant	**Encompasses**
Human capital	Knowledge (scientific, "local", technical, political), education levels, health, individual risk perception, labor
Information and technology	Communication networks, freedom of expression, technology transfer and data exchange, innovation capacity, early warning systems, technological relevance
Material resources and infrastructure	Transport, water infrastructure, buildings, sanitation, energy supply and management, environmental quality
Organization and social capital	State-civil society relations, local coping networks, social mobilization, density of institutional relationships
Political capital	Modes of governance, leadership legitimacy, participation, decentralization, decision and management capacity, sovereignty
Wealth and financial capital	Income and wealth distribution, economic marginalization, accessibility and availability of financial instruments (insurance, credit), fiscal incentives for risk management
Institutions and entitlements	Informal and formal rules for resource conservation, risk management, regional planning, participation, information dissemination, technological innovation, property rights and risk sharing mechanisms

Similarly, researchers have begun comparing climate change adaptation and sustainability efforts (Berman, Quinn, Paavola, 2012; Brown, 2011; Eriksen et al, 2011; Eriksen and Brown, 2011). This strand of literature stresses adaptations should both reduce risk and contribute to overall sustainability in the long-term. Sustainable adaptation, therefore, blends the concerns over long-term sustainability, social justice, and vulnerability reduction. Pursuing sustainable adaptations requires a broader, systematic view of adaptation and risk. Eriksen et al (2011) identify four principles for achieving sustainable adaptations: (1) recognizing the broader context causing vulnerability—including multiple, interdependent stressors; (2) recognizing differing interests and values affect how adaptation unfolds; (3) including and valuing local knowledge into adaptation;

and (4) considering the connections and potential feedbacks between local and global processes. Therefore, it is problematic to consider adaptation as a linear process unfolding seamlessly once a system achieves a certain capacity level. Rather, adapting to climate change is a normative process that demands questioning where, when, why, and for whom is adaptation occurring.

There is a wide variety of explanations of how, why, and through what means adaptation to climate change progresses. Overall, researchers studying the adaptive capacity of systems have proposed a set of determinants they theorize increase the ability of the system to respond positively to a disturbance or perturbation (Smit and Pilifosova, 2001; Smit and Wandel, 2006). Scholars looking at institutional change consider how the rules and norms structuring management and behavior adjust in response to climate change (Anguelovski and Carmin, 2011; Carmin et al., 2012a, 2012b). Finally, those investigating climate governance prioritize the role of power and local, regional, national, and global political economies in describing climate adaptation (Broto and Bulkeley, 2012; Bulkeley, 2010, 2012; Bulkeley and Broto, 2012; Bulkeley and Schroeder, 2011; Cote and Nightingale, 2012; Swynegedow 2010a, 2010b). In this study, we combine and select different aspects of the existing literature to lay out our own conceptual framework connecting adaptive capacity, institutions, and governance to better understand how and why climate change adaptation is likely to unfold in our research sites.

Adaptive capacity refers to the ability of a system to respond to an outside perturbation. Often, there are three steps to adaptive capacity research: (1) identifying a set of factors or determinants of adaptive capacity, (2) conducting an evaluation of the relative adaptive capacity of countries or regions, and (3) finding areas with the greatest vulnerability or least adaptive capacity. This type of study assumes that policy- and decision-makers apply this information to improve response to the impacts of climate change (Smit & Wandel, 2006). Nelson et al. (2007) considered how adaptive capacity relates to efforts to respond to climate impacts and reduce system vulnerability. They outlined an approach in which adaptive capacity describes the preconditions for a system to adapt to outside disturbances through adaptive processes moving towards a level of system adaptedness, representing the normative goals set by managers and stakeholders. Here adaptive processes take two forms: system adjustments and system transformations. Adjustments are short-term and allow systems to cope with impacts and maintain the status quo. Transformations are long-term and involve transitioning the system to a new state better adapted to current or future conditions. Within this framework, a biophysical or social prompt must occur and an appropriate institutional structure must be in place to carry through this process.

Smit and Pilifosova (2001) argue that, rather than focusing on implementing specific adaptations, policy- and decision-makers should seek to build the capacity to adapt. However, high adaptive capacity does not necessarily lead to positive adaptive actions that reduce the risks a changing climate presents (Barnett & O'Neill, 2010; Engle, 2011). Indeed, maladaptions and tradeoffs can exist in the presence of high adaptive capacity, as Barnett and O'Neill (2008) demonstrate in the case of a desalination plant in Melbourne, Australia that increased the vulnerability of at-risk populations.

Among different determinants, scholars have paid special attention to governance and specifically to institutions and politics. Institutions are the "rules of the game in a society" (North 1990, p. 3); they structure, constrain, and allow for social interaction by reducing uncertainty (North, 1990; Ostrom, 1990; 2010). Institutions are formal and informal, written and spoken, and coerced and voluntary. Scholars have applied diverse approaches to analyzing how institutions structure adaptation. Gupta et al (2010, p. 460) argue that "institutions will increasingly need to be able to rise to the challenge of incorporating new information and becoming more proactive and progressive in coping with the projected impacts of environmental change." However, important questions remain, regarding the suitability of existing institutions and how to create ones that are more effective.

Urban planners tend to focus on the need for institutional change within existing planning paradigms (Carmin et al, 2012b). Recently, they have begun advancing a framework for addressing climate impacts and understanding the motivations for cities to pursue adaptive actions. Yet professional planners do not possess well-developed standards and norms for climate adaptation planning to easily process climate impacts and craft solutions (Anguelovski & Carmin, 2011; Carmin, et al., 2012a; Quay, 2010); indeed the field is characterized by experimentation, innovation, instrumentalism, monitoring, and flexibility (Anguelovski & Carmin, 2011; Bassett & Shandas, 2010; Quay, 2010). Hallegatte (2008) identified five planning strategies that utilize these principles: no regrets; reversible and flexible options; buying 'safety margins' in new investments; soft adaptation strategies; and reducing decision time horizons. The focus of this scholarship is designing new rules and norms to guide adaptation planning in urban areas.

TABLE 2: STRATEGIES FOR UNCERTAIN CLIMATE CHANGE (HALLEGATE, 2008)

Planning Strategy	**Description**
No regrets	Actions have socially beneficial outcomes in all projected climate change scenarios
Reversible & flexible strategies	Aim to keep costs of being wrong as low as possible so minimal losses are incurred with termination
Buying safety margins	Including safety margins into infrastructure and the built environment at low- and no-cost increases
Soft adaptation strategies	Using institutional and financial tools for addressing climate impacts
Reducing decision time horizons	Avoiding long-term commitments

Focusing on governance, Eakin and Lemos (2006) call for more attention to how decision-makers go about creating adaptive capacity and designing and implementing adaptive policies. They point to the importance of two independent capacities governance systems possess: policy capacity and administrative capacity. The former refers to "the ability to marshal the necessary resources to make intelligent collective choices about and set strategic directions for the allocation of scarce resources to public ends," while the latter is "the ability to manage efficiently the human and physical resources required for delivering the outputs of government" (p. 8). Together these two capacities enable governments to successfully implement adaptation policy and actions. Lemos and colleagues have called for scholars to give more attention to how systems build (Eakin and Lemos, 2006) and utilize adaptive capacity (Lemos et al, 2013). In other words, it remains unclear as to how adaptive capacity leads to adaptive outcomes.

These issues raise important questions regarding how, why, and through what means climate change adaptation occurs, which is the focus of scholarship exploring the broader political economy of how governance proceeds. To address these questions, Harriet Bulkeley and colleagues (Bulkeley, 2010, 2012; Bulkeley and Broto, 2012; Bulkeley and Schroeder, 2011) argue scholars must more explicitly recognize that adaptation does "not operate within a political vacuum, and more often than not, it is the urban political economies of climate change that matter most in enabling and constraining action" (Bulkeley, 2010, p. 194). They explore this terrain by utilizing the lenses of governmentality—or 'the conduct of conduct' (Foucault, 1991)—and the 'will to improve' (Li, 2007). That is, for them, climate adaptation proceeds from a desire to improve populations by optimizing the relations between people. The main thrust of their arguments is that analysis must "consider how, why, and with what implications projects and measures undertaken in the name of climate change may intervene in the city" (Bulkeley and Broto, 2012, p. 3). To accomplish this, they argue actors must generate the authority to act on the behalf of others (Bulkeley, 2012).

This analytic approach recognizes adaptation as a political process. According to Ericksen and Lind (2008, p. 818), "local adaptive capacity depends on the ability to promote interests in decision-making processes

regarding access to required capital and adjustment options under varying contexts." In other words, power and social relations in part structure adaptation. Bulkeley and Broto (2012) identify experiments as an important site of urban adaptation. They define experiments as "purposive interventions in urban socio-technical systems designed to respond to the imperatives of mitigating and adapting to climate change" (p. 1). Experiments involve public, private, and civic actors. Within experiments, these various actors compete to meet their own goals and visions for climate governance. In examining experiments, Bulkeley and Broto argue that "further work is required to examine the different kinds of experimentation that are emerging in distinct urban contexts, to identify the ways in which experimentation is structured through political economies operating at different scales and through different circuits of power and finance, and to consider whose interests are served through these processes" (p. 13).

While Bulkeley and Broto frame this as "moving beyond an institutional account of governance" (p. 3), we believe this approach to be complementary to an institutional approach. In *Environmentality,* Arun Agrawal (2005) demonstrates that politics, institutions, and identities are the "constituent parts of a given technology of government." Without understanding institutions, it is not possible to completely understand how power operates. Alternatively, it is not possible to understand institutions without understanding the role of power in a system. Clement (2010) argues that understanding power relations and social context is important because not only do institutions affect power distributions, but "power distributions within the group of actors who act at the collective-choice and constitutional levels directly impacts on the design of institutions and the rules implementation at lower governance levels (2010, p. 135).

Focusing on institutions specifically and how they affect the ability of different systems to adapt, Gupta et al (2010) created a heuristic analytical tool they call the "adaptive capacity wheel," designed to assess the capacity of institutions to adapt to climate change. In the wheel, institutions that facilitate adaptation "should allow actors to learn from new insights and experience in order to flexibly and creatively 'manage' the expected and the unexpected, while maintaining a degree of identity" (Gupta et al., 2010, p. 461). Accordingly, the adaptive capacity wheel lists twenty-two criteria within six dimensions (variety, learning capacity, room for autonomous change, leadership, resources, and fair governance), which researchers rate using a five point scale ranging from 'very negative' (-2/dark red) to 'very positive' (+2/dark green) (see figure 2). In principle, these rankings should allow analysts, decision-makers, and stakeholders to increase their understanding of institutional adaptive capacity. The outputs of the adaptive capacity wheel are achieved through interpretation and judgment— and rather than being objective, the wheel reflects the knowledge, experience, values, and beliefs of whoever is doing the evaluation (Gupta et al., 2010). In this study we apply and expand on the criteria suggested by Gupta et al by creating adaptive capacity wheels for each of our four cities; in the next sections, we explain our approach in detail.

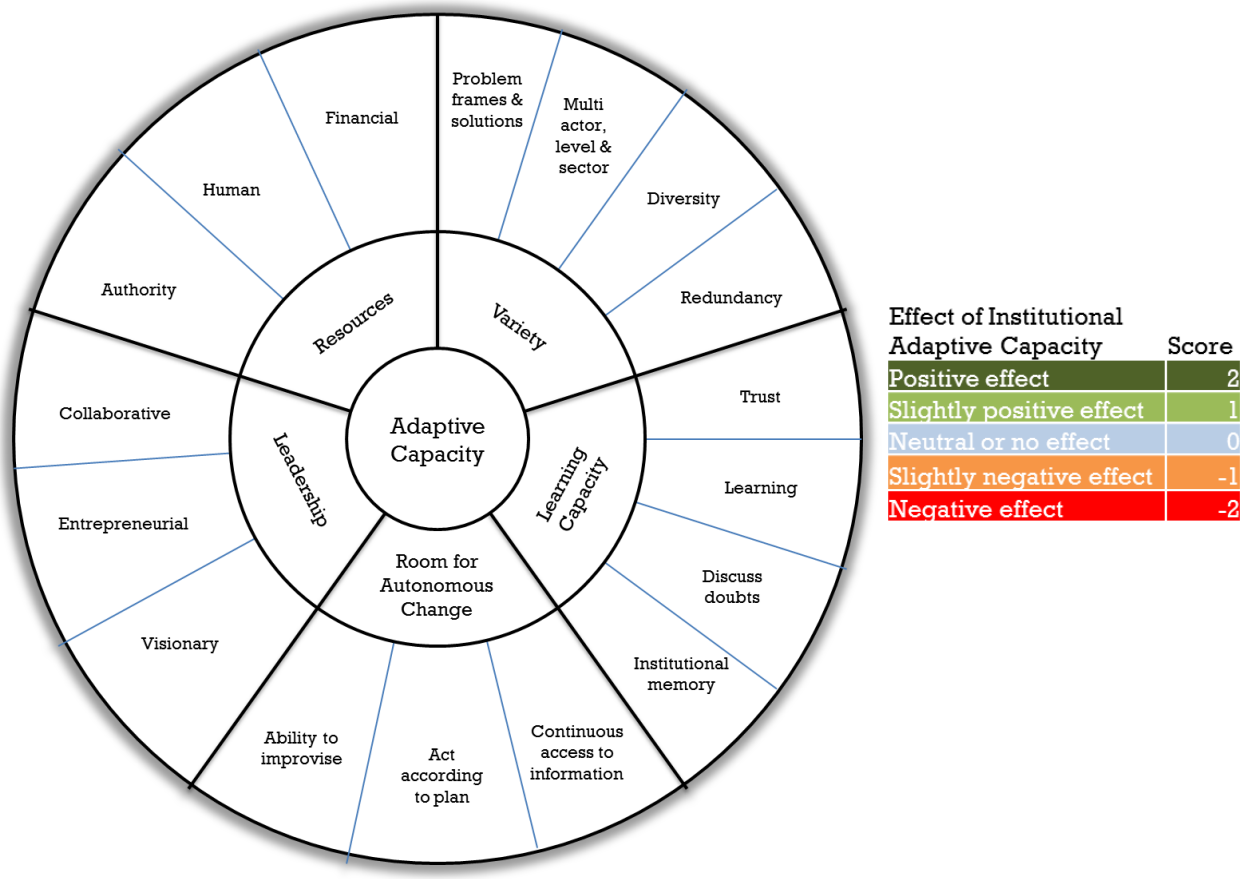

FIGURE 2: ADAPTIVE CAPACITY WHEEL (GUPTA ET AL, 2010)

Next, we describe in detail the elements of the adaptive capacity wheel framework across the cities before we build one specific wheel for each city. For each city, we adapted the wheel to reflect both the variables that applied to our case cities and the data we collected. One advantage of this framework is that since evaluations are based on the experience and knowledge of different actors, the cities can use it to carry out their own efforts to assess resources and constraints. Thus, cities can use the framework both to modify/enhance our assessment, creating a more detailed picture of adaptive capacity, and as a dynamic tool to reassess capacity over time.

Specific elements of the wheel and their definitions (Gupta et al, 2010) are summarized below in table 3.

TABLE 3: ADAPTIVE CAPACITY DEFINITION (GUPTA ET AL, 2010)

Variety	*Variety of problem frames*—room for multiple frames of references, opinions, and problem definitions
	Multi-actor, multi-level, multi-sector—involvement of different actors, levels, and sectors in the governance process
	Diversity of solutions—availability of a wide range of different policy options to tackle a problem
	Redundancy (duplication)—presence of over-lapping measures and back-up systems; not cost effective
Learning Capacity	*Trust*—presence of institutional patterns that promote mutual respect and trust
	Learning—ability of institutional patterns to learn from past experiences and improve their routines
	Discuss doubts—institutional openness towards uncertainties
	Institutional memory—institutional provision of monitoring and evaluation processes of policy experiences
Room for Autonomous Change	*Continuous access to information*—accessibility of data within institutional memory and early warning systems to individuals
	Act according to plan—increasing the ability of individuals to act by providing plans and scripts, especially in case of disasters
	Capacity to improvise—increasing the capacity of individuals to self-organize and innovate; foster social capital
Leadership	*Visionary*—room for long-term visions and reformist leaders
	Entrepreneurial—room for leaders that stimulate actions and undertakings; leadership by example
	Collaborative—room for leaders who encourage collaboration between different actors; adaptive co-management
Resources	*Authority*—provision of accepted or legitimate forms of power; whether or not institutional rules are embedded in constitutional law
	Human resources—availability of expertise, knowledge and human labor
	Financial resources—availability of financial resources to support policy measures and financial incentives

While these criteria are organized in discrete categories, we found that in a real life context, they overlap and complement each other. Although we kept them separate for analytical and heuristic purposes, in practice they are intrinsically connected—both regarding who city officials are and what they do.

APPLYING THE ADAPTIVE CAPACITY WHEEL TO GREAT LAKES CITIES

To assess each city's adaptive capacity, we developed an analytical framework that builds upon and synthesizes institutional, adaptive capacity determinants, and urban adaptation planning research. The adaptive capacity wheel (Gupta et al., 2010) constitutes the heart of our framework. We ask: *In what ways institutions of urban government constrain or facilitate adaptation to climate change in Toledo, Dayton, Elyria, and Avon Lake?* To assess the extent to which each criterion of interest identified within the wheel expresses specific city capacities, we rely not only on our own research, but also on key theoretical assumptions and empirical findings from the urban planning and adaptive capacity literatures. In other words, we base our evaluations of capacities (positively or negatively) both on what we observed in the cities and on what the existing literature suggests and/or shows is important.

Firstly, both the urban planning and adaptive capacity literature highlight the critical role of policy entrepreneurs, social learning, and incorporating adaptation in facilitating adaptation to climate change. Therefore, we give particular weight to the criterion of entrepreneurial and visionary leadership and learning. We believe possessing these three attributes greatly increases the likelihood of city governments planning for climate change.

Secondly, the literature demonstrates that even well-intentioned adaptation efforts can lead to negative outcomes—either by inadvertently increasing vulnerability or by conflicting with other policy objectives. Accordingly, the criterions listed under "Variety," as well as the ability to discuss doubts, are important for avoiding maladaptations and maximizing synergies between adaptation and other policy goals. Thus, these attributes of city government are important to increase the likelihood that actions taken to adapt to climate change will be positive—or at the very least reversible, if it becomes apparent that past choices no longer suit the needs of the city.

Thirdly, adaptation requires access to resources—both tangible and intangible; the adaptive capacity literature describes the general resources necessary to adapt to climate change. As Eakin and Lemos (2006) propose, building adaptive capacity relies upon governments having both administrative and policy capacities, which depend upon having access to required resources. The resources dimension of the adaptive capacity wheel includes three key criterion: authority, human resources, and financial resources. In addition, we assess knowledge as a resource. Financial resources are particularly significant for cities' ability to adapt. Possessing a sufficient amount of financial capital allows cities to move beyond short-term 'core' functions, such as police, fire, water, and so on, to incorporating long-term considerations—such as built infrastructure, sustainability and adaptation. Further, human resources depend upon being able to hire and retain talented individuals within city government. Similarly, infrastructure and technology monitoring and maintenance require significant capital investment. For these reasons we give weight to financial resources and human resources.

Finally, we consider knowledge as an important type of resource in enabling autonomous change. Knowledge is a critical resource a policy-maker or urban center can possess; associations of existing knowledge are crucial to promote networks of knowledge across cities that can translate to actionable outcomes within geographic regions (Levine, 2005). These networks of knowledge ideally amalgamate different kinds of knowledge (i.e. scientific, local and indigenous knowledge, practical and experiential knowledge) that inform action and build resilience of socio-ecological systems (Adger and Tompkins, 2005). They may also encourage participation and buy-in from stakeholders (Lemos, Kirchhoff and Ramprasad, 2012). Knowledge about climate change can be divided into several general and overlapping categories: specific knowledge about the causes,

consequences, and potential solutions to climate change; contextual knowledge, placing the anthropogenic forcings of climate change in historical and geographic perspective; and practical knowledge that enables individual and collective action (Leiserowitz et al., 2010). To be effectively used, these different kinds of knowledge must complement each other and interplay well with other kinds of knowledge currently being used by decision-makers (Lemos, Kirchoff and Ramprasad 2012). Knowledge of projected climate change impacts is important in informing the long-term planning for policy-makers in urban centers. An increase of climate knowledge could potentially increase the city's adaptive capacity.

CLIMATE PROJECTIONS

The current non-glacial climate of the Great Lakes region (consisting of the Great Lakes drainage basin, including parts of Quebec, Ontario, Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, New York, and Michigan) is characterized by warm summers, cold winters, and precipitation in every season. Areas in the north and west of the region tend to have lower temperatures and a greater seasonal temperature range than areas near the Great Lakes shoreline (Pryor, 2013).

Predictions of climate in the Great Lakes region specifically have been developed by statistical downscaling of General Circulation Models (GCMs) in order to take into account local features such as lakes, valleys, and mountains. These models (developed by the Canadian Climate Center (CGM1) and the United Kingdom Hadley Center (HadCM2)) suggest the climate of the Great Lakes region will be 2-4°C warmer and 25% wetter by the end of the 21st century (GLRA, 2000).

The IPCC Fourth Assessment Report predicts that, depending on the quantities of greenhouse gas emissions, the temperature will increase 3-5°C in the Great Lakes region by the end of the 21st century compared to the 1961-1990 mean (Pryor, 2013). The Canadian Regional Climate Model projects changes in temperature probability distributions, showing increasing temperatures in the winter and summer, with variability around the mean remaining relatively constant (Pryor, 2013). Moreover, these projected changes will not likely be uniform over space or time. The CRUTEM3 dataset shows that while the average mean temperature has increased by roughly 0.067°C per decade from 1900 to 2010, decadal increase for 1950-2010 is roughly 0.12°C, increasing to 0.23°C per decade for 1979-2010 (Pryor, 2013). Jones et al (1999) show that the Midwest region has also experienced reduced diurnal temperature range, that is, the minimum temperature at night has increased more than daytime maximum temperatures (Pryor, 2013).

Downscaled global climate models predict that the frost-free season will increase two weeks by mid-century and more than four weeks by the end of the century (Pryor, 2013). The predicted warmer winter temperatures will likely lead to increased evaporation, warmer water temperatures, more variation in lake levels, increased likelihood of extreme precipitation events, and earlier onset of lake stratification (Hinderer, 2010). Projections also include less lake effect snow in winter and a significant increase in the days above 90°F in summer (Hinderer, 2010).

Impacts on lake levels are uncertain, though most models predict a decrease (Pryor, 2013). Output from steady state GCMs predict a decrease of 1.5 to 8 feet by the end of the 21st century, and output from CGM1 predicts a decrease of 1.5 to 3 feet by 2030 (GLRA, 2000). Ice cover on all lakes will likely decrease both in number of days with ice cover and thickness of ice. These changes in lake levels and temperature are expected to feedback and further impact the climate of the region (Austin and Colman, 2007).

Climate change and its effects on the environment will present particular challenges to the urban areas of the Great Lakes Region. Higher temperatures may lead to dangerous conditions in the cities due to the heat island effect, during which residents will face health risks from heat stress and air quality deterioration (Bulkeley et al, nd). In the US, extreme heat events are one of the largest causes of weather related mortality,

responsible for over 3,442 deaths between 1999 and 2003 (Luber and McGeehin, 2008; Pryor, 2013). On July 20, 2011, the majority of the Midwest experienced temperatures over 100°F (Pryor, 2013) and several studies (Meehl and Tebaldi, 2004, Tebaldi et al, 2006, Battisti and Naylor, 2009; cited in Pryor, 2013) project that there will likely be future increases in heat wave occurrence and intensity.

Higher temperatures will also affect the generation and transmission of energy through efficiency losses and damage to transmission infrastructure, a crucial process when air conditioners must function to protect human health (IJC, 2003). Pryor and Tackle's 2009 study shows that more than 40% of freshwater use in the US goes to cool power plants (Pryor, 2013). As Hightower and Pierce (2008) report, cooling plants in the Midwest are mostly adjacent to rivers. This increases their vulnerability during heat waves because periods of extreme heat are associated with lower precipitation and even drought (Pryor, 2013). Extreme precipitation events may lead to damage from flooding and water contamination from sewer overflows (IJC, 2003).

Coastal cities are vulnerable to changing lake levels that will affect coastal property, commercial navigation, recreation, and tourism (Hinderer, 2010). As a result of the multitude of potential impacts, the cities of the Great Lakes region will need to make decisions regarding emergency response and adaptation investment, using available climate projections that provide ranges of likelihood for various climate changes effects. The Great Lakes watershed is home to 40 million people and contains 20% of the world's freshwater (Graham, 2012) and while the uncertainty in climate projections poses a distinct planning challenge to local and regional decision- and policy-makers, much can be done to anticipate action for successful climate adaptation (Lemos and Rood, 2010).

CLIMATE CHANGE IMPACT SECTORS

The climate changes projected for the Great Lakes region will impact sectors important to the region in different ways. The scope of our study examined three key areas of impact: infrastructure, ecosystem services, and public health.

INFRASTRUCTURE

Infrastructure is the basic physical and organizational structures and facilities needed for the operation of a society. It guarantees our energy and water supplies and enables safe and reliable use of road, rail, and air transportation. Climate change impacts, including sea level rise, increasing size and duration of wildfires, and melting ice caps, affect virtually all aspects of energy infrastructure, including electricity, fuel sources, transportation, generation, and use of energy. To meet the uncertain challenges that lie ahead, cities need infrastructure systems that are more resilient and adaptive to climate change. Adaptation is not just a matter of risk management but also about taking the opportunities risk presents to develop new and innovative infrastructure systems and services (RAENG, 2011). This defines what is now known as "The Green Economy", where growth in income and employment is driven by public and private investments that reduce carbon emissions while enhancing energy and resource efficiency as well as preventing loss of biodiversity and ecosystem services (UNEP, 2011).

Infrastructure sectors have developed into a highly technical and interconnected system, enabling any local risk to quickly propagate in intensity and affect the entire system, potentially causing a cascade of failure (RAENG, 2011). For example, a key vulnerability in energy infrastructure includes flooding as a result of sea level rise, increased rainfall, and storm surges. These could affect power stations, particularly those located in coastal areas, as well as fuel supply infrastructure (Perez, 2009). Transportation infrastructure is particularly vulnerable to an array of climate threats, ranging from storm surge, flood, drought, snow, extreme wind, frost, fog, and soil shrinkage. These threats will affect roads, surface and underground rail, airports, seaports and

other coastal infrastructure, inland waterways, pipelines, and oil and gas distribution. Closely linked to transportation is communications infrastructure. High winds can affect telephone service, high altitude communication platforms, wireless communication, and satellite signals (RAENG, 2011).

While vulnerability to climate change depends upon the type, age, design, location, and relative usage of infrastructure, resilience to climate change relies on the applicable regulatory framework and the extent to which it helps foster adaptation to climate impacts. Such a framework will need to address potential risks in the short and medium-term, as well as for the duration of life of the infrastructure. Effective adaptation should account for the wide range of uncertainties, including addressing relatively certain and predictable changes, unforeseeable and erratic changes, progressively compounding changes, complex feedback mechanisms, extreme events, and variation in climatic impacts across locations (Maddocks, 2011).

This complex and challenging decision-making exercise falls under the purview of the federal, state, and local government. The various levels of government play critical roles in facilitating adaptation through law-making and policy development. The federal government's power to review and amend regulations and capitalize on economies of scale ideally positions it to provide leadership for creating adaptive infrastructure. Meanwhile, state governments can tailor local regulations to promote climate change adaptation and ensure that they are congruous with any federal framework that might be adopted. For example, a state can tailor performance-based standards and technical guidelines related to climate resilience for new and existing infrastructure with respect to regional topography and weather patterns. Lastly at the local scale, city planning commissions are important partners in localizing and implementing adaptation and mitigation strategies (Bulkeley, 2009; Maddocks, 2011).

Even with a strong and well-defined regulatory framework, the capability of infrastructure systems to respond to climate change impacts are largely influenced by technology, wealth, human capital, social capital, information and risk management, and appropriate decision making capabilities. Apart from bringing new challenges to natural and built environments, climate change greatly aggravates existing social, economic, and environmental challenges, thereby potentially undermining efforts to achieve the goals of sustainable development (UN-Habitat, 2008).

ECOSYSTEM SERVICES

Ecosystem services are the processes by which the environment provides resources such as clean water, timber, habitat for fisheries, and pollination of native and agricultural plants (ESA, 2000). The Millennium Ecosystem Assessment (MEA) divides ecosystem services into four groups: supporting services, provisioning services, regulating services and cultural services, as shown in figure 1 (MEA, 2005). All the services encompassed in these four groupings affect human well-being and are affected by anthropogenic changes.

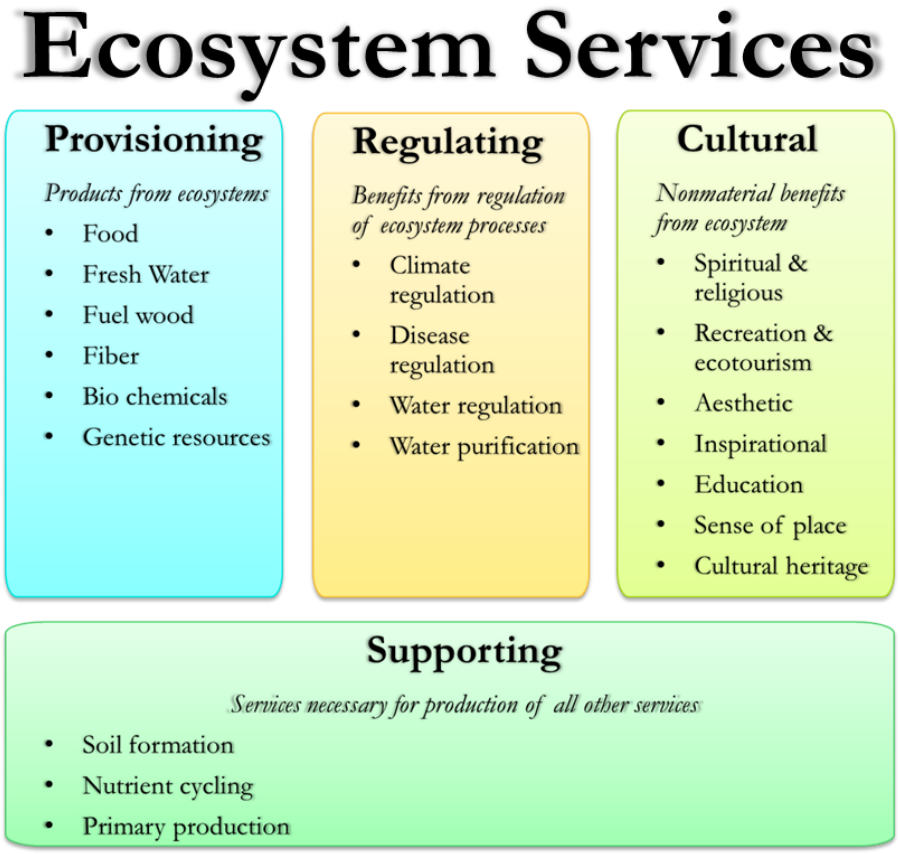

FIGURE 3: TYPES OF ECOSYSTEM SERVICES (MEA, 2005)

As the climate changes, some ecosystem services, such as primary production and food provisioning, may decline or even collapse. Because ecosystem failures are difficult to predict, it will fall upon the stakeholders to adapt to the sudden changes (Breshears et al, 2011). Regulating services are particularly important in adapting cities to climate change, as they help prevent and minimize floods, reduce heat waves, sequester carbon, and improve air quality (Depietri et al, 2012). Nonetheless, all four groupings discussed are important to cities. They not only provide citizens with opportunities to socialize, but also purify the water they drink and provide local produce. A variety of ecosystems, including lawns, parks, urban forests, cultivated land, wetlands, lakes, coastal zones, and streams, exist within urban boundaries (Bolund et al, 1999). Urban ecosystems cover approximately 3% of the terrestrial area, influence biogeochemical cycles, and, if used properly, can enhance the aesthetic environment, which promotes recreation, creates jobs, and produces food (Lal, 2012).

To cope with climate change, cities need to balance societal demands and ecosystem services (Leewuen et al, 2012). For example, ecosystems in urban areas can reduce the "Urban Heat Island" (UHI) effect (Koppe et al, 2004). One of the main causes of UHI is the building mass found in urban areas. Planners and city governments can minimize the effects of the heat island effect and other climate change impacts through thoughtful management of urban ecosystems and urban areas (urban agriculture, green roofs, urban forest, etc.). As people continue moving to cities, urban planners will struggle with making cities more compact and at the same time preserving urban green spaces. Urban ecosystems have the potential to buffer climate change impacts. If correctly implemented in city planning, planners can improve climatic conditions with the use of distributed and interconnected green space networks throughout the city. Urban planners will have to consider each situation as unique, with the characteristics of each green space differing, depending on the function and use of this space (Mathey et al, 2011).

PUBLIC HEALTH AND WELL-BEING

Climate change may profoundly affect public health and well-being through rising temperatures and changes within the hydrologic cycle (Bajayo, 2012). An increased frequency of heat waves due to climate change will lead to an increased number of heat-related deaths among those vulnerable, particularly the elderly and those in poor health (Kasperson and Kasperson, 2001). More frequent and extreme weather events will increase the rates of human injury, heat-related illnesses, and the spread of tropical disease vectors that spawn contagion and massive negative health outcomes. In total, these risks will likely challenge the economic, social, and geophysical environments that promote and sustain human health (WHO, 2008). Negative health outcomes attributed to climate change have already begun to adversely affect populations of developed nations (Bajayo, 2012) with severity of impacts projected to increase in coming decades (IPCC, 2012).

A recent study (Altman, 2012) from the American Meteorology Society projected the relationship between heat, weather, and mortality for 40 U.S. cities. Among those, ten cities within Great Lakes region are likely to experience a considerable increase in Excessive Heat Event days (EHE) due to climate change, with projected dramatic increase in heat-related mortalities. The two urban centers most vulnerable are Detroit, MI and Cleveland, OH. Detroit is projected to experience 4,109 additional EHE mortalities by mid-century and 17,877 by the end of the century. Cleveland is projected to experience 2,530 additional EHE mortalities by mid-century and 16,625 by the end of the century (Altman, 2012).

The impacts of climate change on residents will not be homogenous. Vulnerability to climate change varies across socioeconomic strata, age, gender, caste, race, ethnic affiliation, and indigeneity. Disparities in wealth, employment opportunities, and available resources throughout the Great Lakes region will likely make certain demographics and socioeconomic groups more vulnerable to health problems. These populations tend to be the elderly, the infirm, the poor, children, minorities, or marginalized populations (Altman, 2012). Without access to proper health care and resources, these groups will likely become more marginalized and vulnerable and less resilient to climate related stressors. For example, the inequitable distribution of resources after extreme weather events occur further exacerbates the vulnerability of populations to negative health outcomes (McEntire, 2005).

To enhance the health and wellbeing of any given population in times of climatic change, decision- and policy-makers should support efforts to thread local initiatives into broader policy initiatives at the regional and national levels (WHO, 2008). The World Health Organization has developed an "Environments for Health" framework (see table 4) for municipal health planners to utilize when creating climate adaptation policies while protecting public health. Embedding community consultations into public health policy assists communities to identify development and health-related issues, such as access to safe water, sanitation, and health care. Policies that involve social inclusion will prevent future unrest upon onset of extreme weather events and resource scarcity (Mearns, 2010). The most successful policies addressing public health outcomes

resulting from climate transforms people "from subjects and beneficiaries into citizens with rights and responsibilities" (Mearns, 2010). Great Lakes communities can reduce climate vulnerabilities to public health through the integration of planning and policies that focus on interactions between social, built, natural, and economic systems (Dept. Human Services, 2001).

TABLE 4: ENVIRONMENTS FOR HEALTH (DEPARTMENT OF HUMAN SERVICES, 2001)

Social Environment	*Built Environment*	*Natural Environment*	*Economic Environment*
Networks of relationships which provide opportunities for organization, connection and social support.	**Infrastructure including roads, public transportation, community buildings and urban housing.**	**Ecosystems including air, water, flora and fauna.**	**Global and local economic development, employment opportunities, incomes, assets and resources.**

ADAPTIVE CAPACITY WHEEL CRITERIA IN THE CONTEXT OF GREAT LAKES CITIES

VARIETY

Within our case study cities, a diversity of problem frames and solutions—such as adaptation, mitigation, sustainability, and economic development—became evident during conversations with city officials about climate change and related subjects. City officials expressed concern about how climate change impacts may affect city function within and across several sectors, with the majority of officials citing not only multiple concerns but also discussing how these concerns are linked.

Individuals often connected adaptation and mitigation to economic development during the interviews. One city employee stated that incorporating climate concerns is particularly important in order to "think about the future a little bit and figure out how to get jobs [within the city] from that." Another interviewee highlighted the importance of linking climate initiatives and economic development: "I think coming at it from a little bit more of a better green practices approach seems to be the way in for people, you know? A way in for kind of the more conventional business crowd." These two narratives—firstly, those implementing climate policies can also create jobs and, secondly, that framing initiatives as saving money in the short- or medium-term—were often used to justify taking action on climate change.

City interviews often described a multi-level, multi-jurisdictional and multi-actor involvement in city governance processes. For example, some respondents stated that high-level decision-makers have supported sustainability efforts. In Toledo, for instance, a city official related the following about the mayor: "Every time I've asked him for support on different initiatives, he [has] let us run with the ball." Dayton provides an additional example of multi-actor involvement in the context of city sustainability initiatives. A city employee reports that "the idea of environmentalism has now mainstreamed [within the city government]." However, this employee also mentioned the need to apply appropriate "political pressure" to gain interest from decision-makers, suggesting that more needs to be done to bring more actors on board.

Partnerships with organizations and institutions outside of city government also emerged as important for building adaptive capacity. For example, the Ohio Department of Natural Resources has been proactively

studying the potential impacts of climate change in the state. They provide training and technical assistance to local decision-makers through workshops and collaborative research. Further, they are compiling a list of climate related funding opportunities.

LEARNING CAPACITY

When comparing across the four cities, certain sectors (such as Public Services, Water and Planning) were more likely to report engaging in partnerships than in broader knowledge networks. Officials report the value of these partnerships for achieving mutual interest, but also for building trust and learning across sectors. The role of leaders and key people that bridge departments and increase collaboration is essential for the cities' ability to build adaptive capacity. That many officials have worked for decades within city government also boosts the cities' institutional memory and policy capacity.

An alternative strategy many departments are using to enhance learning and communication is utilizing social media to connect with the broader public. Interviews report Twitter, YouTube, Facebook and blogs offer potential new and effective outreach mechanisms. These efforts remain largely inchoate, but they are developing rapidly. Similarly, cities are seeking to utilize text messaging as a way to warn people of potential crises. Such systems would likely require individuals signing up for the service. Using social media may facilitate learning if cities can use communication channels to monitor and inform policies and processes. Social media may also facilitate institutional memory, if cities use it to gather information from citizens in order to monitor and/or evaluate their policies.

ROOM FOR AUTONOMOUS CHANGE

We interpret this criterion to reflect both the ability/experience of cities to implement sustainability-related policy and their access to knowledge and information to support these actions. Across the four cities, investment in practical, publically supported and financed projects directed towards revival and renewal of downtown and/or special zoning districts emerged as a common theme. To some degree, all cities are trying to integrate sustainability into these projects. When compared across the four cities, most sustainability goals are framed in terms of promoting development, saving money and/or improving quality of life. However, to date, no city has a formal sustainability plan, though Dayton and Toledo are beginning the process of creating such a plan. Instead, sustainability-related projects, which might increase each city's adaptive capacity, have occurred without a central, unifying plan. The impetus behind some of these initiatives is sometimes exogenous, such as Toledo's efforts to separate its combined sewage system under the US EPA Consent Decree. Others are more endogenous, such as Dayton's desire to be a vibrant, environmentally friendly city. In any case, they are all examples of room for autonomous change that cities can capitalize on to build adaptive capacity.

In general, there exists, at least in the abstract, a willingness to adapt to climate change within each city we studied. Indeed, a handful of departments—notably those dealing with drinking water, sewage treatment, and storm water management—have begun to incorporate climate change into their general management practices. Yet, in none of the cities has the city government translated this willingness into institutionalized climate adaptation practices and plans, despite signs that thinking about it is becoming more common.

Regarding access to climate knowledge and information, our research found that there is a disconnect and, at times, distrust between information producers (i.e. universities, governmental agencies) and users in the four sites. When asked from where they received their climate information, their answers fluctuated from complete unawareness to citing specific sources such as the Weather Channel. Some expressed doubts regarding weather forecasters: "I don't have that much faith in forecasters. I don't think they can do much beyond two hours. But anyway, no, we don't do any long-term tracking. Casual glance at the farmer's almanac,

roll our eyes and throw it away." Some admitted to not using any type of forecasting: "We don't do much climate forecasting at all, other than the week ahead, looking and predicting what the ozone levels will be." Moreover, despite greater public awareness of climate change in the region (GLAA-C, 2013), we encountered a few skeptics of the anthropogenic nature of climate change and the data available during our interviews. A few city officials expressed it as follows: "No, there certainly isn't that I have found and it's a challenge just to find credible resources as well that you can trust implicitly" and "I've seen so many statistics that have countered each other."

LEADERSHIP

City governments that express willingness to adapt, have an ability to communicate with community stakeholders, and display leadership qualities are more likely to effectively build adaptive capacity. Across all four of our study cities, we found 177 examples of interviewees describing themselves or their departments as possessing one these three qualities. Over half of these observations were descriptions of community outreach (95 coded examples). Leadership was the second most mentioned attribute, while willingness to adapt came up only 18 times. Taken together, this may suggest that many respondents are willing to engage with communities and take a leadership role, yet are not doing so in a systematic fashion that considers the long-term impacts of climate change. Indeed, respondents often prioritize short-term needs and goals due to funding and human resource constraints. On the other hand, it is possible that high degrees of uncertainty and ambiguity surrounding climate change and impacts is impeding the ability of respondents to foresee the need to explicitly deal with long-term climate change.

All cities expressed a willingness to lead on climate adaptation and sustainability and respondents often were able to name other individuals they believed to be leaders. However, from the interviews there is little evidence of leadership on long-term, systematic adaptation. Instead, leadership typically is present in connecting current department and government goals to short- and medium-term climate impacts and mitigation. The presence, or lack thereof, of a policy champion emerged as an indicator for how much communication across departments or sectors was likely to exist within the cities. For example, for both Dayton and Toledo, one key person was mentioned in the majority of interviews as critical for the dissemination of climate and sustainability information and as the main organizer for efforts addressing these concerns.

RESOURCES

FINANCIAL RESOURCES

The lack of stability in regards to funding sources was a strong consideration for many of our interviewees. All cities reported deep financial difficulties and offered tight budgets as a primary constraint, especially since the economic recession beginning in 2008. Departments with dedicated enterprise funds often report having a degree of predictability in their budgets. However, as population changes occur, so does the availability of these funds. Departments must spend enterprise funds on the specific sector the funds originate. This decreases the total flexibility that departments have in addressing their own internal priorities.

On occasion, departments reported having been successful in receiving grants from outside organizations and the federal government. Interviewees reported receiving grants from the Better Buildings Initiative (BBI), Environmental Protection Agency (EPA), Community Development Block Grants (CDBG), and the Neighborhood Stabilization Program (NSP). These grants typically come with specific targets that departments must meet. For example, NSP funding goes towards demolishing houses and departments must spend it by the end of the year. Beyond the narrow scope of these grants, many of them are phasing out or decreasing as stimulus funding is ending.

Thus, budgetary constraints are negative for city adaptive capacity. Given the economic situation of the cities, if addressing these financial constraints is not possible, cities may have to rely on other facets of adaptive capacity in which they are strong. In addition, creative sources of funding and the potential success of economic development initiatives (including sustainability) will be crucial for increasing adaptive capacity in the long term.

HUMAN RESOURCES

Though departments often report being understaffed, they typically also report having high quality staff members. Many interviewees express their own dedication to and knowledge of the city. For example, in Elyria, one official, who has worked for the city for 25 years, attributes his deep knowledge of the city and its operations to his long tenure in office. Such long tenures and relevant experience were common across all four cities we studied. The accumulated human capital and commitment from officials allow departments to overcome staffing shortages—at least to some extent. For example, another interviewee reported walking through the sewage treatment every Saturday and Sunday, even though he is not paid to do it.

Interviewees often highlighted the creativity of individuals to find money and overcome barriers as being important aspects of human resources. Knowing where to find additional sources of funding is of particular importance. A city council member in Elyria underscored this point: "You got to be creative and you got to know where to look for these grants." Having staff knowledgeable and dedicated to writing grants and securing outside funding is essential to accomplishing internal city priorities.

Finally, cities have successfully managed to share human resources by forming committees and task forces across departments, as well as through informal community and regional networks. The permeability between departments allows for a degree of free flow of ideas and knowledge through the city governments. Furthermore, interviewees often highlighted the importance of regionalism and learning from what other cities are doing. For example, a leader in Toledo emphasized going to other cities, such as Milwaukee, that are working on similar environmental or sustainability programs.

INDIVIDUAL CITY CAPACITIES, CONSTRAINTS, AND ADAPTIVE CAPACITY

In the following section, we first provide a background for each city studied. Table 5 provides basic demographics for each. We then describe the overall capacities and constraints of each individual city related to adaptive capacity. Next, we analyze these factors within the context of the adaptive capacity wheel in order to assess the overall adaptive capacity of each city. Finally, we provide risk indices and create vulnerability maps for each city.

TABLE 5 2010 CENSUS DATA

	Dayton	Toledo	Elyria	Avon Lake	State of Ohio
Population	**141,527**	**287,208**	**54,533**	**22,581**	**11,536,504**
Population under 5 years	6.9%	7.4%	6.9%	5.7%	6.2%
Population 65 years and over	11.8%	12.1%	14.3%	14.5%	14.1%
Median household income	$ 28,843	$ 34,170	$ 42,383	$ 81,635	$ 48,071
Persons below poverty line	32.5%	25.6%	16.5%	4.5%	14.8%
Racial make-up					
White	51.7%	64.8%	78.1%	95.7%	82.7%
Black	42.9%	27.2%	15.5%	1.1%	12.2%
Other	4.2%	8.9%	6%	3.8%	5%

DAYTON

The city of Dayton is located in Montgomery County in the Miami Valley region of Ohio. The Great Dayton Flood of 1913 caused severe flooding throughout the area, spurring growth in the suburban communities farther from the Miami River. The 2010 census population was approximately 141,500 and has been declining since the 1980s. The percentage of the population below the poverty line is higher than the state average, while median income and population over 65 are lower than the OH average (US Census, 2010).

Dayton prides itself on its history of innovation, especially in the aviation field. The city is home to the Wright Brothers' first plane and Wright-Patterson Air Force Base, the largest U.S Air Force base in the country. Dayton hosts research and development in industrial, astronautical, and aeronautical engineering through institutions such as Tech Town, a technology campus supporting aerospace and advanced materials research. The main contributors to Dayton's economy are the defense, aerospace, and healthcare industries. With the decline in manufacturing, Dayton has developed a significant service economy with legal, insurance, and healthcare sectors.

In 2007, the City Commission approved a Sustainable Practices Policy, furthering commitment to the U.S. Conference of Mayor's Climate Protection Agreement. The policy focuses on saving energy, money, and resources, protecting the environment, and improving the quality of life in and around Dayton. Moreover, research has been ongoing for tapping into the region's geothermal potential. In 2010, the Greater Downtown Dayton Plan was introduced with a focus on job creation, infrastructure improvements, housing, recreation, and collaboration. In addition to this plan, Dayton has launched a campaign focused on becoming an immigrant-friendly community and encouraging innovation.

Interviewees in Dayton identified a range of potential concerning impacts. Some public officials thought of flooding as a major concern: "…and while we have a system of five dams that really do a good job of protecting us, there will be that one flood event that they weren't engineered for." But other public officials were more confident of the ability of the city to respond to climate change impacts: "I don't know if there's any kind of climatic incidence that would get the city of Dayton up in arms to the point like, what do we do? Because, like I said, we've kind of addressed all the issues that we have faced." Regarding other climate-related effects, Dayton planners were concerned with the impact the Emerald Ash Borer had had on the trees and how that would affect their green spaces (a concern shared by officials in Toledo and Elyria). For example, in the words of one official "…having those trees that are both pollution and drought tolerant at the same time, I think, will be challenging. You can look at our canopies right now and, you know, they are very stressed. And that coupled with the Emerald Ash Borer and some of the other just natural [impacts]." Finally, some interviewees are worried about vulnerable populations in the city, especially those to whom resources may be less available: "the thing that concerns me most is that the people that are going to be most affected are the poorest people, and we have—we're a poor city."

CAPACITIES

In terms of leadership, Dayton possesses a variety of assets and capitals that should aid in adapting to climate change. City employees, decision makers, and elected officials often use the frame of economic and social vibrancy to discuss sustainability and, to a lesser extent, adaptation. Many city employees consider being a 'sustainable city' as a way to distinguish Dayton from other Midwest localities and attract young professionals, small businesses, and even immigrant communities. As one interviewee told us: "We think that that's a way to differentiate ourselves from other Midwest cities. I don't like using the 'green' term but a sustainable city; all those things combine to make it—at least we think, it elevates us to a place of an even playing field, if not an elevated playing field."

Other leaders are able to connect environmental and climate policy to the identity of their city. For example, one interviewee, often referred to by others as a leader, stated: "we are really pleased that our mayor took the initiative to sign the city up [to a national climate challenge], because we in Dayton have been kind of environmental leaders for a number of years." In these cases, leaders argue that taking action on climate mitigation and adaptation makes sense as an extension of the sense of place the city possesses. Cultural capital aids in the implementing of climate policy.

Further, respondents typically stated that high-level decision-makers in their city supported their efforts to address sustainability concerns. A city employee reported "the idea of environmentalism has now mainstreamed [within the city government]." However, this employee also mentioned the need to apply appropriate "political pressure" to gain interest from decision makers. This, and other examples, demonstrates that leaders often are acting as policy entrepreneurs, in that they are utilizing their political and social capital to connect policy solutions to problems. While so far this ability has not been applied to adaptation, the potential to do so is there.

Beyond individual leadership, there are also examples of collective leadership. One city employee in Dayton reported that the creation of a sustainability task force "was more of an organic thing…it was probably several people that came together and affected a lot of different things. I don't think it was any one person with a torch." Another high-ranking city employee echoed this, stating that "it is now a cross-departmental team of individuals who basically care. I mean they are volunteers." That is, various individuals from across the city government have collaborated to collectively enact change that moves beyond their job descriptions. In many ways, these groups are acting as collective entrepreneurs in that they make use of their shared and combined social capital—namely the connections they have formed through the city government—to push for the changes as a group.

In addition, the city also possesses a number of dedicated and talented employees. An interviewee in Dayton described an example of someone going beyond his job description. The city manager was trying to decide whether or not to push for an increase in taxes or cut back on services. According to the interviewee: "when it came to that point, [City Manager] went—he talked to 30, 35 different community groups, maybe more, over a series of months and he called it 'the listening tour'—and he did. He sort of threw this out there and then listened. And it was very effective."

Dayton has a long record of incorporating community and county input into city governance. For example, priority boards, though falling out of use recently, have historically offered a medium for neighborhoods to directly express their concerns. Seven priority boards have historically acted as a link between local citizens and the city government. In theory, each priority board consists of representatives from a defined region. City government employees and officials then seek input from these boards on how to best conduct government business. Multiple interviewees informed us the city is working to reorganize these boards to increase their efficacy.

Interviewees in Dayton reported participation in many partnerships of mutual benefit. These partnerships are often driven by initiatives for sustainability and economic development. One respondent said, "If it's something that we can do some cross-collaborations on, not just internal to the city, we partner with folks outside of the city as well to get grants." These partnerships may aid in increasing adaptive capacity by building social capital among city staff, the public, and partners. While sustainability and adaptation are not synonymous, the concepts are intrinsically linked and can build off one another. The Water department reported the greatest number of partnerships, likely tied to the majority of sustainability initiatives it houses. Interestingly, many interviewees referenced partnerships and outreach efforts of other departments and entities, often referring to them as being integral to the city's plan for moving forward. This level of buy-in and integration can aid in the transfer of information and facilitates institutionalization of these undertakings.

At times, these linkages also span political levels and jurisdictions. For example, the city works with the regional Miami Conservancy District, which preserves the watershed on which Dayton and other nearby municipalities rely. Interviewees reported strategizing with the Conservancy District on efforts to protect the watershed from the potential impacts hydraulic fracturing fluid disposal might have on water quality. By coordinating with the Conservancy District, the city has been able to protect its interests in the region—including areas outside its jurisdiction—without attracting controversy or conflict with other local governments. Dayton also collaborates with the Miami Valley Regional Planning Commission to develop large transportation, environmental, and economic projects—including an air pollution reduction campaign. These networks demonstrate institutional arrangements and civic relations that can aid in adaptation.

Some infrastructure in Dayton also increases the city's resiliency and adaptive capacity. The city has been making steady progress investing in green infrastructure to increase its urban resiliency and adaptive capacity. For example, city officials are taking steps to plan a geothermal infrastructure that serves as an economic development tool, along with innovative low-interest financing for buildings and homeowners for energy improvements that reduce energy consumption. In 2011, the city partnered with a local private engineering

consultancy to determine the economic viability and overall feasibility of the use of ground-source geothermal systems that rely on the city's abundant aquifers to serve the downtown Dayton business district. Apart from attracting a lot of new businesses, the study showed significant annual energy cost savings potential in the range of 5 to 34% over more conventional systems, which is an example of an economic/environment win-win.

Another effort towards green energy has been the installation of the largest solar facility in southwest Ohio by the Dayton Power & Light Company. This has been an indirect response to the state's energy legislation that calls for 25% renewables by 2025. The facility, which was completed in 2010, generates over 1100 MWh, enough to power 150 homes annually. The city is also looking into building energy efficiency and has entered into a 10-year performance contract with Honeywell for city-owned buildings. The program is projected to save an average of $420,000 in building energy and operating cost annually while helping to modernize facilities and reduce the carbon footprint of buildings.

One of the creative ways Dayton is incorporating sustainability into routine operations is by looking for ways to capture methane released from wastewater treatment. Following the award of around $1.7 million in federal stimulus through the American Recovery and Reinvestment Act fund, the city is installing gas-scrubbing equipment that captures methane gas produced by waste digesters at Dayton's wastewater treatment plant. The captured gas is cleaned and made suitable for potential sale and re-use as a clean energy fuel source for cogeneration. The digester gas-scrubbing helps reduce operation and maintenance costs, and at the same time is environmentally beneficial since methane is a potent greenhouse gas.

CONSTRAINTS

A major factor constraining adaptation in Dayton is the low rate of inclusion/consideration of climate change issues in the everyday functioning of the city. As one city employee in Dayton told us, even though the city is "having much more extreme weather events" he does not believe climate change "really gets factored in—at least not yet." Other officials in Dayton echoed this sentiment. One interviewee pointed out that regarding adaptation, "we're still working on that. As far as climate adaptation and things like that, I think—I'm on the Planning Committee [and] when [public official of ODNR] is going to do some workshop in June for adaptation-type stuff, so hopefully tying that in with the sustainability plan that's going to be hopefully worked on over the next couple of months [will better incorporate adaptation]." Therefore, while it is likely that adaptation may eventually become a focus of the city government, current lack of widespread support in the city government hinders building and utilizing adaptive capacity.

Another critical constraint working against Dayton adapting to climate change is a lack of financial resources and competition from many different needs. One interviewee told us: "In a city such as Dayton, an urban city, funding is a big issue right now because there's a battle between protecting the environment, managing climate initiatives—which is important—and sustaining city services." Similarly, another employee reported that "to take on more is a challenge with a smaller organization and limited funding to be able to do it." Budgets are likely to continue to decrease during the next few years as federal stimulus funding phases out.

One effect of current financial constraints is that Dayton has been unable to properly staff its departments. "I guess we have about 1200 employees now. Down from like 2300 when I first started 20 years ago. So our work force has really shrunk. Primarily because of lack of money" remarked a Dayton public official in August 2012. With less staff covering basic city services and functions, more people are wearing more hats, straining this crucial resource. As a result, less human capital is available to mobilize adaptive initiatives. For two decades now, staff numbers have fallen substantially, though this is largely due to hiring freezes once people quit, retire or are fired: "During these terrible times—and we haven't fired very many people; it's just, you know, we haven't hired to replace people who were retiring."

An example of the lack of financial capital and human resources combining to reduce adaptive capacity is the Regional Air Pollution Control Committee (RAPCA) of Dayton and Montgomery County Public Health. A lack of federal funding, combined with a decrease in Title V fees from the State of Ohio, has resulted in a 25% reduction in staff over the past three years. Shortage of both funding and staff will critically constrain RAPCA's ability to enforce local and federal regulations on air pollution within Dayton. Not only can lack of enforcement be negative for mitigation of greenhouse gases in the city and increase exposure to pollution, but it can also curb adaptation.

Additionally, Dayton has limited access to usable climate knowledge, especially concerning potential impacts on the city. Often, city employees described being unsure where to find legitimate climate information. As one city employee told us: "it's a challenge just to find credible resources as well that you can trust implicitly." Another interviewee told us that they need "information in the short term…given by somebody with status, somebody people trust and that's hard to find these days." This limitation in terms of access to technical knowledge hinders the city's ability to plan for long-term climate impacts. One respondent described creating their sustainability and climate strategy through Google searches.

Pushing out information and gaining public support were also pointed out as challenges. Some respondents questioned the types of communication methods used, based on actual readership and the challenges associated with having constant contact through social media and the internet. As one respondent said, "you have got to invest a significant amount of time and making sure that you are really pushing out information as often. And it's got to be information that's both useful, relevant, timely and so we haven't found that balance between using social media as a mechanism of informing—much beyond just a press release—versus our statutorily required public notification process." The majority of interviewees reported being very confident in their existing plans and processes, however there were references to gaining new momentum being difficult at times through comments such as, "that's just not how our system is set up" and "there hasn't been great organized support." Integrating new information into a set system, such as is present in Dayton, may prove to be a challenge.

APPLYING THE ADAPTIVE CAPACITY WHEEL

We find Dayton to possess both strong political leadership and policy entrepreneurship. The urban adaptation literature describes the ability of entrepreneurial leaders to connect policy solutions to problems and politics as being a key attribute for facilitating adaptation. Various leaders both identified themselves and were identified by others as taking initiative to push for sustainability and, to a lesser extent, adaptation policies in city governance. These efforts have helped integrate these concerns into the broader discourse of vibrancy that permeates city decisions. Further, the city has exhibited a history of collaboration—particularly around environmental protection, such as the Miami Valley Conservancy District and the city 'Green Team'. This ability to collaborate is particularly important in light of human resource constraints.

Collaboration is likely facilitated by, and facilitates the city's strengths, in trust, multi-level governance networks, and bringing together multiple problem frames. The city works to integrate both community and regional stakeholders into governance by collaborating with community boards and the Miami Valley Conservation District. These efforts have contributed to trust building, as stakeholders are likely to feel governance that incorporates their input is more legitimate.

Nevertheless, we rated Dayton's visionary leadership as being neutral—at least in regards to climate change adaptation. Adaptation remains largely a short-term, reactive consideration, as it is not fully integrated into the long-term thinking of the city. On the other hand, the city has shown the ability to think in creative and long-term ways about development in general, which prevents us from rating this criterion as negative. Indeed, if the city is able to harness visionary leadership in the realm of climate change adaptation, Dayton would greatly increase its overall adaptive capacity.

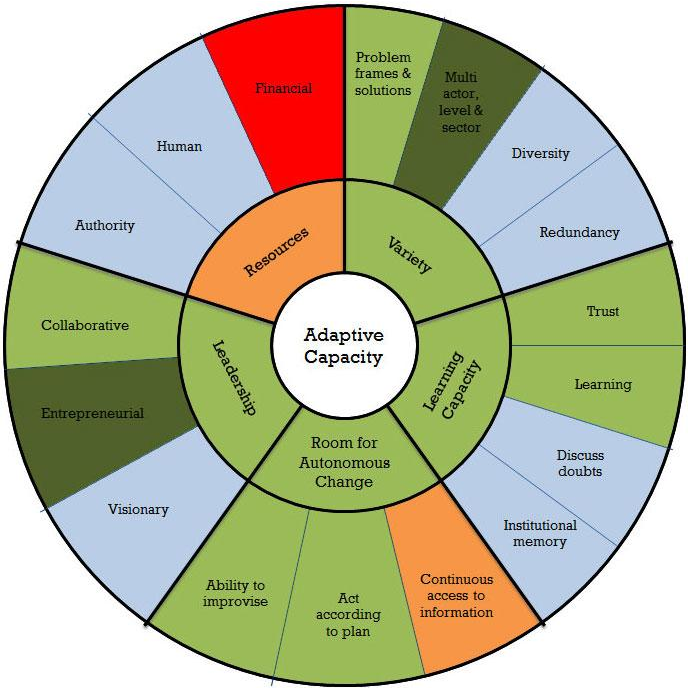

FIGURE 4: DAYTON ADAPTIVE CAPACITY WHEEL

However, to accomplish this task, Dayton must increase its access to resources. Lack of financial resources is the most significant constraint the city is facing in regards to climate adaptation—and likely in nearly every other major effort. Presently, the city does not have enough financial capital to invest in adaptation efforts. Additionally, the lack of financial resources influences Dayton's deficit of human capital. Though the city has many dedicated, talented employees, it does not have enough of them. Individuals that care about adaptation cannot give enough attention to it, as they must focus on other areas of governance.

Finally, lack of access to usable climate information (as well as other kinds of information necessary to inform adaptation decisions) represents a limitation to the integration of adaptation into everyday governance. Partially, this is due to the lack of formalized information-sharing networks within the city. Interviewees with high social capital reported being able to navigate informal networks to access information regarding city operations, but without more formalized information sharing, Dayton's efforts to address the impacts of climate change will likely be constrained. Perhaps more significant is the reported difficulty many interviewees expressed regarding accessing credible and salient climate change information. Though many interviewees showed detailed knowledge of past and current changes in weather and climate patterns, they consistently lamented they did not sufficiently know about likely future impacts. They also expressed an interest in accessing more information regarding what practices similar cities have put in place to deal with climate impacts.

DAYTON RISK ANALYSIS

Note: These maps should serve as a tool, or starting point, for the city. They do not indicate definite patterns and they are not predictions.

The variables included in the risk index for Dayton, OH included demographics (i.e. percentage below 2010 poverty level, percentage under 5 years of age, percentage over 65 years of age, and percentage minority), distance to 100-year flood plain, distance to green spaces, and distance to areas with high vacancy. The existing priority boards and neighborhood boundaries were overlaid to allow for visual reference. In addition to the equally weighted map seen in figure 5, maps with highest risk weighting for proximity to flood plain, proximity to green space, proximity to high vacancy areas, and population demographics are available in the appendix.

While no neighborhood was considered at highest risk in all five calculations, two were considered at highest risk in four and another was considered high in three.

- Southern Dayton View: Considered high risk in Equal Weight and calculations weighted for proximity to flood plain, proximity to green space, and population demographics.
- Riverdale: Considered high risk in Equal Weight and calculations weighted for proximity to flood plain, proximity to green space, and population demographics.
- Miami Chapel: Considered high risk in Equal Weight and calculations weighted for proximity to vacancy and population demographics.

While these areas possess a number of risk factors that have been associated with climate change impacts, their actual vulnerability needs to be further examined. As described throughout this report, opportunities for taking advantage of neighborhood adaptive capacities can be explored. For example, as Dayton looks to implement and expand their urban forestry and street tree replacement program in an effort to counter recent losses due to pest infestation and increase community engagement, targeting areas potentially most vulnerable due to heat and distance from green space may make sense. Interestingly, one of the two neighborhoods where this program is being piloted, Five Oaks, was considered to be at high risk due to proximity from recreation space.

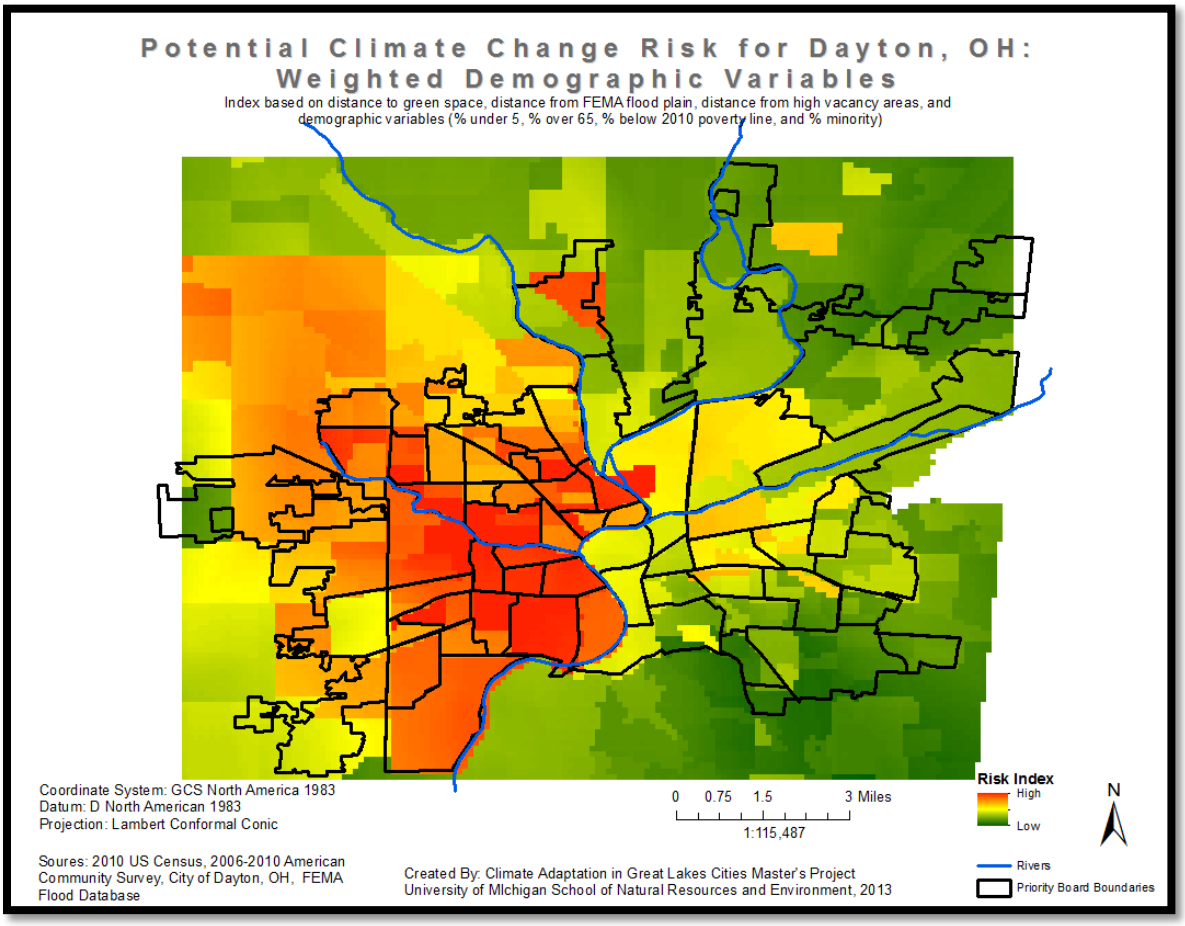

FIGURE 5: POTENTIAL CLIMATE CHANGE RISK FOR DAYTON, OH

ELYRIA

Situated at the fork of the Black River, Elyria is the seat of Lorain County in northeast Ohio. Home to Cascade and Burr Oak Parks, Elyrians enjoy picnicking, biking, hiking and canoeing along the Black River. The Garford Manufacturing Company, located in Elyria, invented the first single-headlight car and created the first padded bicycle saddle. Herman Ely founded Elyria in 1817 in order to build water mills along the Black River. The 1940s through the 1970s was a period of tremendous growth, progress, and prosperity and the city population doubled to more than 50,000. During this time, Elyria was one of the fastest growing cities in Ohio.

As of 2010, the population was approximately 54,500. Per-capita income and median household income are both below the average for the state. Percentage of the population below the poverty level is higher than the state average. Roughly seven percent of the population is younger than five years, and about fourteen percent of the population is sixty-five years or older. Manufacturing remains the largest portion of economic activities, followed by retail, wholesale, and accommodation and food service sales (Census, 2010). The closing of three major car plants in the 1970s and 1980s in the region led to high unemployment and economic stagnation in Elyria. Currently, the city is the world headquarters of companies like Ridge Tool, Invacare Corporation, EMC Corporation, Bendix Commercial Vehicle Systems and Diamond Products, but the service industry is replacing its dominant manufacturing base.

Despite these difficulties, Elyria has found creative ways to begin work on sustainability initiatives. It currently collaborates with the Northeast Ohio Sustainable Communities Consortium, the Lorain County Storm Water Management District, and the Black River Remedial Action Plan. After a $70 million renovation, Elyria High School recently re-opened with new, green infrastructure. Educational institutions in the region are also implementing sustainability research and projects. Lorain County Community College and Oberlin College are equipped with solar panels, geothermal energy sources, green rooftop rain gardens, and have developed partnerships with more than ten other universities at the regional and national level that offer degree programs in sustainability, wind-turbines, and energy conservation.

In Elyria, many public officials were concerned about flooding, particularly as it relates to land erosion in Cascade Park along the Black River. One official related: "Two large bodies of water and, when we get a heavy downpour, are meeting in Cascade Park causing some definite hydraulic problems and erosion issues throughout the park." Officials in Elyria also were concerned with ageing infrastructure and its ability to withstand climatic stressors. Elyria is unique among the four cities, in that officials partially address this concern through sharing amongst strong interregional networks. One interviewee related that they "work together with other communities on who's got the right equipment, where we can borrow the equipment." Furthermore, Elyria had concerns regarding the increase in vector-borne illnesses. One interviewee responded when asked about climate impacts: "The other concerns would be that during significant drought periods, that's when we see amplification of the West Nile virus, like this dry summer that we just had."

CAPACITIES

A majority of interviewees expressed some level of concern regarding climate change. In the city, a handful of departments have begun to incorporate climate change into their general management practices. Mostly this is occurring within departments dealing with water, such as sewage treatment, and storm water management.

An attribute benefitting Elyria's adaptive capacity is the social and human capital the city government possesses. These capitals allow city employees to access equipment and call in favors. One interviewee reported to us that at least for small items: "We usually just call each other up and ask for something." We received similar comments from a variety of other departments. In these cases, departments rely on social

capital to create informal networks with other departments to share resources. The operation of the city government seeks to encourage these networks, as department heads meet with each other on a routine basis. Furthermore, individuals have been able to build their own networks due to their long tenure within the city. Multiple interviewees have worked for the city for twenty or thirty years. During this time, they have been able to build relationships throughout the city.

Many interviewees also stressed maintaining communication and relations with the broader community. One interviewee told us: "the first rule that I always follow is have good community. Have good lines of communication, not just having email or phone calls, but meet in person." Good communication extends beyond day-to-day work and into day-to-day life for some individuals. For example, one city council member reported that he received phone calls at home and often spoke with constituents during his daily life—including waiting in line at the grocery store. Such informal interactions with the public drive home the point that messy social ties, which are difficult to identify and measure, almost certainly will aid in climate adaptation. More formal interactions, such as newspaper articles, special event participation, newsletters, and regular public-access television interviews by the mayor of Elyria, further increase public communication. Additionally, the city is starting to incorporate social media into its communication strategy. As one city employee in Elyria stated: "I've had two years—two summers—where I've had college interns coming in and they set us up for Facebook and Twitter and I've never—I don't Tweet—but we're there." Whether or not social media fulfills this promise remains to be seen. Another similar effort entails using text messaging to deliver fast warnings of dangerous conditions, such as severe weather and public health risks.

Active participation in regional networks promotes Elyria's adaptive capacity as well. The city interacts with the Northeast Ohio Sustainability Communities Consortium (NEOSCC), the Northeastern Ohio Coordinating Agency (NOACA), regional Tree City meetings, the Oberlin Project, Lorain County Community College, and the Lorain County Growth Partnership. Also, interviewees repeatedly referred to the importance of regionalism and learning from nearby and similar communities. Many interviewees expressed their own dedication to and knowledge of the city. For example, in Elyria, one official with 25 years of experience attributes part of his current ability to accomplish tasks to his long tenure and deep knowledge of the city and its operations. The accumulated human capital and commitment from officials allow departments to overcome staffing shortages—at least to some extent. For example, another interviewee reported walking through the sewage treatment facility every Saturday and Sunday without compensation.

Elyria has also received a number of grants during the past few years. As a city official informed us: "I think our city as a whole has done an excellent [job] in obtaining grant money, which is outside money, whether it be federal grants or state grants…we got a $3.2 million grant for two years to employ about eighteen firefighters." The city also received $535,000 through ARRA in 2009 to reduce energy consumption and has budgeted most of it to residential energy retrofits, including free programmable thermostats and a weatherization rebate program. A number of interviewees mentioned the Elyria Health Department as being particularly successful in bringing in grants. This ability to identify, apply for, and receive outside money is particularly beneficial in light of recent economic troubles.

Finally, individuals in the city expressed having some flexibility in allocating their budget towards unexpected expenses. One interviewee reported that: "if something happens you can say we're not working overtime this year, switch that over here to buy a new pump." Other interviewees expressed similar abilities to shift from expected outlays to surprises. Thus, departments have some flexibility in cutting back in some areas to fund their priorities.

CONSTRAINTS

Much like other Rust Belt cities, Elyria faces declining tax revenue, which limits its ability to sufficiently staff city departments and create new initiatives. The city government laid off many employees after the start of the economic recession in 2008, while recent retirees have not been replaced. "The whole city government issue is undermanned; we went through some layoffs and stuff like that so, back in '08, '09 when the economy went down the tubes, so we're battling that" stated one respondent. He went on to say "it does come down to staffing. We can program all day long but if we don't have people to mow the grass, line the soccer fields, line the baseball fields, then we can't offer those programs." Many Elyria staff members have experienced additional burden by absorbing the work left by the dearth of staffers. These staff members are so occupied in "putting out fires" and applying for grants in a time of declining funds that they have little time or human power to implement adaptation initiatives.

The city has not fully integrated adaptation and sustainability into city planning and governance. Some interviewees attributed this to a lack of complete understanding of the issues. For example, one interviewee described the difficulty he is having with teaching residents and politicians about the importance of urban trees, such as "what they do with water run-off and things of that nature and how important they are with energy savings." Further, the overall level of technical knowledge regarding likely effects of climate change was low. Many interviewees expressed a desire for more easily accessible, credible, and salient information on likely climate impacts.

Ecosystems around the city are in a degraded state, which has led to erosion issues, increased maintenance costs, and some health concerns. The EPA has designated the Black River one of the forty-three Great Lakes Areas of Concern due to past industrial contamination. The Black River also flows through Cascade Park, which the city prides as an area of recreation. In recent years, severe rain events have led to erosion along the banks of the river in the park.

APPLYING THE ADAPTIVE CAPACITY WHEEL

Elyria's greatest capacity is its ability to pool resources, work together, and be flexible. The city government has collaborated with a variety of nearby organizations to achieve its sustainability goals, which tend to center around renewable energy and storm water management. Decision-makers within the city repeatedly stressed their commitment to regionalism and learning from nearby communities. The city's participation in multiple regional planning consortiums reflects this commitment. Additionally, efforts by the city to work with Lorain County, nearby communities, and local institutes of higher education to develop renewable energy and 'green' technology industries attests to the government's willingness to collaborate vertically and horizontally to achieve its sustainability and development goals. Though collaboration centered explicitly on adaptation is lacking, institutions with which the city is working, such as Oberlin College, are considering climate adaptation. Thus, considering the city has some concerns regarding climate change, these collaborations entail opportunities to gain knowledge on adaptation.

In addition, social capital present within the government connects departments together. Many individuals working for the city have lived most of their lives in Elyria and held a job with the government for decades. They know each other, their city, and many of the residents. Because of this, Elyria has positive trust and collaborative leadership, and incorporates stakeholder input from multiple levels. This social capital will likely aid the dissemination of climate information through the city government as individuals learn more about potential impacts and strategies to ameliorate them. On the other hand, communication networks in Elyria are often informal and built on years of interaction, which may make accessing these valuable streams of knowledge and experience difficult for new employees.

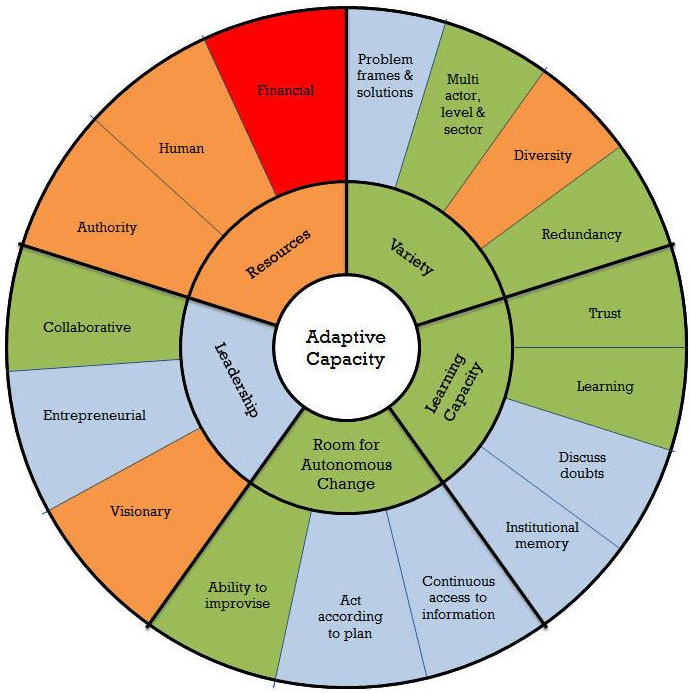

FIGURE 6: ELYRIA ADAPTIVE CAPACITY WHEEL

As with each of the cities we studied, there is a distinct lack of resources within Elyria. Financial capital is scarce and limiting. Without a steady, sustainable level of revenue, it is difficult for the city to plan for the medium-term—let alone the long-term—time horizon adaptation requires. The various interviewees that described needing to lay-off and not replace retiring staff due to budgetary constraints further demonstrate the difficulty the current financial conditions place on short-term operations and planning.

These budgetary concerns also likely decrease the city's visionary leadership. The main focus of city government is managing short- and medium-term concerns and priorities. There is little space for systemic, far-reaching thinking regarding the future of the city.

ELYRIA RISK ANALYSIS

Note: These maps should serve as a tool or starting point for the city. They do not indicate definite patterns, and they are not predictions.

The map included is a risk index for Elyria, OH, showing a composite of distance to green spaces and distances from FEMA flood plains, overlaid with demographics supported by literature to be most vulnerable to the impacts of climate change in US cities. We have aggregated each separate risk analysis for the flood risk, green spaces and demographics layer, to show one composite map where areas highlighted red are those areas that deserve priority by policymakers regarding climate adaptation.

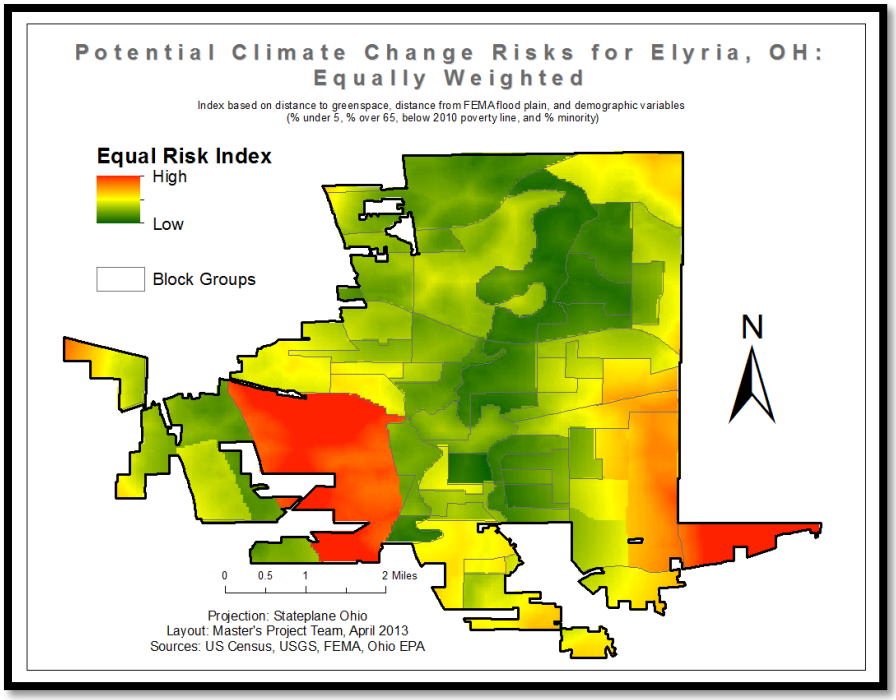

FIGURE 7: POTENTIAL CLIMATE RISK FOR ELYRIA, OH

As can be discerned from the included equally weighted map (subsequent maps of different weights included in the appendix), the southwest section of Elyria is considered to be at very high risk due to proximity to the floodplain, lack of local green spaces, and presence of vulnerable populations. The same can be said of the southeast corner of Elyria, though at a smaller geographic scale. The most insulated sections to the projected impacts of climate change are block groups located within the center and northern section of the city. Consideration of the potential distribution of impacts from climate change when implementing adaptation and sustainability policy can ensure that the most effective, economic and equitable actions are taken.

TOLEDO

Toledo is the fourth most populous city in Ohio and is the county seat of Lucas County. The city sits on the western end of Lake Erie on the Maumee River in Northwest Ohio, north of what was formerly the Great Black Swamp. The 2010 Census reported a population of 287,208. The percentage of the population below the poverty line, as well as the percentage of the population below 5 years of age, is above the state average, while median income is below the average.

Toledo is known as "The Glass City" because it is home to companies innovating in the glass industry. Companies such as Owens-Illinois, Owens-Corning, and Libbey Glass originated in Toledo, manufacturing products such as automotive glass, construction materials, windows, and bottles. The automotive industry also has a long history in Toledo. General Motors, Chrysler, and Jeep had factories in the metropolitan area, and Electric AutoLite, Sheller Globe Corporation, and Dana Corporation began in Toledo, employing people in automotive part factories. After the decline of auto manufacturing in the region, the city is focused on redevelopment and revitalization to draw people back to the Toledo area. Current priorities include ensuring community safety, creating jobs through developing a regional economy, stabilizing neighborhoods, and encouraging health and wellness. In the 2000s the city has seen growth in "green jobs," through University of

Toledo and Bowling Green State University grants for solar energy research and the opening of Xunlight and First Solar plants.

Toledo has had problems with water pollution from combined sewer overflows in the past and currently has a federally-mandated environmental program, Toledo Waterways Initiative, to implement a plan lasting until 2020 to update sewer and wastewater facilities. The city is currently developing a sustainability plan through the Toledo Lucas County Sustainability Commission to promote sustainability locally, coordinate activities among groups, and improve the sustainability bottom-line of local governments.

Many Toledo public officials expressed concerns regarding climate change impacts related to water. Concerns about flooding, drought, and water quality of Lake Erie were mentioned in regard to how these will affect Toledo's infrastructure and the economy. It was frequently mentioned that flooding from extreme rain events is already occurring, management is difficult because of the flat topography of the area, and officials are worried about future climate change increasing their severity. Some public officials related the challenge of keeping public support dealing with extreme rain events when they occur infrequently and drought is experienced in-between. "You don't have any water coming through your system! And so we have all these facilities that people's rate dollars went to that provide no benefit." The Public Utilities department connects floods, droughts, and runoff to the overall quality of the region, "…we rely heavily on recreation and tourism and how a climate change could affect that… I know we've already had a lot of algal blooms because of it and which really impacts our tourism. So for me, I think that's how it's going to affect our tourism, which will directly impact the economic viability and stability of our area." The sediment runoff from extreme storm events into the Maumee River and into Lake Erie, along with the required dredging to maintain access to the port, was categorized as a "serious issue" by the Environmental Services department, and the problem may become more significant when combined with declining lake levels. Finally, ecosystem-related concerns were expressed dealing with maintaining urban ecosystems, as one official put it, "I mean without having rain it's got a huge impact on municipality with 90,000 street trees" and on preserving the unique Oak Openings ecosystem. One official described its importance by saying, "Oak Openings is one of the areas that has the greatest biodiversity in Ohio. There is one-third of Ohio's endangered species within the Oak Openings…You know, my biggest concern is what's going to happen in the face of climate change."

CAPACITIES

Decision-makers discussed sustainability as a way to revitalize the city. They described implementing piecemeal sustainability policies and initiatives when opportunities arise, rather than through coordinated plans. However, recently Toledo leadership has engaged with the Toledo-Lucas County Sustainability Commission on their creation of a community-wide plan. Work on this plan remains preliminary. One official informed us, "we haven't dealt with climate change head-on, so it's not like we have identified climate change as an issue we are going to tackle organizationally and then develop these strategies for doing it, so from that standpoint… I will say that there is broad support from the staff for any of these initiatives that we take for, you know, general sustainability issues. So reducing our consumption of electricity, reducing our consumption of fossil fuels, I think everybody is on board for that." Decision-makers are seeking sources of information to design this plan.

One way officials are accessing climate information is by actively engaging with networks in the Great Lakes region that are considering future climate change. These networks have the benefits of contributing to regional planning efforts, increasing city officials' awareness of climate adaptation options, and facilitating the distribution of knowledge throughout the region. For example, there are connections with groups operating at a variety of levels, including the federal level, through the National Estuarine Research Reserve and participation in NOAA's 2010 Great Lakes Climate Needs Assessment. Regional collaborations include the Storm Water Conservation District and the Toledo Metropolitan Area Council of Governments (TMACOG).

Within the city, the GreenTown conference that took place in October 2012 helped to connect the public and private sectors in Toledo to have conversations about sustainability planning. The city has previously had issues with collaboration across departments, but there is evidence that this is improving due to the action of current city leadership. One official said, "I've worked for several mayors, but the current mayor that we have has gained trust amongst regions, other entities, private, public, you know, and that's allowed us to really bust through some barriers because there was a trust issue going on a little bit." Information about future climate impacts and adaptation options, as well as shifting focus to regional planning and pooling resources through networks, is contributing to the city's adaptive capacity.

The city is pursuing economic growth related to sustainability, which has benefits for adaptation. They are using collaborations and grants effectively to fund sustainability initiatives. The city is leading a partnership between business, government and academia to emerge as a center for the solar industry. There has been strong collaboration between the University of Toledo, Owens Community College, First Solar, and the Lucas County Economic Development Corporation, drawing upon Toledo's strength as a glass-manufacturing hub to transform the city into a solar power innovator. In 2011, the City of Toledo and the Toledo-Lucas County Port Authority unveiled a $5.2 million one-megawatt solar field that was funded through a mixture of public and private sources. The field was made from locally-sourced panels from First Solar and will supply the Collins Park water treatment plant with a quarter of its energy needs. Other innovative projects include a 250 kW ground-mounted solar system that is installed in a former brownfield by a private Ohio-based glass manufacturer, partially financed through a $700,000 Ohio Energy Office grant through American Recovery and Reinvestment act (ARRA) funds. Increasing use of solar energy makes Toledo more resilient to climate-related energy disruptions while developing the economy. An effective strategy for economy will increase city resources (human and financial). In building energy efficiency, the Toledo-Lucas County Port Authority is administering a creative program called Better Buildings Northwest Ohio which is partly funded by a $15M start-up grant from the U.S Department of Energy. The program offers low-cost financing to building owners to help pay for high-efficiency improvements to their facilities and building systems. As of 2013, more than 50 energy efficiency projects have been completed through this program, with a total investment of over $20 million. The city's goal is to save 20% energy usage in 7.5 million square feet of buildings by 2015.

Due to its past issues with storm water management, the city is updating its sewer system and experimenting with green infrastructure. A legal obligation to separate combined sewage overflows and reduce overflow events, though limiting to budget flexibility, has put Toledo in a better position for dealing with future storm events. During the first phase, the city increased the Bay View Wastewater Treatment Plant's capacity to treat peak wet-weather flows and installed a twenty-five million gallon underground retention basin that helped store increased wet-weather flows until the main plant can further treat the wastewater. Green infrastructure organizations, such as Toledo-Lucas County Rain Garden Initiative have strong support at the community and council level. The initiative is a collaborative enterprise of 14 organizations, including USDA, American Rivers, and Ohio State University Extension. The program has increased public awareness of the benefits rain gardens possess and offers limited funding to homeowners and organizations. Storm water is one of Toledo's biggest concerns in regard to climate change, and having developed support and organizations focused on flexible green infrastructure strategies, as well as public acceptance, contributes to adaptive capacity.

CONSTRAINTS

The recession and a longer economic decline have led to shortages in staff, money, and time across the city. Many city employees related limitations on the lack of time that they can spend on new initiatives outside of those that are critical to the current function of the city. As one official put it, "I think the most obvious constraint that you are probably going to hear from anybody is just the amount of hours in the day, the amount of people on the ground. There are only so many things you can focus on in a given day." When

priority is given to maintaining current city services, such as police and fire, and resources are scarce, it is difficult for the city to engage in long-term planning and plan for climate change. Beyond constraining government operations, interviewees mentioned that after real estate prices declined, the city government lost political support for green standards because of concerns over their effects on development.

Additionally, many city officials remain unsure what impact climate change will have on their department's daily operations. One official stated "I need to be better informed on what we are likely going to see, how these [natural] resources are going to be impacted by climate change." When asked about planning and climate change impacts, another official stated "you know the local planning commissions and stuff don't usually have the expertise to know these things and don't necessarily have the political will to do them." Further, they expressed that it was difficult to translate scientific research into action. An official related, "We could go on a website and say, 'What am I going to look like?' and I will tell you, but what does that mean for me and how do I put boots on the ground to make something happen about it?" Thus, both the lack of legitimate, credible, and salient climate information greatly hinders the ability of Toledo to adapt to climate change.

Further, some city officials worried that environmental and economic goals sometimes conflicted. Interviewees frequently stated that the focus and framing of issues has to be economic to get support in difficult economic times. Concerning the communication with other decision makers, one official said "when I'm out there talking to elected officials, to business groups, all that, you'll rarely hear me say the word 'environment'. I'm talking about economic development. I'm talking about the bottom line. I'm talking about all these other things that get their attention." Some departments see sustainability and adaptation as mostly the responsibility of the designated environmental departments. When asked about climate change, one interviewee responded "it's hard from my perspective because what we do is not environmental, it's planning, you know." The silos of environmental consideration is limiting to the integration of climate adaptation planning into major city decisions.

APPLYING THE ADAPTIVE CAPACITY WHEEL

Leadership is a strong capacity in Toledo. Key decision-makers demonstrate both the ability to be entrepreneurial and collaborative. Respondents' willingness to test and implement new policies is an important characteristic increasing long-term adaptive capacity. For instance, the Department of Environmental Services has installed rain gardens throughout the city to attenuate the effects of severe rain events, visited regional cities to learn best practices, and formed partnerships with local, civic and private organizations to address sustainability challenges. Another example is located in the Lucas County Metro Parks, where enterprising individuals created a sustainability team, which has decreased energy and material consumption through programs such as reducing department vehicle fleet size.

Additionally, the leaders demonstrate a willingness to work with and learn other departments, civil society, and other cities will likely help innovations spread through the city. The aforementioned visits to other cities, to learn and share best practices, is one example of this. Others also demonstrate that the city has successfully integrated a variety of problem frames and solutions, as well as worked at multiple levels of governance. The city engages and works with neighborhoods, the county, and regional, state, and federal agencies. For example, the city collaborates with the Toledo-Lucas County Sustainability, which is a partnership between Lourdes University, University of Toledo, private sector groups, Lucas County MetroParks and the Toledo Metropolitan Area Council of Governments, among other institutions, whose goal is to promote sustainable policy and initiatives throughout Toledo and Lucas County. The city also works with the Lucas County Land Bank, which identifies, takes possession, and allocates abandoned properties throughout the county in order to reduce blight and protect property values. Though the Land Bank only began in 2010, already it has worked with community groups and the city to create community gardens and green spaces—including an

orchard and a large downtown park with an amphitheater. By collaborating at multiple levels and with various actors, the City of Toledo increases perspectives, knowledge, and experience in city governance, which should help awareness of and solutions to climate impacts disseminate more rapidly throughout the city.

On the other hand, individual innovations tend to focus on solving immediate or short-term problems, such as storm water management and invasive species. A holistic, long-term vision would increase Toledo's adaptive capacity. Partly constraining long-term planning is the deficit of financial resources and knowledge within the city government of Toledo. The city must allocate what resources it has to short-term priorities.

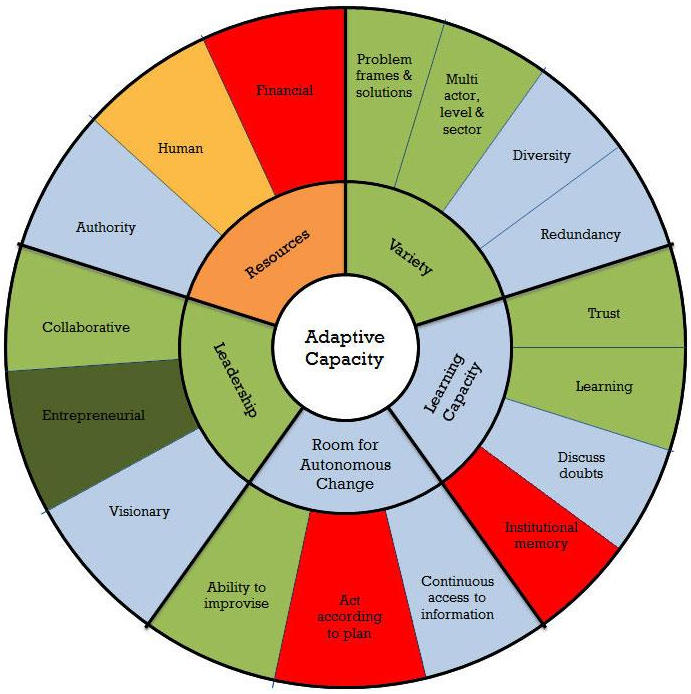

FIGURE 8: TOLEDO ADAPTIVE CAPACITY WHEEL

The lack of financial resources within the city particularly constrains both short-term and long-term adaptive planning. The city lacks the requisite financial resources to completely deal with climate change impacts. The priority of maintaining essential services, such as police and fire, and the EPA Consent Decree created a Long Term Control Plan for combined sewer overflows that are not easily affordable for the city, leaving few funds available for new initiatives that address needs that seem less immediate. Staffing departments is also difficult. The city has not replaced many recent retirees.

The reduction in staff, resulting from the retirement of senior workers, also contributes to a lack of institutional memory. At a time when the hours of city workers are most valuable, it is important for them to be able to access knowledge gained by the previous experience of their departments. Our research did not find evidence of a clear system by which current city staff have access to this type of information. The city lacks a formal plan for sustainability and adaptation planning, though it is developing one. The lack of a plan decreases the ability of individuals to take action concerning climate adaptation individually, as information concerning possible consequences and appropriate responses has not been supplied. The city does have an overall emergency plan, though it seems not to be well understood by those outside of emergency services. Warning systems, such as sirens, exist for extreme weather events and the city is currently working toward a text message based alert system, though it is not yet operational.

Further, the city lacks easy access to valuable technical and scientific information regarding likely climate impacts on the city. Without this information, it is difficult—if not impossible—for Toledo to plan for climate change. Additionally, scientific data may not be suitable to the governing needs of the city. Therefore, better access and the presence of boundary organizations would greatly benefit Toledo in adapting to climate change.

Note: These maps should serve as a tool or starting point for the city. They do not indicate definite patterns and they are not predictions.

The variables included in the risk index for Toledo, OH included demographics (i.e. percentage below 2010 poverty level, percentage under 5 years of age, percentage over 65 years of age, and percentage minority), distance to 100-year flood plain, distance to green space, and distance to areas with high vacancy. The neighborhood district boundaries proposed in the 20/20 plan were overlaid to allow for visual reference. A series of weighted risk calculations were conducted to assess which areas within the city boundary were at greatest combined risk. In addition to the equally weighted map seen in figure 9, maps with highest risk weighting for proximity to flood plain, proximity to green space, proximity to high vacancy areas, and population demographics are available in the appendix.

When comparing across all maps, several areas are consistently considered to be at higher risk. These include:

- Northern portion of Old West End
- Southwest portion of Fort Industry
- Southern portion of Onyx
- Southern portion of Downtown-Warehouse-Uptown-Collingwood Springs
- Central portion of Scott Park-Secor Gardens
- Northern tip of Totco

While these areas possess a number of risk factors that have been associated with climate change impacts, their actual vulnerability needs to be further examined. As described throughout this report, opportunities for taking advantage of neighborhood adaptive capacities can be explored. For example, as Toledo looks to implement and expand non-traditional storm water management tools (i.e. rain gardens and tree planting) to fortify water management infrastructure, targeting areas potentially most vulnerable to localized flooding may make sense.

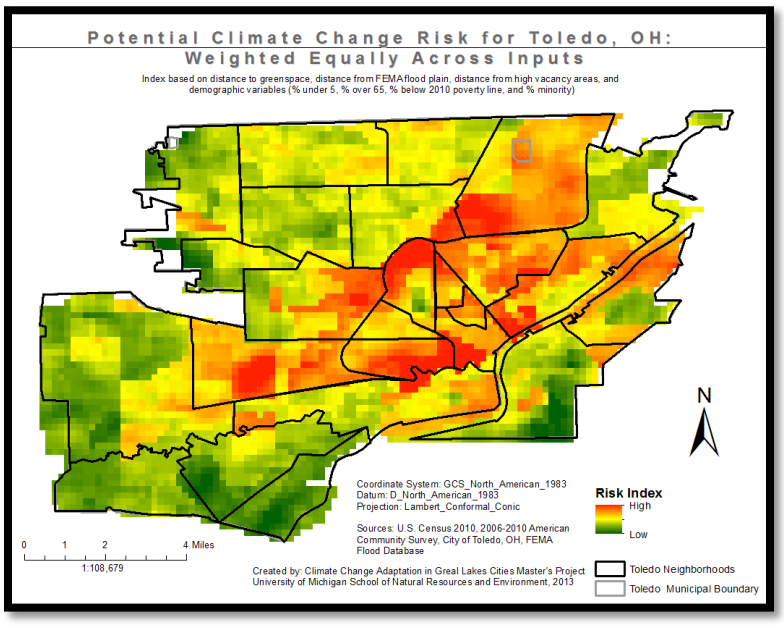

FIGURE 9: POTENTIAL CLIMATE RISK FOR TOLEDO, OH

AVON LAKE

Avon Lake is a small town on the shores of Lake Erie, just outside of Cleveland. Part of Lorain County, Avon Lake did not officially become a city until 1961. The city is home to an estimated 22,602 people, with per-capita income, median household income, home ownership rate, and median value of owner occupied units all higher than the state's average. The percentage of people living below the poverty level in Avon Lake is lower than the average for Ohio (U.S. Census, 2010).

Avon Lake's economy has historically been tied to manufacturing (mainly sawmills and shipyards) with industry continuing to play a large role today. Industrial companies such as Lubrizol, Ford, and PolyOne Corporation have facilities located in the area. GenOn operates a coal-fired power plant facility in Avon Lake that will likely close in 2015 due to high costs from EPA non-compliance. Other economic activities include merchant wholesaler sales, retail, accommodation and food service (U.S. Census, 2010).

The city has 220 acres of parkland, including a Metropark, along with beaches and a boat launch for tourism and recreation. Current environmental programs include P.I.P.E. (storm sewer public involvement and public education program), the Renewable Energy Task Force, the Sustainability Master Plan, updating the storm water and sewer system to comply with EPA regulations, and Avon Lake's municipal utilities' work.

Though Avon Lake, OH was the city in which the fewest interviewees expressed concerns about climate change, some officials interviewed worry about the impact of extreme events. In particular, officials relayed doubts about the capacity of current sewer and drainage systems. One official stated, "When we get beyond a hundred year storm event, we are going to be in trouble in Avon Lake. I'll just be frank." When speaking about precipitation, another official responded "Even if they separate all the storm waters, we're still going to see an increase. Unless you put in a brand new system, your infiltration is a big problem."

CAPACITIES

The city's efforts to establish partnerships and networks across sectors and departments can potentially increase its adaptive capacity. Many of the interviewees reported having good personal relationships with other departments, such that they could "just pick up a phone and ask a question" if they needed assistance. This ease of informal communication can facilitate social capital. Most interviewees participated in multiple methods of public outreach—websites and special events being the most common forms. In addition, Water Pollution and City Council both mentioned social media as an outreach method that they have started to use. Finally, Avon Lake has a TV channel, called Avon Lake Community Television, which is available on multiple channels and the web, which the city uses to disseminate information.

Though faced with some budgetary challenges, financial capital is a potential capacity for the city. As one city official stated, "over two-thirds of our budget is covered by plan review fees and permit fees, so we're in pretty good shape." Another mentioned that, "we get a budget of $20,000 a year. I don't think we even used a fourth of that last year." Though the total city budget is not expanding and there are restrictions in the way it can be spent. Therefore, financial capacity to deal with climate change impacts will depend partly upon the flexibility of funding streams and budgets, continued relative economic stability, any successful development that the new freeway exit may bring, future success of the Chamber of Commerce initiatives, and the final fate of the GenOn plant.

Human capital can potentially increase adaptive capacity in Avon Lake. While there have been difficulties with actually implementing sustainability projects, including solar energy installation, there are city officials that have demonstrated their commitment to researching these possibilities and attempting to get them started. Examples of this include the sustainability task force, the Sustainability Master Plan, and partnerships

with the zoning department for allowing renewable energy development. These are solid beginnings from which to build upon in order to implement additional climate and/or sustainability projects.

The P.I.P.E. (Public Information/Public Education) program is another example of the human capital that exists in the city. The program is a working group of the Environmental Affairs Advisory Board and is under the direction of the city engineer. P.I.P.E. program activities educate the community about storm water management and works towards achieving compliance with EPA directives. These outreach activities center on Al the Alligator, a mascot who educates about storm water management on the Avon Lake TV channel, city website, and occasionally, in-person. As part of their outreach strategy, the P.I.P.E. program also hosts a photo contest.

Avon Lake's financial capital, high levels of well-being, availability of human capital and existence of partnerships can all increase city adaptive capacity, should city officials support the implementation of adaptive strategies. The recent focus on sustainability also suggests that the city might be more aware of the need to consider environmental impacts. If response to climate impacts can be framed to overlap the city's current sustainability efforts, there is potential to further enhance adaptive capacity.

CONSTRAINTS

Although some elements of partnerships and networks facilitate adaptive capacity in Avon Lake, there are other elements that may be considered as constraining to overall capacity. For example, very few interviewees reported participating on more than one external network or partnership, except the Services Department and the Economic Development Board. Each of these entities had a very specific focus or goal for these relationships: street tree viability for the Services Department and small business sustainability for the Economic Development Board. Thus, even though the capacity for networks around specific issues exists, they are not yet being utilized on a larger scale or for climate adaptation-specific efforts. Additionally, Avon Lake is not engaging with the available county and regional partnerships, which can also constrain total city adaptive capacity. Whether it is a question of lack of interest, constraints on time, or some other factor, remains to be explored. It may be worth exploring if city interest in adaptation plans increases in the future.

Further, the lack of formalized communication networks between departments and with the public may constrain adaptive capacity. When asked about communications within the city, responses varied but a lack of structure and/or need was reported. One respondent explained the lack of structured communications across departments as "that's just how this place is set up." While city employees and officials frequently mentioned internet technologies, multiple interviewees were not certain whether the information on their site was updated, what information was posted and available, or how they advertised for people to visit the site for information. Finally, interviewees rarely mentioned established channels to receive information or feedback mentioned, with surveys and complaint calls being the main mechanisms discussed.

As mentioned above, despite its financial advantages compared to the state average, Avon Lake does experience some financial constraints. For example, one interviewee stated: "Right now, in this climate, you are not able to hire people. You are not able to get capital costs out there because they are trying to save—that's a tough sell." Lack of resources also negatively affects staffing ability, which constrains human capital. For example, another interviewee mentioned that "the numbers are going to go down; they are not going to go up, okay, for my workforce because we are not bringing in the tax revenue that we used to." Other financial concerns for Avon Lake include the potential closure of the GenOn plant, which would affect the city budget and the school system. Also, a recent paramedic levy did not pass. Finally, the city is in the process of trying to separate its sewer system.

Some officials within Avon Lake are skeptical of climate change. In one example of the mistrust regarding climate change and climate science that periodically surfaced in Avon Lake, one city official stated that "I don't believe in climate change at all. I believe in sustainability, but sustainability is different from climate change." In another example, "I'm not sure that I can see anything in particular climate-related. I mean, that really has no bearing on any of our, like, renewable energy types of things. At this point, I can't foresee it having any effect on any of our use of properties or placement of buildings." The perception that climate change does not exist constrains adaptive capacity by decreasing the ability to make connections between city planning, climate change adaptation, mitigation, and sustainability. It also places the city in a more reactive position, as they will necessarily only respond to climate events or consequences as they happen, rather than being able to plan ahead based climate-driven trends. Finally, it means that adaptation measures will be implemented only if they happen to correspond with the city definition of sustainability, which decreases the range of options that would otherwise be available to the city. This also increases the potential for maladaptations or trade-offs with adaptation, in the event that sustainability planning and adaptation do not correlate.

A different public official cites institutional conservatism as a barrier to adapt to climate change. For example, "…you're here to provide a service that has to be continuous and conservatism—if it's worked in the past it generally works in the future, so utilities don't often like to change…we're not necessarily seeing the need for innovation..." Institutional conservatism, in conjunction with the perceived lack of present and future impacts, constrains adaptive capacity. Not only are utilities habituated to specific goals and procedures, they do not perceive any external drivers that might otherwise motivate change. Another respondent reports that "once you get to a certain age it's hard to learn down. You know, you've been doing it for so long it's hard to change your ways," reflecting the difficulty that people may face when trying to implement new ideas and initiatives.

APPLYING THE ADAPTIVE CAPACITY WHEEL

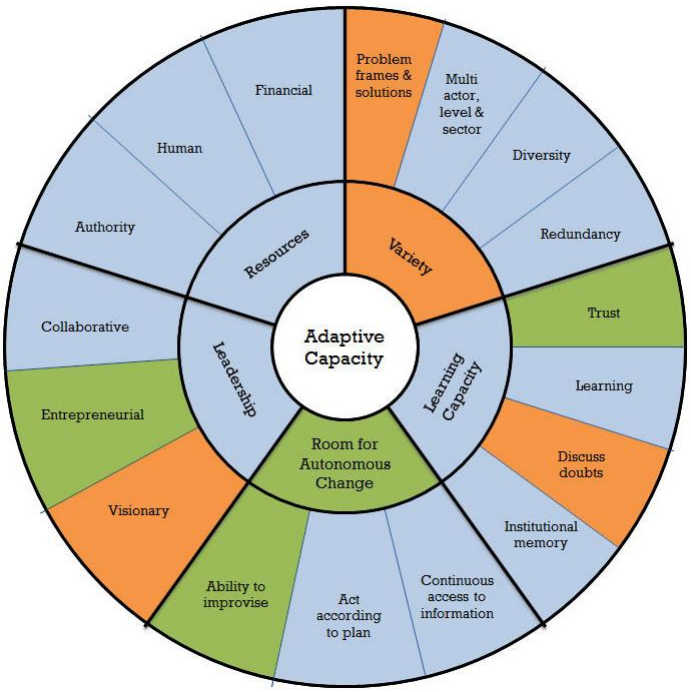

FIGURE 10: AVON LAKE ADAPTIVE CAPACITY WHEEL

Avon Lake is the smallest city in our study. There were fewer participants in our interviews. Therefore, the limited information we gathered makes it more difficult to assign a score for each facet of the adaptive capacity wheel. The following discussion focuses on aspects of the wheel that did have sufficient information to inform an analysis of adaptive capacity.

Avon Lake's entrepreneurial leadership increases its adaptive capacity. Interviewees expressed a willingness to implement new policies if they believed them necessary. For example, efforts to develop renewable energy demonstrate officials' commitment to innovate. Interviewees also reported an ability to improvise within the job to react to pressing concerns. However, Avon Lake does not have particularly visionary leadership—especially in connection to sustainability or adaptation. Instead, decisions tend to be short-term and reactive. Expanding decision-making time horizons is an important step towards

increasing the city's adaptive capacity.

Compared to other cities in our study, Avon Lake possesses a steady financial base. Though we do not think financial capital is a capacity, it is not currently constraining adaptation. City departments are not severely understaffed and the city does not face severe resource constraints like others in the region. The city needs to continue wisely allocating its resources and can be well positioned to prepare for potential negative impacts when necessary.

Finally, interviewees in Avon Lake highlighted the role of trust in city governance. As a small city, there exists a great deal of face-to-face interaction. People generally know their colleagues, and individuals are able to call upon social capital to achieve particular goals. Such networks and capacities would help mainstream adaptation in city governance.

AVON LAKE RISK ANALYSIS

Note: These maps should serve as a tool or starting point for the city. They do not indicate definite patterns and they are not predictions.

To construct the analysis of potential climate change risk for Avon Lake, three main factors were taken into consideration: the distance to green space, the distance from the 100-year flood plain and demographics considered being at higher risk (percentage under 5 years, percentage over 65 years, percentage below poverty level, percentage minority). A total of four maps were constructed for the city, three with one factor weighted higher, and one with all factors weighted the same. The analysis of the map with all the factors equally weighted will be further discussed.

When all factors are ranked as having equal influence on the distribution of risk, the amount of green space in the city of Avon Lake makes the potential of risk lower on the east side of the city, specifically in the areas surrounding Belle Park, in between Jaycox and Walker road. However, the area where most potential risk could occur is located in the west side of the city. This area is located between the railroad tracks that lead outside the city and Powdermaker ditch. This difference in potential risk could be due to the fact that there are less green spaces in the west side of Avon Lake, and this risk is increased by this area's nearness to a flood plain. There are two small areas on the southeast side of the city that appear to have moderate risk potential. These are the areas surrounding the golf course and the areas between Lear and Krebs road. These areas could have a moderate risk due to the green space above them buffering some of the potential risk in the area. Overall, the areas with higher risk are also areas with high concentrations of the demographics considered at risk. Finally, the amount of green space available in the city seems to be an asset for reducing potential risk.

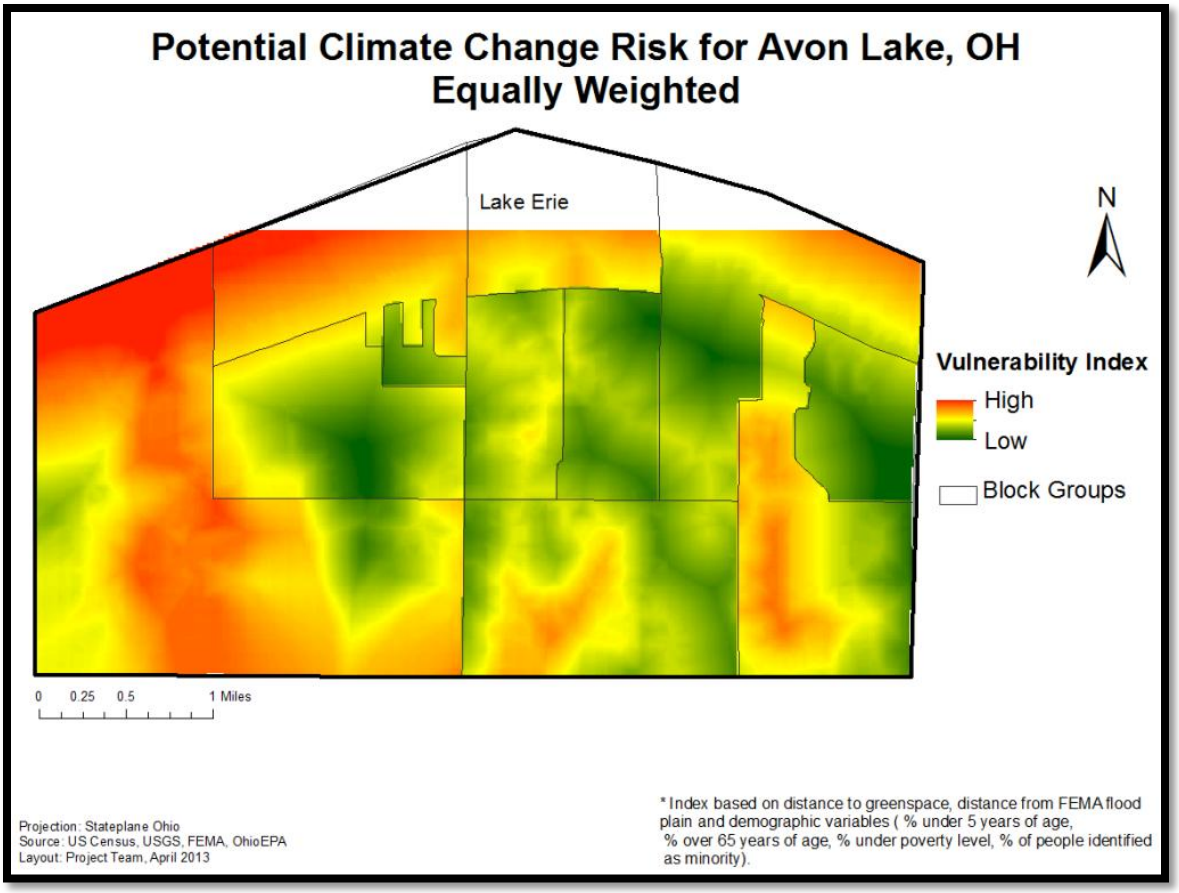

FIGURE 11: POTENTIAL CLIMATE RISK FOR AVON LAKE, OH

BEST PRACTICES

Adaptation is a dynamic process, involving multiple stakeholders from different sectors tackling complex issues. Adaptation is needed at the local level because local residents may be already experiencing climate change impacts and will do more so in the future. Adaptation processes are not easily implemented, as various constraints within the city make implementation difficult. As one city official told us in an interview: "If climate change things need to happen more with building codes and zoning codes and a lot of fundamental land management issues and I think those are tough things to do and I don't think they get done well at all. And you know the local planning commissions and stuff don't usually have the expertise to know these things and don't necessarily have the political will to do them."

Most adaptive processes in cities are currently in nascent stages or more broadly defined as sustainability. Yet there is growing consensus in the scientific literature and some political circles that it is best to anticipate projected impacts and implement adaptive processes in a preparatory rather and responsive fashion (NRC, 2010). Many believe that feeling at risk from extreme weather events could provide the impetus or a "window of opportunity" to implement adaptive measures (Penning-Roswell et al, 2006). Many adaptation initiatives also have the potential to provide co-benefits to quality of life of the city's citizens. For example, near-term benefits of adaptive processes can reduce emergency response costs, enabling future resilience and adaptive capacity (Rosenzweig, 2010).

Although many cities in the US have developed strategies for adaptation at the local level, many of these initiatives and the strategies employed have not been coordinated or integrated to those of other cities or regions. However, networks of sustainability practitioners have developed, most notably the International Council on Local Environmental Initiatives (ICLEI) to push for different aspects of sustainability in urban settings such as climate protection and clean energy initiatives. As of 2013, local governments from over 500 cities across 49 states in the United States have joined ICLEI, ranging from big cities (New York, Atlanta) to entire counties and small towns. ICLEI members are committed to reduce greenhouse gas emissions by a locally determined amount, while simultaneously developing a local climate action plan (ICLEI & Wheeler). However, as the focus of action plans is on sustainability, more robust action plans for adaptation need to be developed at the local level. One problem with conflating sustainability and adaptation is the potential masking of tradeoffs between adaptation and sustainable development options. Hence, there is a need for policymakers and planners to better differentiate between sustainability, mitigation and adaptation processes (Byer et al, 2012). In contrast there is a growing literature that focuses on understanding potential synergies between adaptation, mitigation and sustainable development ('triple win') interventions (Syampungani et al, 2010). However, empirical evidence from urban applications is limited.

The literature offers many examples of best practices and strategies cities can deploy to increase their adaptive capacity and/or implement effective adaptation options. Many scholars and planners suggest adopting decision-making frameworks that favor robustness and include uncertainty information (Hallegatte, 2008; Quay, 2010). A robust strategy is most insensitive to future climate conditions, rather than being the best strategy in a particular climate future. Uncertainty refers to embracing the fact that future climate conditions are unknowable and potentially novel, yet identifying alternative scenarios to capture as many possibilities as possible. It is important to identify quantitative signals to help decision-makers recognize when a potential scenario is becoming more likely (Hallegatte, 2008). Hallegatte (2008) identifies five planning strategies that utilize these principles: no regrets; reversible and flexible options; buying 'safety margins' in new investments; soft adaptation strategies; and reducing decision time horizons. Below, we organize our summary of best practices using Hallegatte's criteria (table 2).

TABLE 6: BEST PRACTICES FOR CLIMATE ADAPTATION

Sector	*Examples of adaptation options/Best practices*	*No regret' strategy*	*Reversible/Flexible*	*Existence of cheap safety margins*	*Soft strategies*	*Reduced decision horizons*	*Synergies with mitigation*
Ecosystem services	Strategic wetland restoration	++	+				+
	Create and manage buffer zones around ecological reserves	++	-		+		+
	Mitigate air, water, and soil pollution	++					+
	Intensive management of climate-sensitive species	+	+		+		
	Promote landscape connectivity to facilitate species adaptation	+	-				+
Regional networks & knowledge	Facilitating scientist-stakeholder information sharing addressing adaptation needs and uncertainties	++	+		++		
	A multilevel governance framework for adaptation responses, setting goals, regulations and financial support given to local governments by national government	++	+		+		
	Inter-agency, regional coordination to protect ecosystems and vulnerable species	++			+		+
	Share knowledge and best practices with nearby cities to achieve outcomes towards regional adaptation	++	++		+		
Emergency preparedness	Insurance, early warning and evacuation schemes	++	+	+	+		
	Improving social care networks/social safety nets	++	++				
	Institutionalize risk/vulnerability analysis in long term plans	+	+		+		
	Emergency back-up systems/infrastructure	+	-	+			
	Restrictive land use management	+	+	+	+		
	Adopt portfolio of actions to reduce and transfer risk	+	+	+	+		

Sector	*Examples of adaptation options/Best practices*	*No regret' strategy*	*Reversible/Flexible*	*Existence of cheap safety margins*	*Soft strategies*	*Reduced decision horizons*	*Synergies with mitigation*
Public Health	Research & development on vector control and vaccines	+					
	Reevaluate and revise maps detailing populations at risk for climate impacts	++					
	Utilize urban forestry to reduce heat island effects and improve air quality	+	++		+		++
	Improve communication of climate risks and resources to vulnerable populations	+	+		+		
	Assess coping capacity of health care system in extreme weather events	+			+		
Infrastructure	Invest in wetland restoration and rain gardens for storm water management	++	+		+	+	+
	Determine critical infrastructure and assess climate impact vulnerabilities in the short and long term	++					
	Prioritize building a climate resilient energy sector by investing in alternative forms of energy generation and distribution	+					++
	Develop robust disaster management plans to resume critical services during emergencies	++			+		
	Implement green building codes for new building projects						++

No regret options are actions with socially beneficial outcomes in all projected climate change scenarios (Heltberg, Siegel, & Jorgensen, 2008). For example, climate-proofing new buildings through creating new building codes requiring efficiency and insulation is beneficial in any future scenario because the decrease in energy needs will save money and mitigate further climate change (Hallegatte, 2008). By using computer simulations, Pyke et al (2011) concluded that low impact development that decreases impervious surface area while maintaining high-density levels is a positive planning strategy for storm water management in all climate scenarios.

Reversible and flexible strategies aim to keep the costs of being wrong as low as possible so plans can be terminated with minimal cost. For cities, this may entail taking short-term actions that can be adapted over time as impacts become more evident (Quay, 2010). For example, cities can implement restrictive land use planning then alter restrictions through time as information changes (Hallegatte, 2008).

Including safety margins into infrastructure and the built environment at low- and no-cost increases the robustness of a city to withstand climate impacts. For example, Copenhagen uses run-off figures that are 70% larger than current levels of need (Hallegatte, 2008). Such margins allow for continued population growth and increased rainfall intensity. Including safety margins now is more efficient than retrofitting run-off

infrastructure in the future. A similar strategy to 'no regrets' options is planning for the 'worst case' scenario in which the worst outcomes are planned for so that all potential scenarios are covered (Quay, 2010).

Soft strategies refers to institutional and financial tools for addressing climate impacts. Forcing planners to think ahead several decades or creating suitable insurance policies to extreme weather events can increase the flexibility and robustness of urban areas to climate change (Hallegatte, 2008). Creating formal, dedicated climate units in city governments that monitor implementation and effectiveness of climate adaptation plans can increase the legitimacy, coordination, and support for such policies (Anguelovski & Carmin, 2011). To mitigate the effects of urban heat effects, Katzschner (2011) argues that planners must incorporate building design and open spaces that create diverse microclimates and cooling effects, while ventilation should be considered at the city level. Similarly, Mathey et al (2011) found that a 'richly structured system of many parcels of interconnected green spaces, supported by unrestricted cold air corridors from outlying areas, can positively influence the entire urban micro-climate" (p. 434). Creating the institutional tools for implementing such strategies requires altering the scale at which such considerations take place and increasing coordination between regional and levels of governance.

Finally, reducing the time horizon for decision-making means that some planning decisions may be best served if long-term commitments are avoided. For example, if there is a great deal of uncertainty regarding climate conditions in fifty to one hundred years, it might be most efficient to build cheaper buildings with shorter lifespans (Hallegatte, 2008). Though this may seem to contradict taking a long view in climate adaptation planning, these types of decisions can make the most sense when the long-term outcomes are uncertain.

CONCLUSION

Dayton, Elyria, Toledo, and Avon Lake all must adapt to climate change. The Great Lakes region is likely to experience multiple negative impacts due to a changing climate. Most relevant impacts include increased temperature, severe heat events, flooding, freeze-thaw events, and invasive species as well as decreases in lake levels and ice cover. Decision-makers in every city expressed concerns regarding these likely impacts.

Each city studied in this project possesses unique capacities enabling and constraints inhibiting adaptations designed to attenuate projected impacts. In our analysis, dedicated leadership emerged as one key capacity. Leaders in each city demonstrated an ability to champion causes and act as policy entrepreneurs. So far, efforts by leaders to adapt to climate change are highly uneven throughout the cities. Though leaders often expressed concern surrounding the potential impacts of climate change, they also described lacking access to sufficient information regarding climate change and the financial and human resources needed to implement solutions.

A long economic decline since the late 1970s, combined with the acute effects of the recent economic recession, has greatly reduced the financial base with which each city operates. Nearly all interviewees had a story to tell regarding the myriad effects the economic downturn has had on their job. Because of financial constraints, available funds are spent on core city priorities. Additionally, though city staff constantly demonstrated high competence and dedication within their jobs, city departments tend to be understaffed. Expanding the scope of government within this climate is difficult, to say the least.

Further, cities do not have sufficient access to scientific information, nor the capacity to use it, necessary for robust adaptation planning. Scientific knowledge is often inaccessible and perceived as not usable. Further, city decision-makers do not have the technical training to fully digest, weigh, and compare relevant information. We utilized the adaptive capacity wheel to analyze how these constraints and capacities combine to shape the overall adaptive capacity of each city.

For the city of Dayton, decision-makers view climate change as a threat to plans seeking to increase the economic and social vibrancy of the city. The city government is primarily concerned with attracting new and retaining existing residents and businesses. Rather than focusing on large, Fortune 500 companies, which used to call the city home, Dayton is prioritizing small businesses run by immigrants and young college graduates. Thus, adapting to climate change serves two primary functions in achieving this goal. Interviewees frequently framed environmental and social policies as ways to brand Dayton as a place possessing a high quality of life. Adaptation would aid in creating this identity. Climate change will also challenge social and economic goals. As our vulnerability maps demonstrate, substantial regions of the city remain at risk to climate change impacts, which have the potential to constrain Dayton's economic growth and vibrancy.

Decision-makers in Elyria are concerned about the potential that climate change will worsen erosion and invasive species, as well as lead to increased heat events. Well-connected individuals, possessing relatively high social capital, populate the city government. Because of this, the city is able to share resources and knowledge. Further, city employees and officials reported being well connected to the broader city community—often interacting with citizens both as part of their job and in their everyday life. However, decision-makers have not deeply considered the effect climate change might have on city functions. Climate change will likely challenge the city's efforts to reduce erosion in Cascade Park and increase urban forestry as well as negatively affect city infrastructure, such as the sewage treatment plant and roads.

In Toledo, decision-makers reported concern over the potential for climate change to worsen sewage overflows and flooding. The city is converting many abandoned lots into rain gardens and community

gardens, as well as attempting to increase general green space. Further, Toledo has begun pursuing renewable energy generation and production as an economic development strategy. In accomplishing these and other goals, the city departments successfully collaborate with each other and outside organizations. Yet Toledo's climate change considerations remain short-term and often reactive. The city has not yet created a plan to guide city efforts. Therefore, while examples of entrepreneurial leadership are apparent, it is unclear whether the city will be able to sufficiently deal with projected climate impacts.

Finally, Avon Lake is located directly on the shore of Lake Erie. Climate change has not infiltrated into the city governance, though multiple interviewees reported being interested in sustainability. Compared to the other cities we studied, Avon Lake possesses a solid economic base. Yet climate change threatens to hinder sustained economic growth, as projected lake levels decrease and severe weather events may negatively affect infrastructure, ecosystems, and people. Critical for the city of Avon Lake is to begin the process of evaluating potential vulnerabilities. The maps we produced in the appendix provide a starting point for such an evaluation.

Thus, each city faces unique challenges. Nevertheless, each city has the capacity to ameliorate these impacts, so long as it begins to systematically plan for adaptation. Important for this will be taking advantage of partnerships with organizations that can bridge the gap between scientific information and practical governance needs. Organizations such as universities and research units in the region can provide salient and credible information to local decision-makers in Ohio. If leaders are able to capitalize on these resources, assimilate this information into core departmental and city goals in order to create long-term and flexible plans, and implement the type of policies we describe in table 6, Dayton, Elyria, Toledo, and Avon Lake will become more resilient to climate change.

SUGGESTIONS FOR FUTURE RESEARCH

If any future research is conducted on the subject of adaptive capacity in the Great Lakes cities, researchers would do well to revisit Avon Lake, Dayton, Elyria and Toledo, OH to see how their capacities and constraints have changed since summer/fall of 2012. All four adaptive capacity wheels should be updated to document change and assist knowledge building. Utilizing a variety of qualitative research methods might also contribute to more robust data gathered, i.e. pre-interview surveys, focus groups, participant observation, etc. Future research teams should also strive to integrate our IA with that of other GLAA-C teams of previous years. If risk analysis maps are created in GIS for each of the cities, downscaled climate projections could be incorporated to get a more accurate proxy of impacts. Future groups could also incorporate a data layer on impermeable surfaces to help approximate urban heat island impacts.

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APPENDIX

SUSTAINABILITY PROJECTS AND PROGRAMS

Sustainability Projects and Programs in our Project Cities		
Projects in Dayton, OH	*Dayton, OH*	• Geothermal energy project for downtown area (in planning phases) • Construction and expansion of bike trails • Well-field protection (aquifer protection program) • Urban forestry program (volunteer collaboration) • Riverfront development as a part of Downtown plan 20/20 (Miami Conservancy District, County Metro Parks collaboration) • Recycling program
	Montgomery County, OH	• Dayton Region Green-3 (DRG3) certification program (Montgomery County, Dayton Area Chamber of Commerce) • Biodiversity conservation, habitat restoration (Five Rivers MetroParks) • River front development • Recycling Program • Wetland bank
	State/Federal	• Farmer nutrient-reduction credits (Miami Conservancy District) • Water trail protection and development (Miami Conservancy District) • Renewable energy grants (DOE) • Habitat/biodiversity conservation programs (ODNR)
Projects in Toledo	*Toledo, OH*	• CSO separation Consent Decree by 2020 (USEPA) • Community gardens including rain and kitchen gardens constructed as storm water best management practices • Energy Special Improvement District, solar manufacturing/installation (Port Authority) • Recycling program (collaboration with Ann Arbor, MI)
	Lucas County, OH	• Great Lakes Coastal Resilience Planning Guide –an online guide for best management practices in coastal areas • Energy audit program (University of Toledo, Lucas County Soil and Water Conservation District) • Rain gardens (Lucas County Soil and Water Conservation District) • "Healthy Homes" initiative, lead/asbestos abatement • Biodiversity conservation and restoration projects, species habitat corridor (MetroParks of Toledo Area)
	State/Federal	• Coastal Wetlands Climate Vulnerability Assessment for Lake Erie (for construction of wind farms) • Adaptation plan, coastal wetlands and wildlife (ODNR) • Ohio storm water best practices and assessment project (ODNR) • Renewable energy grants offered by the Department of Energy (DOE)

Projects in small cities (pop. <60,000)	*Elyria, OH*	• CSO separation Consent Decree by 2020 (USEPA) • Maintenance of Cascade Park (Lorain County MetroParks) • Emergency management plan of 2006 • Energy efficiency and rebate programs • Materials Recovery Facility, recycling program (Lorain County Solid Waste Management) • Brownfield rain and food gardens • Bike trails connect with neighboring cities
	Avon Lake, OH	• CSO separation Consent Decree by 2020 (USEPA) • Sanitary sewer awareness and education program • Renewable energy projects, solar and wind • Energy audits for residential buildings
	Lorain County, OH	• Potential offshore wind project, Lake Erie (Lorain County Office of Sustainability) • Combined Regional Sewer Authority (Avon Lake and Elyria) • Materials Recovery Facility, Elyria (Lorain County Solid Waste Management) • Regional bikeways program (Lorain County MetroParks) • Bike trails connecting to Indiana and Pennsylvania

The following list is based on definitions from the IPCC AR4, USGCRP 2012, Ontario Expert Panel on Climate Change Adaptation (2009), whenever possible. Other references include NOAA, and US EPA as noted.

Climate Change

Climate change refers to a change in the state of the climate that can be identified (i.e. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC Fourth Assessment Report)

Adaptation

a) Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, i.e. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature shock-resistant plants for sensitive ones, etc. (IPCC Fourth Assessment Report)

b) Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities and moderates negative impacts. (USGCRP, 2012)

Adaptive Capacity

a) The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures. (IPCC Fourth Assessment Report)

b) The ability of a system to adjust to climate change (including climate variability and extremes) in order to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (Ontario Expert Panel on Climate Change Adaptation, 2009)

Capacity building

In the context of climate change, capacity building is developing technical skills and institutional capabilities in developing countries and economies in transition to enable their participation in all aspects of adaptation to, mitigation of, and research on climate change, and in the implementation of the Kyoto Mechanisms, etc. (IPCC Fourth Assessment Report)

Coping Range/Capacity

The capacity of systems to accommodate variations in climatic conditions. (IPCC Fourth Assessment Report)

Effects

Changes in the physical characteristics of climate that are driven by forcings. These usually describe indicators from a management or status perspective.

Extreme weather event

An event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density of weather events. (USGCRP, 2012)

Impacts

Changes in the engineered or natural environment that affect human or ecosystem behavior and can be altered or avoided by direct action. They are often the result of climate effects coupled with existing conditions in built or natural the environment. For example, severe storms and paved surfaces can lead to channeled storm water and flooding. This, in turn, can lead to further cascading impacts, such as water supply contamination and property damage. Reducing the amount of paved surface, or changing storm water management practices can avoid this particular impact. Climate impacts are generally problems that can be solved through action.

Indicators

Observables that are unambiguously affected by natural or anthropogenic climate change. Precipitation, temperature, sea level rise, extreme weather, snow cover, snowfall, and glacial melt are some examples. NOAA limits this definition to observable physical changes. Ecological and environmental changes are often included in a broader definition of indicators used by many organizations.

Integrated Assessment

A method of bringing together knowledge of ecosystems, people, and policy in order to find solutions for particularly challenging or "wicked" problems. Assessments summarize scientific knowledge to build consensus and guide decision making around a particular resource management, environmental or sustainability issue. (Vaccaro, 2009).

Mitigation

a) Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. (IPCC Fourth Assessment Report)

b) An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks. (Ontario Expert Panel on Climate Change Adaptation, 2009)

Climate Prediction

A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate – including weather variations – in the future, for example, at seasonal, interannual, or long-term timescales. (USGCRP, 2012)

Climate Projection

A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases or aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon the emission/concentration/radiative forcing scenarios used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty. (USGCRP, 2012)

Resilience

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. (Ontario Expert Panel on Climate Change Adaptation, 2009)

Uncertainty

An expression of the degree to which a value is unknown (e.g. the future state of the climate system). Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can therefore be represented by quantitative measures (i.e. a range of values calculated by various models) or by qualitative statements (i.e. reflecting the judgment of a team of experts). (IPCC Fourth Assessment Report)

Urban Heat Island

The elevated temperatures in developed areas compared to more rural surroundings. (US EPA)

Vulnerability

a) The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate and global change, including climate variability and extremes, as well as climate change in conjunction with other stressors. (USGCRP, 2012)

b) The degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (Ontario Expert Panel on Climate Change Adaptation, 2009)

Exposure

The severity and frequency that a system experiences a given type of event.

Sensitivity

The susceptibility of a system is to a particular type of impact.

Risk

The probability of an event occurring multiplied by the severity of the consequence.

Great Lakes Adatation Assessment for Cities

Satellite image from NOAA, Great Lakes Environmental Research Laboratories

With support from the Kresge Foundation and the Graham Environmental Sustainability Institute, this Integrated Assessment (IA) will strengthen the science and decision making necessary for more effective urban climate adaptation in the Great Lakes region (both Canada and the U.S.). The IA is being led by several University of Michigan (U-M) faculty research teams in coordination with partners across the region and the recently funded Great Lakes Regional Integrated Sciences and Assessment center (GLISA). Details at www.glisa.umich.edu.

BACKGROUND

Effective adaptation to climate change is nowhere more critical than in cities because most people now live in urban environments. The Great Lakes watershed accounts for one-fifth of the world's fresh water and houses approximately 10% of the US and 25% of Canadian populations (40 million people total).

Climate change impacts in the Great Lakes region are anticipated to worsen risks of flooding, reduce water availability and quality, increase problems related to heat stress, and negatively impact economies in cities dependent on tourism and recreation. Despite these anticipated risks and their substantial adverse impacts on populations in the Great Lakes region, many urban decision makers highlight the need for place-based climate science and options for responding to impacts.

The Great Lakes Adaptation Assessment for Cities will work closely with regional partners and urban decision makers to identify adaptation needs, opportunities for action, and relative costs of different response options.

EXPECTED OUTCOMES

For cities to develop and implement effective climate adaptation policies, they require a wide range of scientific, social, and policy information. This project will engage experts from diverse fields to:

- Work with city staff and decision makers from five representative Great Lakes cities to develop climate adaptation plans or strategies. The plans will provide implementation steps for the cities and will serve as case studies for similiarly situated cities in the region.
- Integrate social and climate science data for a collection of: 1) city-level adaptation plans, activities, and spatial data; 2) web-based surveys of local government officials; 3) information about existing and future infrastructure investments; and 4) a website with adaptation reports on approximately 15 key Great Lakes cities.
- Create a Cities Impacts and Adaptation Tool that can be used by stakeholders to synthesize, communicate, and apply climate-relevant knowledge for urban resilience under different climate scenarios.
- Establish an Urban Council on Sustainability and Adaptation to create greater awareness about the likely urban impacts of climate change and the need for targeted actions to respond to these impacts.

U-M FACULTY LEADS

Arun Agrawal, School of Natural Resources & Environment (SNRE); Elisabeth Gerber, Ford School of Public Policy; Larissa Larsen, Taubman College of Architecture & Urban Planning; Maria Lemos , SNRE; Marie O'Neill, School of Public Health; Richard Rood – College of Engineering.

PROJECT WEBSITE

Please visit the Integrated Assessment section of the Graham Insitute website at www.graham.umich.edu

GLISA

GRAHAM ENVIRONMENTAL SUSTAINABILITY INSTITUTE

M planet blue

http://www.graham.umich.edu/ia/great-lakes-climate.php

Public Perceptions and Attitudes Toward Climate Change: Fact Sheet

GLAA-C
Great Lakes Adaptation Assessment for Cities

Overview of the Survey

For local governments, understanding public perceptions and attitudes towards climate change can be a powerful planning tool. This fact sheet highlights the findings from a survey conducted on the general public's perceptions of climate change. It aims to inform local government staff, elected and appointed representatives, and the general public on how participants in the Great Lakes Region view climate change issues.

The following information was generated from a random-sample phone survey completed by 2,049 participants between April and May of 2012. The survey targeted midsized cities with populations between 25,000 and 300,000, in the Great Lakes Region, which included eight US states and one Canadian province. The complete survey results are available through GLAA-C and may be attained by contacting Beth Gibbons at– elzrenc@umich.edu or via the GLAA-C website at– www.graham.umich.edu/glaac.

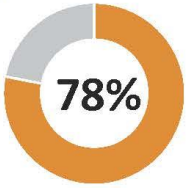
Key Findings:

- 78% of survey participants believe that we are in a period of climate change and of these 85% believe human activity has played a significant role in causing climate change.
- While 47% of participants anticipate climate change will lead to adverse impacts in the Great Lakes Region, only 25% believe that they themselves or their families face risk from climate change impacts.
- The majority (63%) of participants believe that climate change will increase existing environmental hazards, such as drinking water pollution.
- The majority (69%) of participants believe that local government should take action to protect their community against climate change impacts.
- A majority of participants (55%) perceive universities as a trusted source of climate change information.

Kites on Lake Huron

Source: Flicker Creative Commons-ColorblindRain

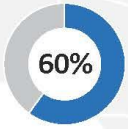
78% of survey participants responded that they believe that climate change is taking place.



"I believe we are in a period of climate change."

Of the 78% of survey participants that believe climate change is taking place...

"I believe that human activity has played a significant role in causing climate change."

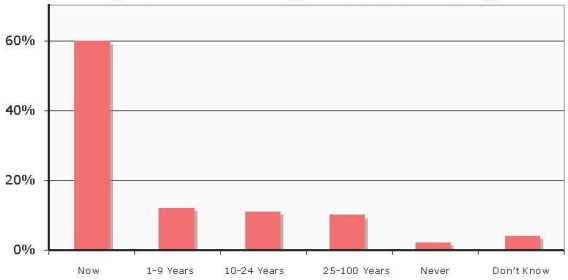


" I feel that climate change has already impacted my community."

"I believe that climate change will impact my community within the next 25 years."

"When do you think the results of climate change will impact your local community?"

Perceptions on Timing of Climate Change



"Only 2% of participants feel that climate change will never happen."

The Great Lakes from Marshall Space Flight Center Source: NASA

Environmental Hazards

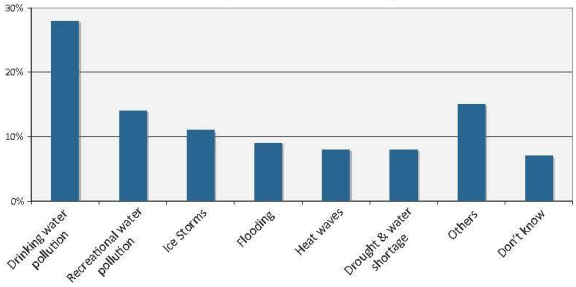
The majority (63%) of respondents believe that climate change will increase existing environmental hazards. When asked to identify the most severe threat facing their community, participants identified **drinking water pollution** nearly 2 to 1 over any other threat. However, 54% responded that they are 'not informed' or only 'slightly informed' about their local governments plans, actions, and policies related to drinking water pollution.

This lack of knowledge extends beyond drinking water. Overall 51% of participants report "not being informed at all" or being only "slightly informed" about their local government's policies, plans, and actions to deal with a particular hazard. Only 12% of those surveyed feel "very" or "extremely" informed about their local governments' plans.

Despite a lack of knowledge about local government plans, survey participants strongly support local government taking action to address climate change impacts. Over all 79% believe some effort should be made by local government, and 44.2% believe large or extremely large efforts should be made.

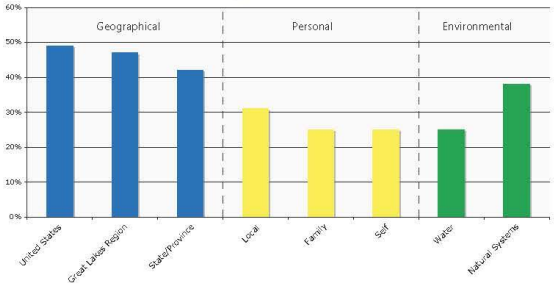
Most Serious Hazard to Community

"Which hazard do you believe is the most serious threat to your community?"



When ranking the severity of environmental hazards– 87.8% of survey participants stated their belief that flooding was 'not at all a risk' or a 'moderate risk' to their community.

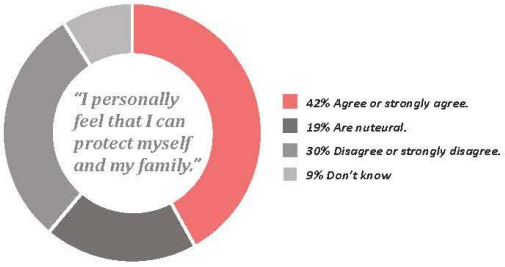
Scale of 'Large or Extremely Large Impacts' from Climate Change



Lack of Personal Risk

The survey revealed critical information on respondents' perceptions of climate change impacts across scales. The majority of respondents reported that the United States (49%), The Great Lakes Region (47%) and their state or province (42%) would experience large or extremely large impacts from climate change. When asked about impacts to their local area (31%), family (25%) and self (25%), fewer respondents feel that there would be large or extremely large impacts from climate change.

Likewise, 48% responded they feel they could protect themselves and their family from the negative impacts of climate change. In contrast to this, 58% of participants believe they have little or no influence over climate change.



Conclusions

Despite growing social consensus around climate change practitioners still struggle to prioritize actions in their communities. The survey results identify a need to translate global threats into tangible local impacts. This step is vital as communities attempt to make a case for climate action and champion solutions to build more resilient communities.

For some cities, this may involve strategic public outreach and education; for others, it could be building new coalitions of private, public, and nonprofit representatives.

The worst case margin of error for this data is +/- 2.16%.

CITY IDENTIFICATION AND SELECTION

The initial criterion for the selection of research sites was predicated upon urban centers within the geographic region of the Laurentian Great Lakes. It was also important that our research cites be located within identified current and potential future climate zones. Given that our research team is comprised of eight graduate students, we thought it sufficient to only select four cities within the Great Lakes to research.

SELECTION PARAMETERS

To provide more interesting research and allow for cross-comparison, we decided that two of the cities should be coastal and two should be inland. Examining the adaptive capacities of urban centers varying in population size would also increase the relevance of our work, thus we decided to select two "small" cities with a population between 25,000 – 50,000 inhabitants, with two "large" cities having no more than 250,000 inhabitants. We excluded the state of Michigan, given its inclusion in the previous GLAA-C project which concluded in April 2012. Thus, we chose the following cities at random, due to their match in various selection criteria:

> Akron, OH; Ashtabula, OH; Avon Lake, OH; Bay Village, OH; Beloit, WI; Bowling Green, OH; Buffalo, NY; Cincinnati, OH; Cleveland Heights, OH; Dayton, OH; Eastlake, OH; Elkhart, IN; Elyria, OH; Erie, PA; Findlay, OH; Fond du Lac, WI; Fort Wayne, IN; Goshen, IN; Green Bay, WI; Highland Park, IL; Ithaca, NY; Joliet, IL; Kokomo, IN; Lackawanna, NY; Lima, OH; Madison, WI; Manitowoc, WI; Mansfield, OH; Marinette, WI; Marion, OH; Massillon, OH; Medina, OH; Michigan City, IN; Minneapolis, MN; New Albany, IN; Northbrook, IL; Oregon, OH; Oswego, NY; Portage, IN; Racine, WI; Rochester, NY; Rocky River, OH; Sandusky, OH; Sheboygan, WI; South Milwaukee, WI; St. Paul, MN; Syracuse, NY; Toledo, OH; Two River, WI; Warren, OH; Willowick, OH; Zion, IL.

CITY RESPONSE AND ACCEPTANCE

We identified the mayors of several of these cities, and decided to extend an invitation to these mayors to participate in our research study. Between the months of May and June in 2012, our team emailed electronic invitations, as well as sending hard copy letters, to mayors of the following cities:

> Akron, OH; Beloit, WI; Bowling Green, OH; Cincinnati, OH; Cleveland Heights, OH; Dayton, OH; Elkhart, IN; Elyria, OH; Erie, PA; Findlay, OH; Fond du Lac, WI; Fort Wayne, IN; Goshen, IN; Green Bay, WI; Highland Park, IL; Ithaca, NY; Joliet, IL; Kokomo, IN; Lima, OH; Madison, WI; Manitowoc, WI; Marion, OH; Massillon, OH; Medina, OH; Michigan City, IN; Minneapolis, MN; Northbrook, IL; Portage, IN; Racine, WI; Rochester, NY; Sandusky, OH; Sheboygan, WI; St. Paul, MN; Syracuse, NY; Toledo, OH; Zion, IL.

The following cities sent letters of approval of being included in our research, either from the mayor or another public official:

> Avon Lake, OH; Cleveland Heights, OH; Dayton, OH; Elyria, OH; Fort Wayne, IN; Joliet, IL; Toledo, OH

The principal investigators of this project expressed their interest in conducting an "all-Ohio" study, thus narrowing our list of cities to:

> Avon Lake, OH; Cleveland Heights, OH; Dayton, OH; Elyria, OH; Toledo, OH

Our final research sites became Dayton, OH (large population, inland), Toledo, OH (large population, coastal), Elyria, OH (small population, inland) and Avon Lake, OH (small population, coastal).

INTERVIEW QUESTIONS

PRIORITIES

1. What are the priorities for your office/department?
2. What are the priorities for the city?

OPPORTUNITIES AND CONSTRAINTS FOR DEVELOPMENT AND PROGRAM IMPLEMENTATION

1. What are some sustainability-related programs adopted/initiated by the city? Can you give us some examples?
2. Now talking more specifically about mitigation…
    - What incentives exist at the city level to curb or decrease emissions?
    - Does the city have plans to promote energy efficiency or energy conservation?
    - Can you tell me more about plans and goals related to renewable energy sources?
    - How are decisions about energy use and production made at the municipal level?
3. Is climate adaptation or mitigation included in these plans?
4. We're interested in knowing more about funding/financing of initiatives and programs, can you tell us more about that process?
    - Is the city facing budget problems at this time? Where does much of your revenue come from? Do you have flexible sources of revenues?
    - What about funding for environmental and/or sustainability initiatives?
5. How easy is it for your department to innovate? How do you think you are innovative in this area? Can you give us an example of an innovative effort you are proud of?
6. Do you collaborate with others on any climate related efforts? How? Can you give us an example?
7. Do the collaborations work?

POTENTIAL IMPACTS OF CONCERN

1. In terms of both climate and weather impacts, what concerns you most?
2. Has the city experienced any extreme weather events in the past 10 years?
3. Can you describe the city's response to the event – from the early warnings and notification to what happened during the event to any assessment or policy changes that occurred after the event took place? Was there anything you felt went particularly well? That you felt unprepared for? That surprised you?
4. Do you have any formal emergency response plans in place at the city level? Department-level?

USE OF CLIMATE SCIENCE

1. What kind of information do you use? Where do you get your climate information?
2. Is the information you receive useful?
3. How would you prefer to get climate information (format/method)?

CONSIDERATION OF HUMAN HEALTH

1. What public health programs are currently offered?
2. Is the city taking preventative measures to prepare for future climate change induced human health issues (i.e., increased heat wave frequency, intensity, and duration impairing health)?

ECOSYSTEMS AND THE BUILT ENVIRONMENT

1. Are there specific environmental concerns about potential impacts of climate change?
2. What is the city policy for land-use planning (zoning, etc.)?
3. In your opinion, will changes to the water levels in the Great Lakes affect your city?
4. (If yes) How so?

VARIABLE: CONSIDERATION OF INFRASTRUCTURE

1. How does the city plan, coordinate, and implement infrastructure maintenance and repairs (drinking water, storm water, roads, bridges, electric, etc.)?
2. Has preparing for or adapting to climate change influenced this process of updating infrastructure?
3. In Ann Arbor, we have had a very hot summer…Have you had any power outages similar to ours? Do you have means to prevent it? What grid are you on?

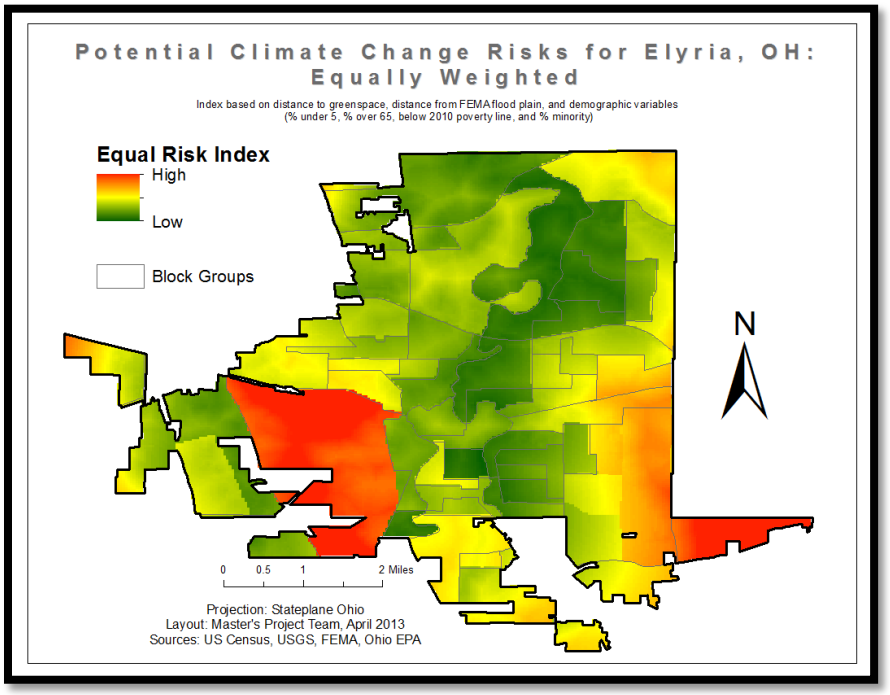
PUBLIC INVOLVEMENT

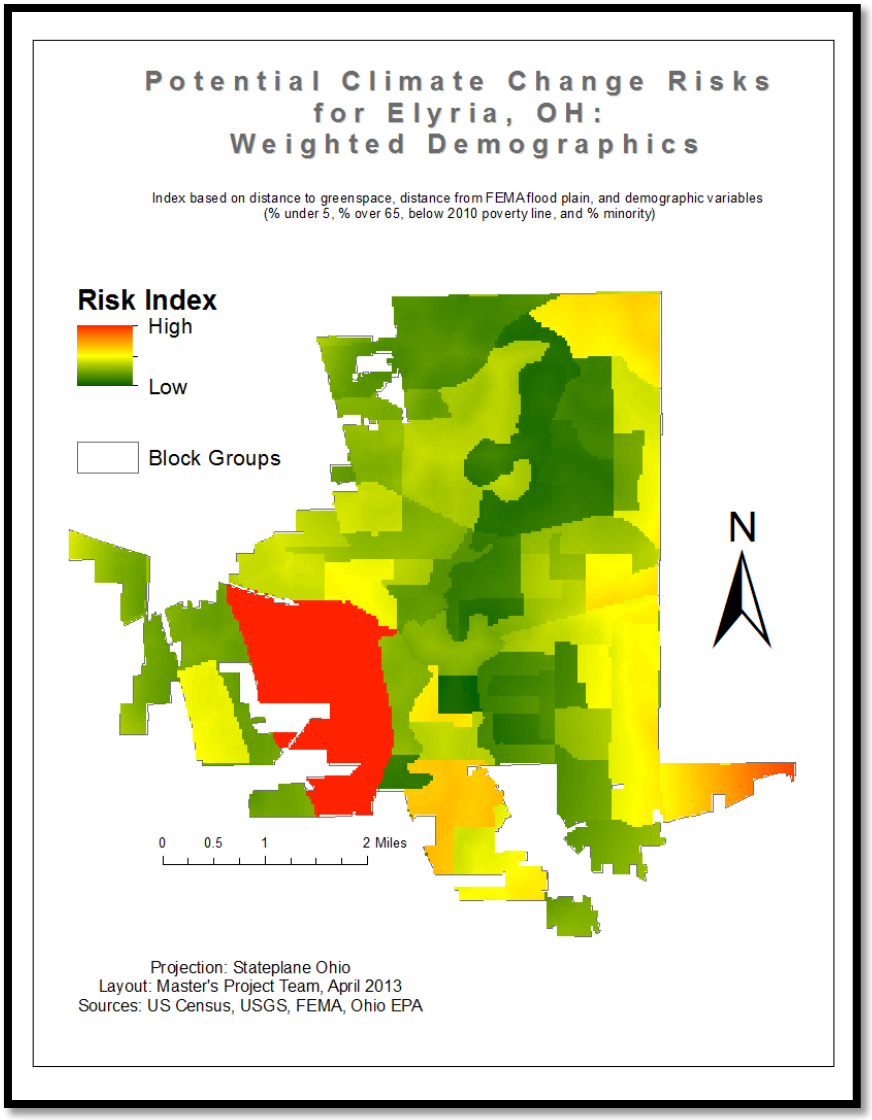
1. How do you keep the community involved in what you are doing?
2. Do you have a targeted audience for these communications?

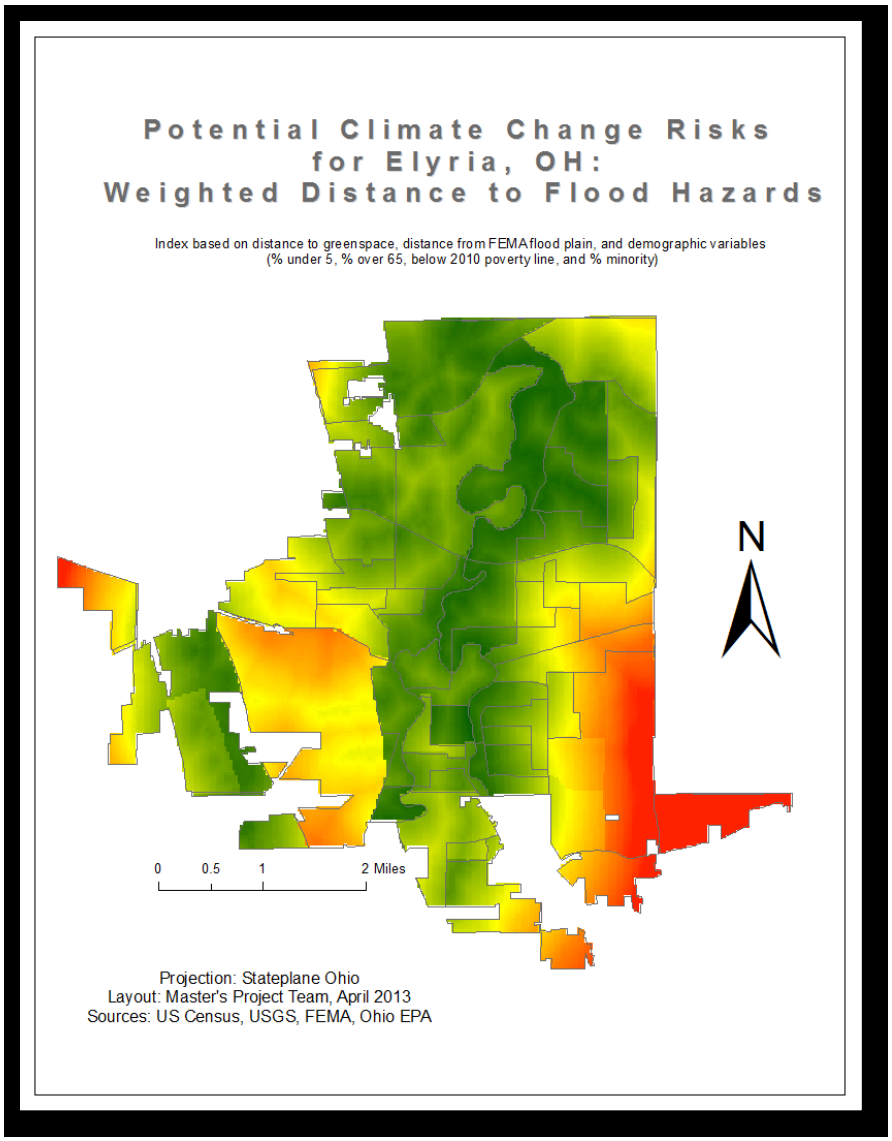
BARRIERS AND CHALLENGES TO ADAPTATION

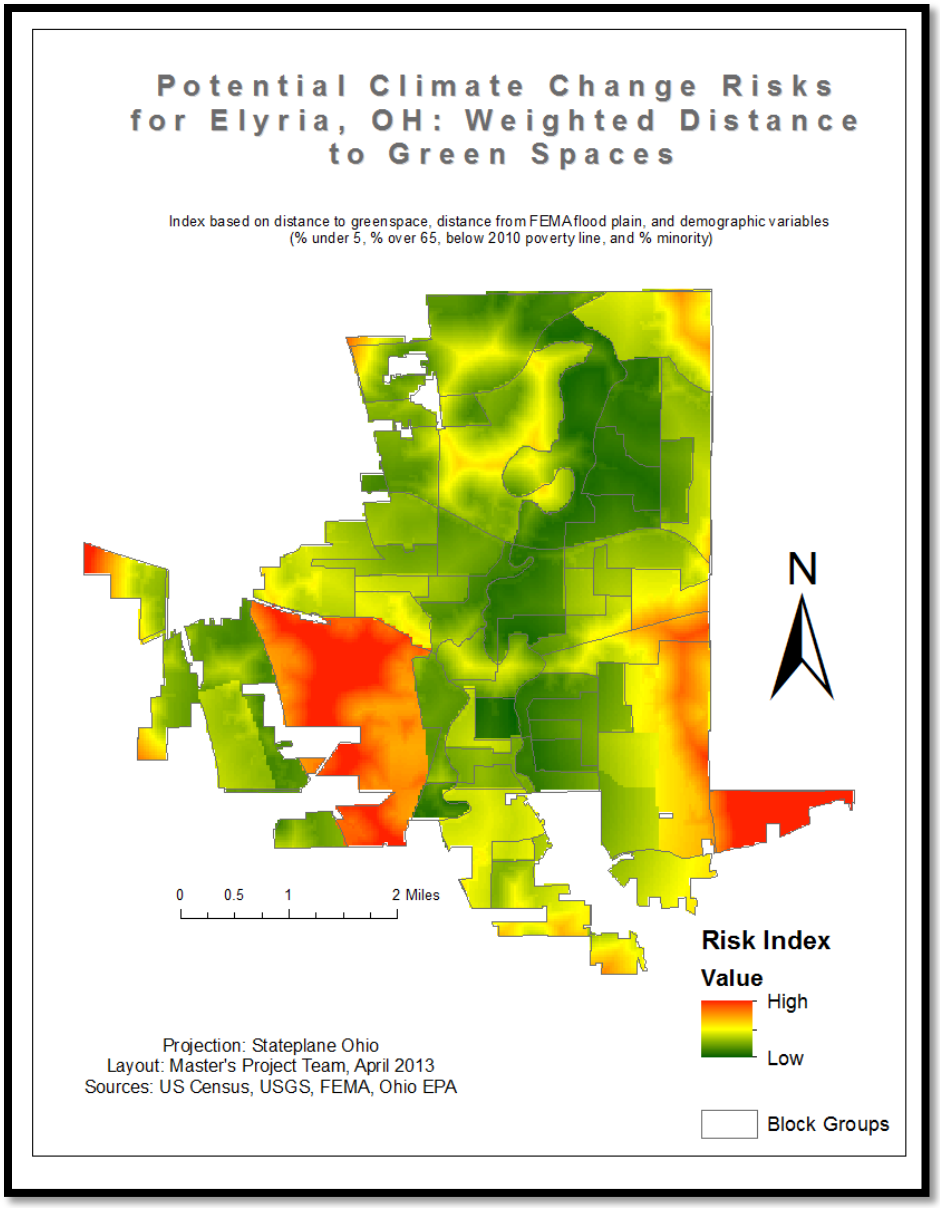
1. What are main opportunities for you to address climate issues? What are the main constraints that make it difficult?
2. What additional mitigation projects might the city undertake if there were no constraining factors?

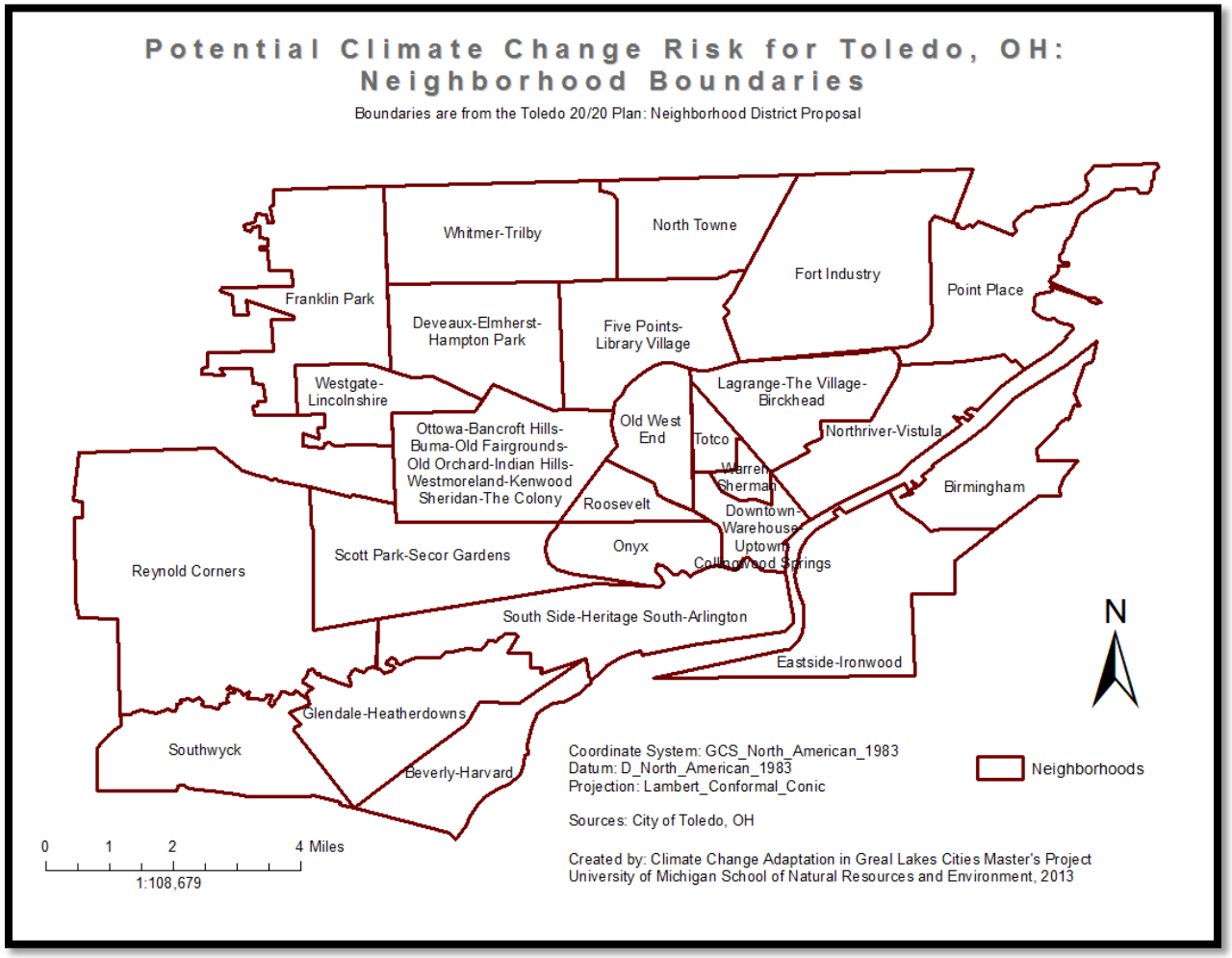
ELYRIA, OH

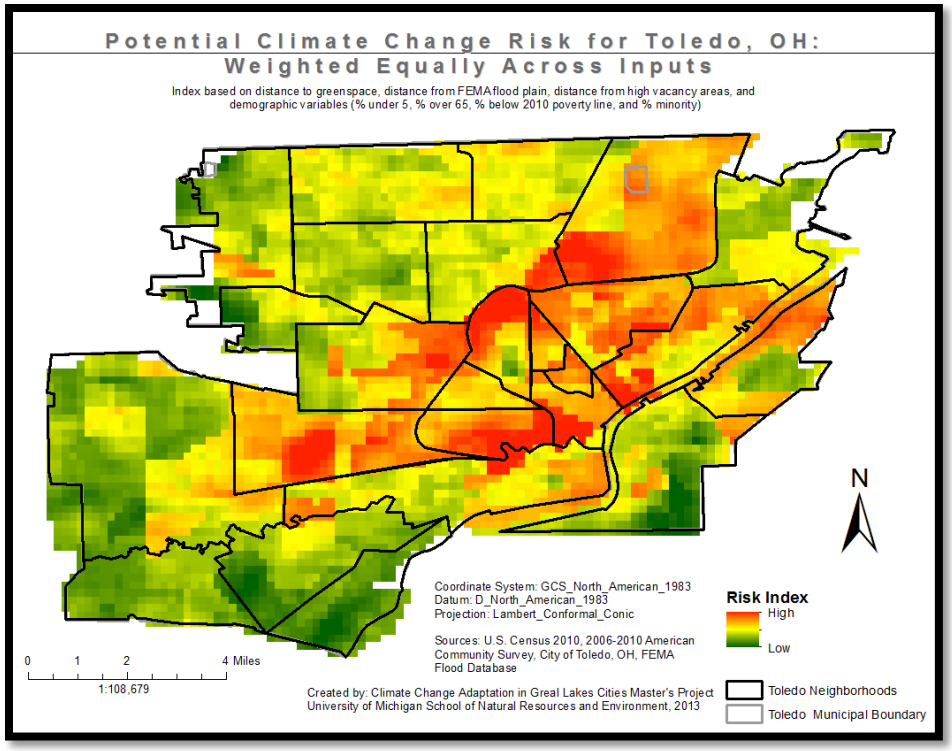

Potential Climate Change Risks for Elyria, OH:
Equally Weighted
Index based on distance to greenspace, distance from FEMA flood plain, and demographic variables
(% under 5, % over 65, below 2010 poverty line, and % minority)
Equal Risk Index
High
Low
Block Groups
N
0
0.5
1
2 Miles
Projection: Stateplane Ohio
Layout: Master's Project Team, April 2013
Sources: US Census, USGS, FEMA, Ohio EPA

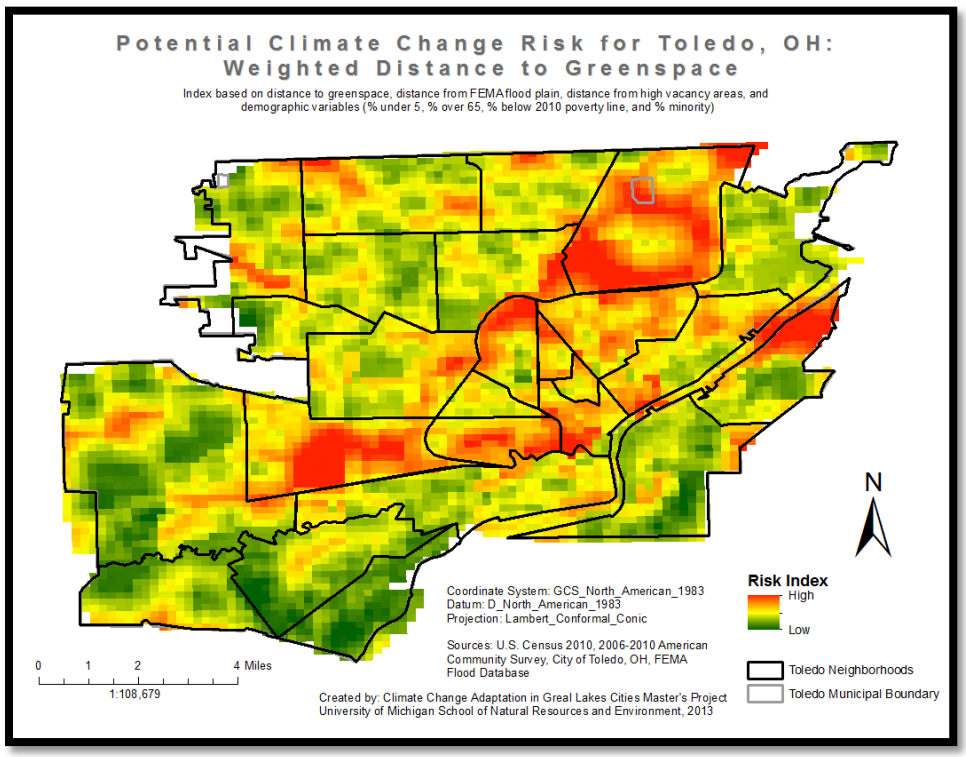

Potential Climate Change Risks for Elyria, OH: Weighted Demographics
Index based on distance to greenspace, distance from FEMA flood plain, and demographic variables (% under 5, % over 65, below 2010 poverty line, and % minority)
Risk Index
High
Low
Block Groups
N
0 0.5 1 2 Miles
Projection: Stateplane Ohio
Layout: Master's Project Team, April 2013
Sources: US Census, USGS, FEMA, Ohio EPA

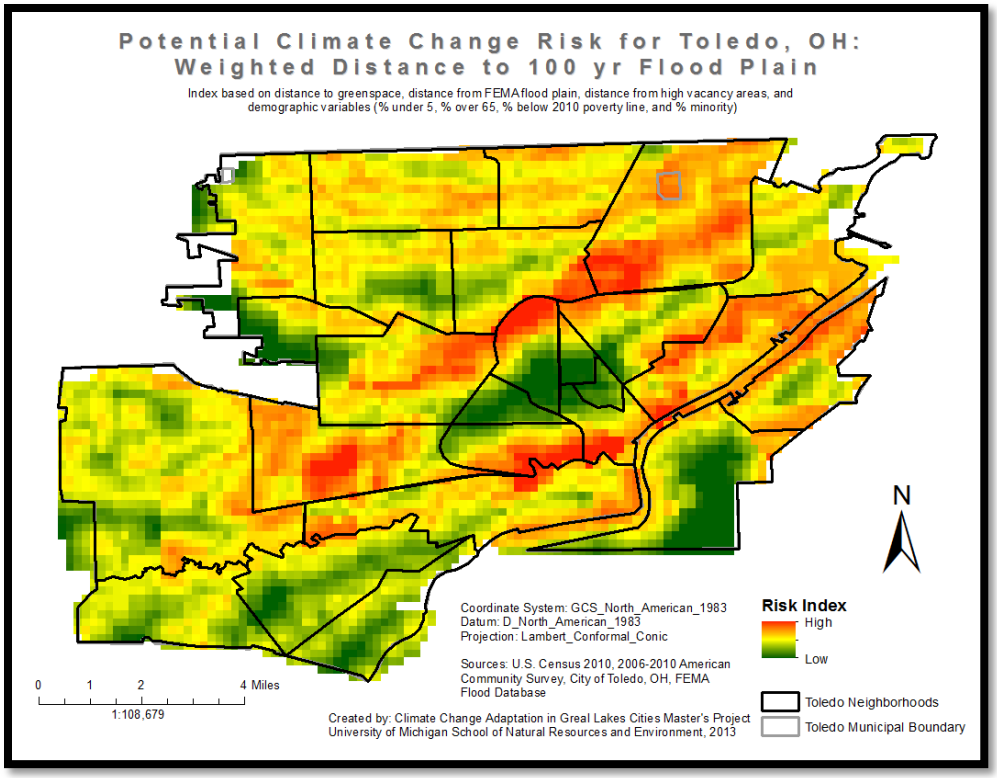

Potential Climate Change Risks
for Elyria, OH:
Weighted Distance to Flood Hazards
Index based on distance to greenspace, distance from FEMA flood plain, and demographic variables
(% under 5, % over 65, below 2010 poverty line, and % minority)
N
0
0.5
1
2 Miles
Projection: Stateplane Ohio
Layout: Master's Project Team, April 2013
Sources: US Census, USGS, FEMA, Ohio EPA

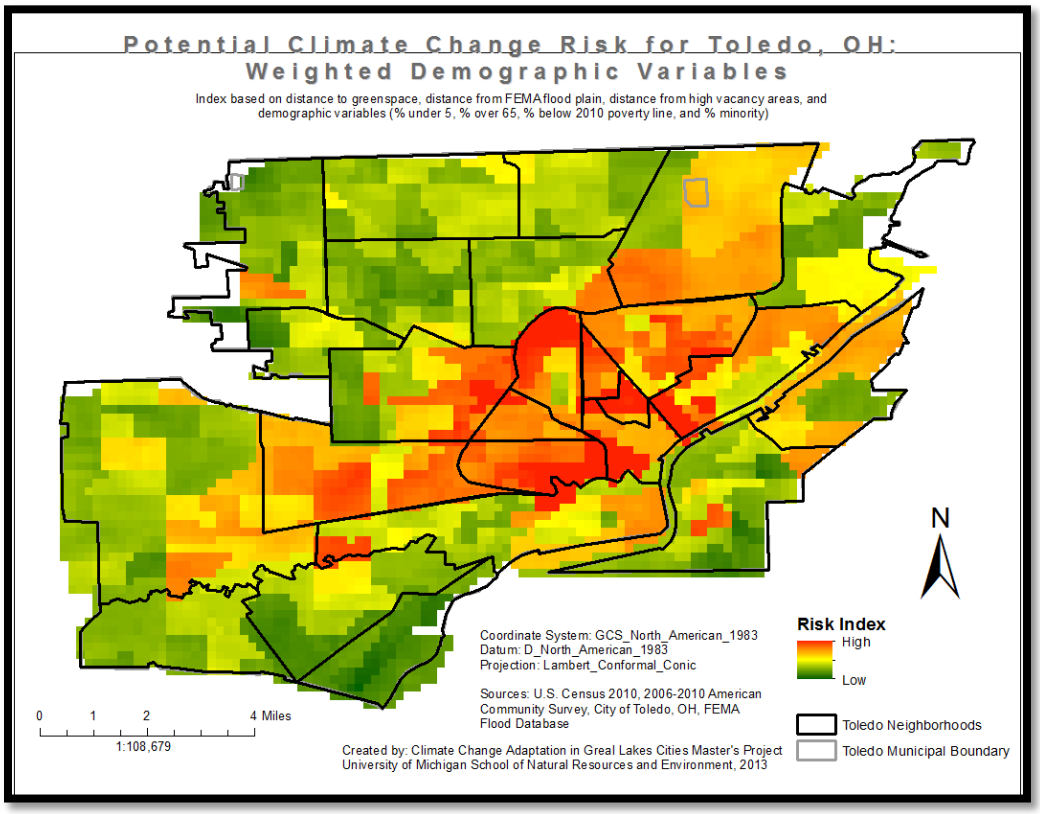

Potential Climate Change Risks for Elyria, OH: Weighted Distance to Green Spaces
Index based on distance to greenspace, distance from FEMA flood plain, and demographic variables (% under 5, % over 65, below 2010 poverty line, and % minority)
N
0 0.5 1 2 Miles
Risk Index
Value
High
Low
Block Groups
Projection: Stateplane Ohio
Layout: Master's Project Team, April 2013
Sources: US Census, USGS, FEMA, Ohio EPA


Potential Climate Change Risk for Toledo, OH:
Neighborhood Boundaries
Boundaries are from the Toledo 20/20 Plan: Neighborhood District Proposal
Whitmer-Trilby
North Towne
Fort Industry
Point Place
Franklin Park
Deveaux-Elmherst-Hampton Park
Five Points-Library Village
Westgate-Lincolnshire
Lagrange-The Village-Birckhead
Old West End
Totco
Northriver-Vistula
Ottowa-Bancroft Hills-Buma-Old Fairgrounds-Old Orchard-Indian Hills-Westmoreland-Kenwood Sheridan-The Colony
Warren-Sherman
Roosevelt
Birmingham
Downtown-Warehouse
Uptown
Collingwood Springs
Onyx
Reynold Corners
Scott Park-Secor Gardens
South Side-Heritage South-Arlington
Eastside-Ironwood
Glendale-Heatherdowns
Southwyck
Beverly-Harvard
N
0 1 2 4 Miles
1:108,679
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: City of Toledo, OH
Created by: Climate Change Adaptation in Greal Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Neighborhoods


Potential Climate Change Risk for Toledo, OH:
Weighted Equally Across Inputs
Index based on distance to greenspace, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
N
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: U.S. Census 2010, 2006-2010 American Community Survey, City of Toledo, OH, FEMA Flood Database
Risk Index
High
Low
0 1 2 4 Miles
1:108,679
Created by: Climate Change Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Toledo Neighborhoods
Toledo Municipal Boundary


Potential Climate Change Risk for Toledo, OH:
Weighted Distance to Greenspace
Index based on distance to greenspace, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
N
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: U.S. Census 2010, 2006-2010 American Community Survey, City of Toledo, OH, FEMA Flood Database
Risk Index
High
Low
0 1 2 4 Miles
1:108,679
Created by: Climate Change Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Toledo Neighborhoods
Toledo Municipal Boundary


Potential Climate Change Risk for Toledo, OH:
Weighted Distance to 100 yr Flood Plain
Index based on distance to greenspace, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
N
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: U.S. Census 2010, 2006-2010 American Community Survey, City of Toledo, OH, FEMA Flood Database
Risk Index
High
Low
Toledo Neighborhoods
Toledo Municipal Boundary
0 1 2 4 Miles
1:108,679
Created by: Climate Change Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013


Potential Climate Change Risk for Toledo, OH:
Weighted Demographic Variables
Index based on distance to greenspace, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
N
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: U.S. Census 2010, 2006-2010 American Community Survey, City of Toledo, OH, FEMA Flood Database
Risk Index
High
Low
Toledo Neighborhoods
Toledo Municipal Boundary
0 1 2 4 Miles
1:108,679
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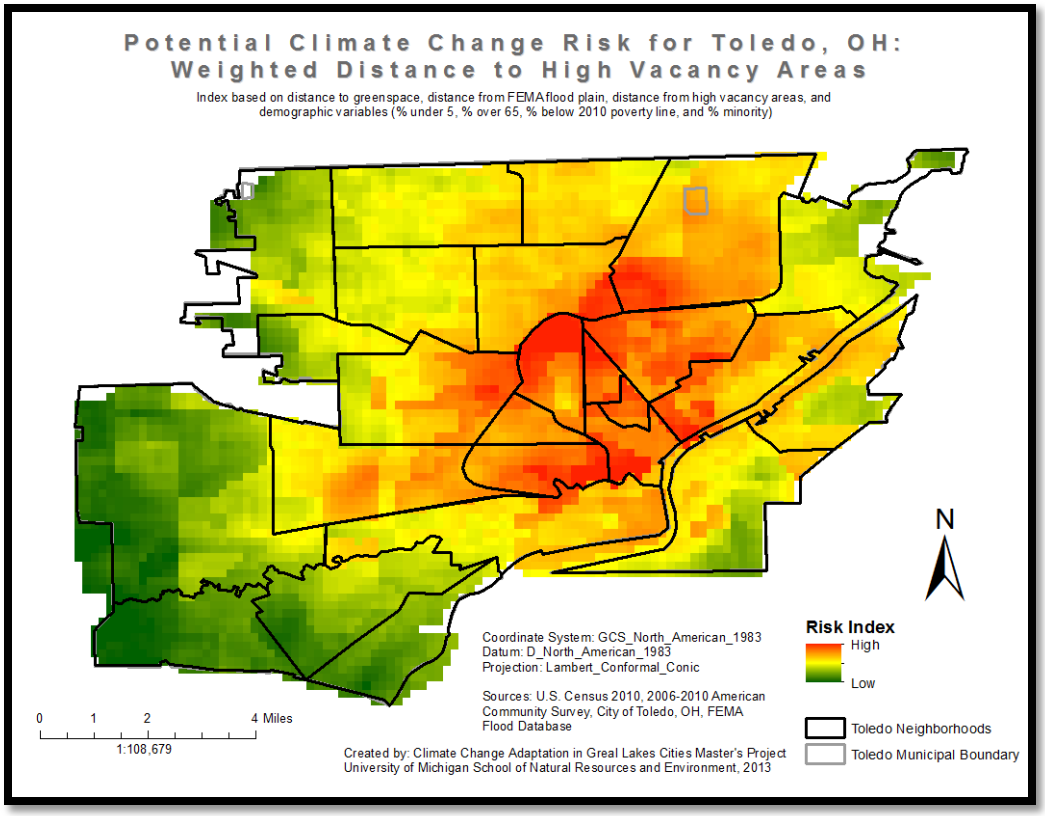
Potential Climate Change Risk for Toledo, OH:
Weighted Distance to High Vacancy Areas
Index based on distance to greenspace, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
N
Risk Index
High
Low
Toledo Neighborhoods
Toledo Municipal Boundary
Coordinate System: GCS_North_American_1983
Datum: D_North_American_1983
Projection: Lambert_Conformal_Conic
Sources: U.S. Census 2010, 2006-2010 American Community Survey, City of Toledo, OH, FEMA Flood Database
0 1 2 4 Miles
1:108,679
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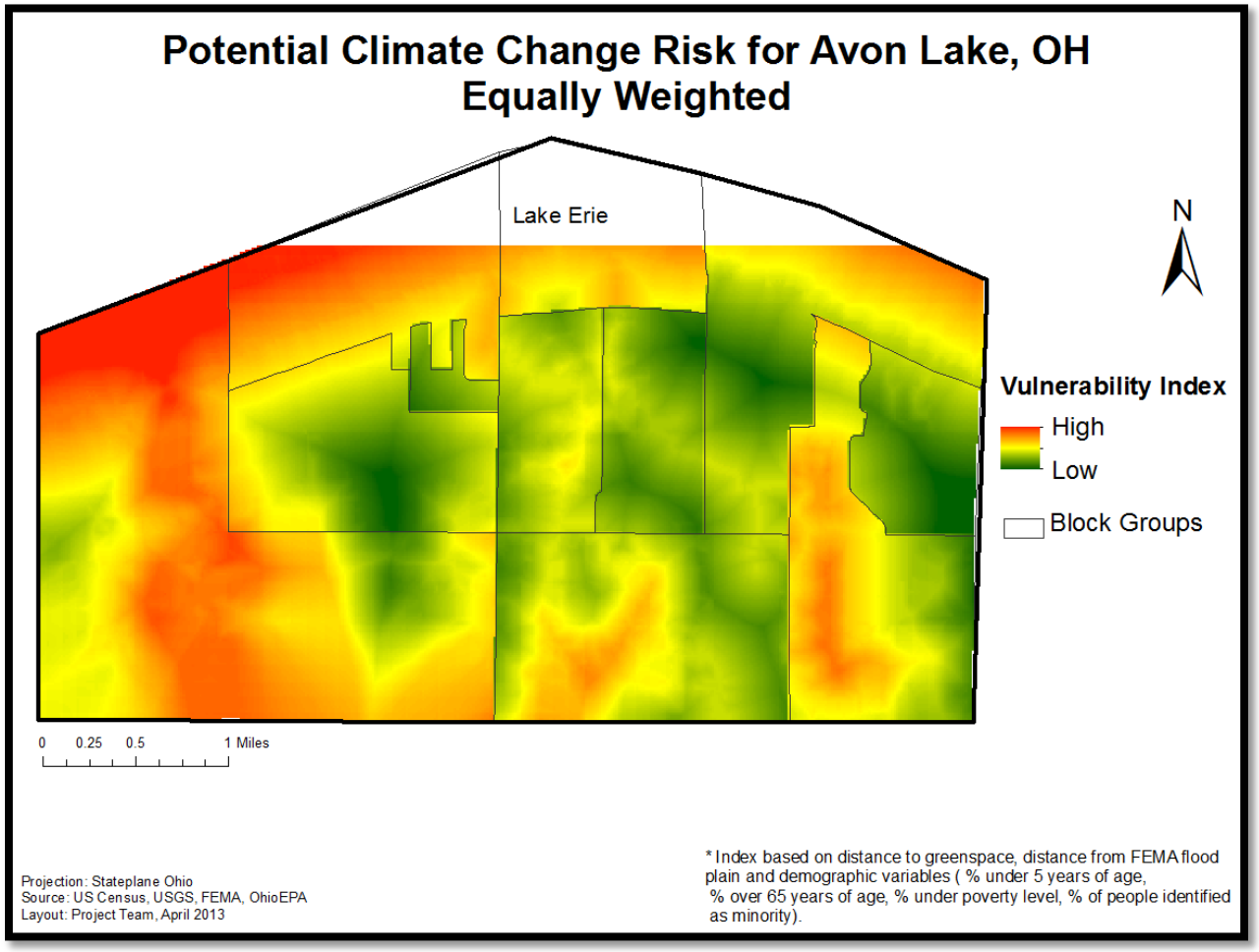
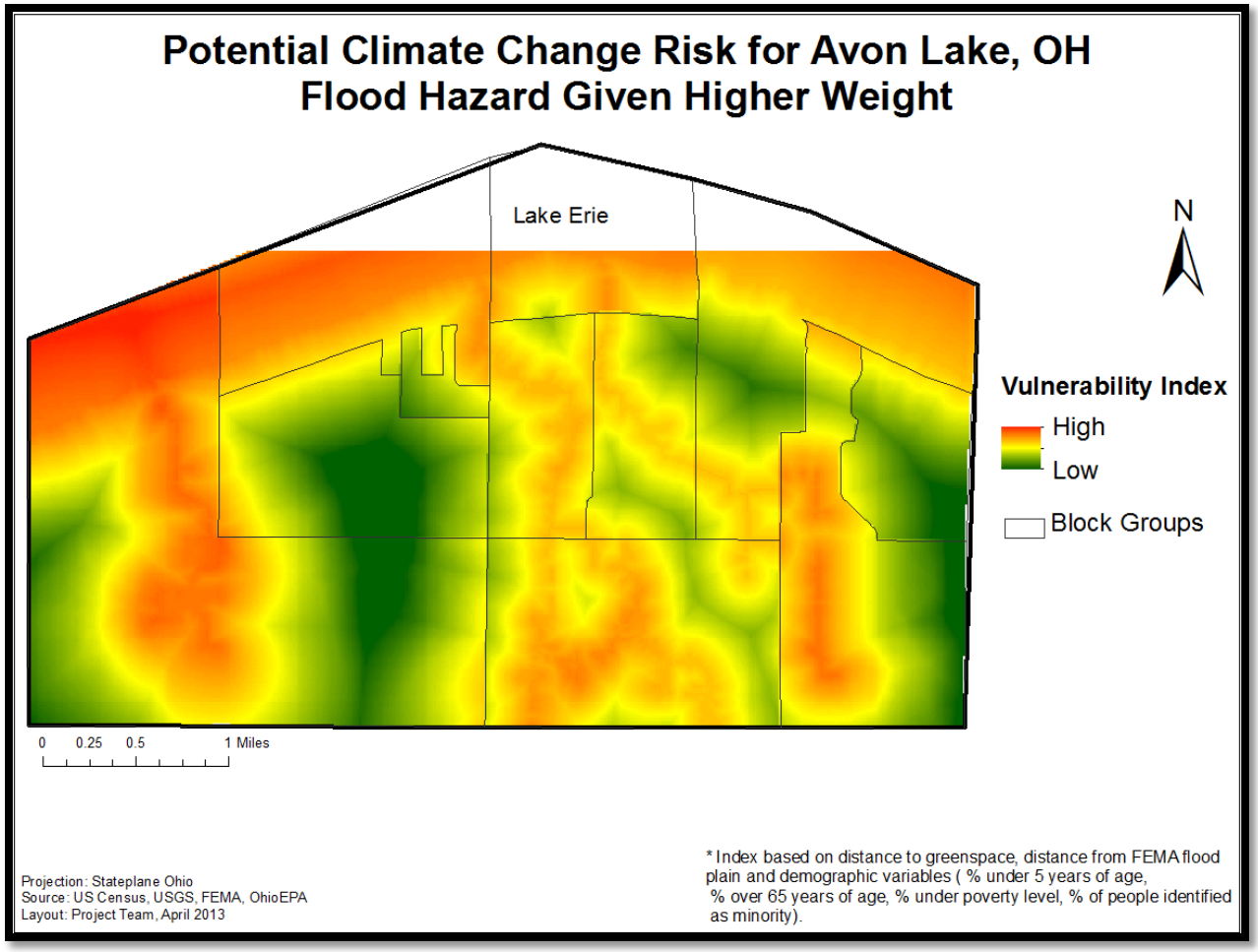
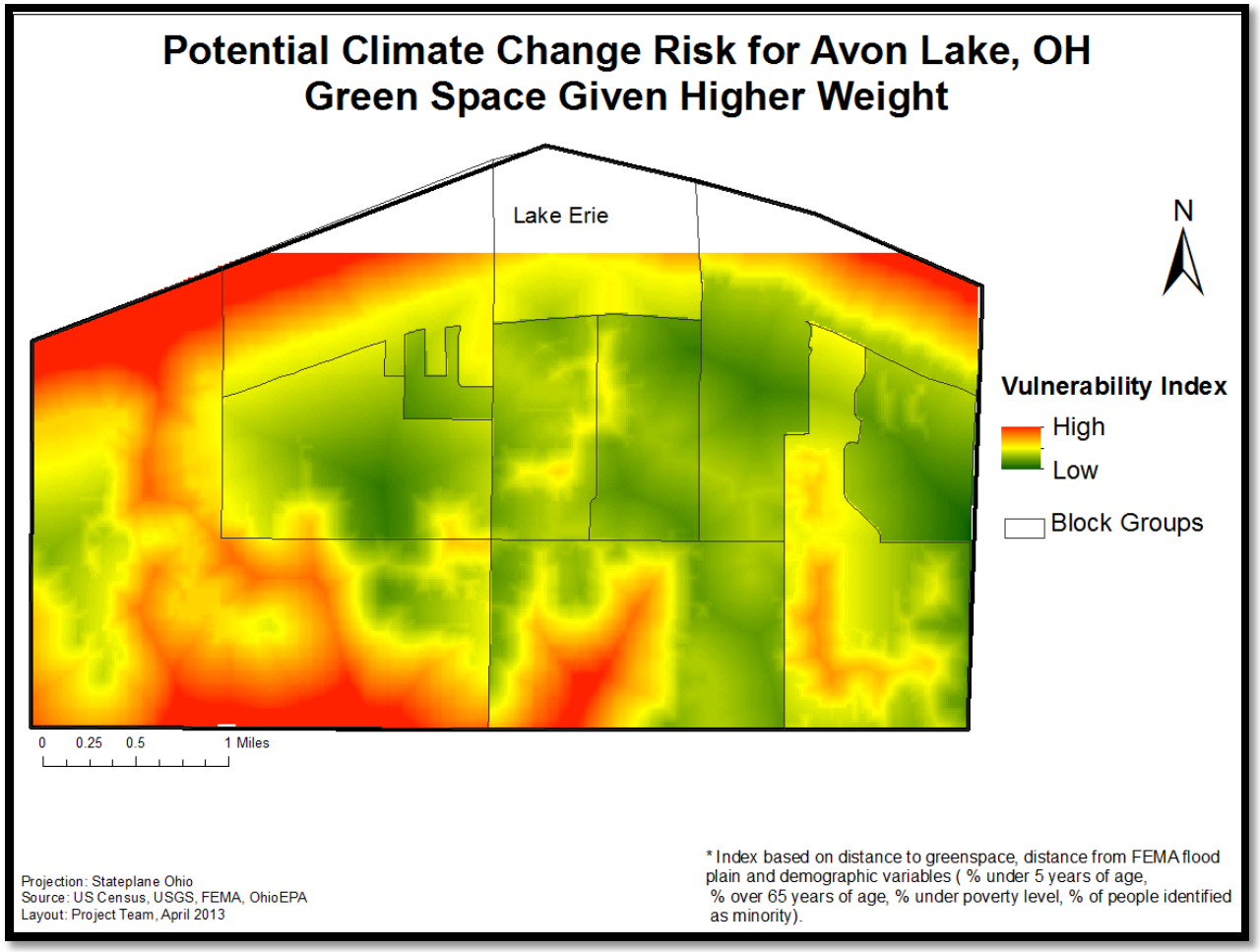
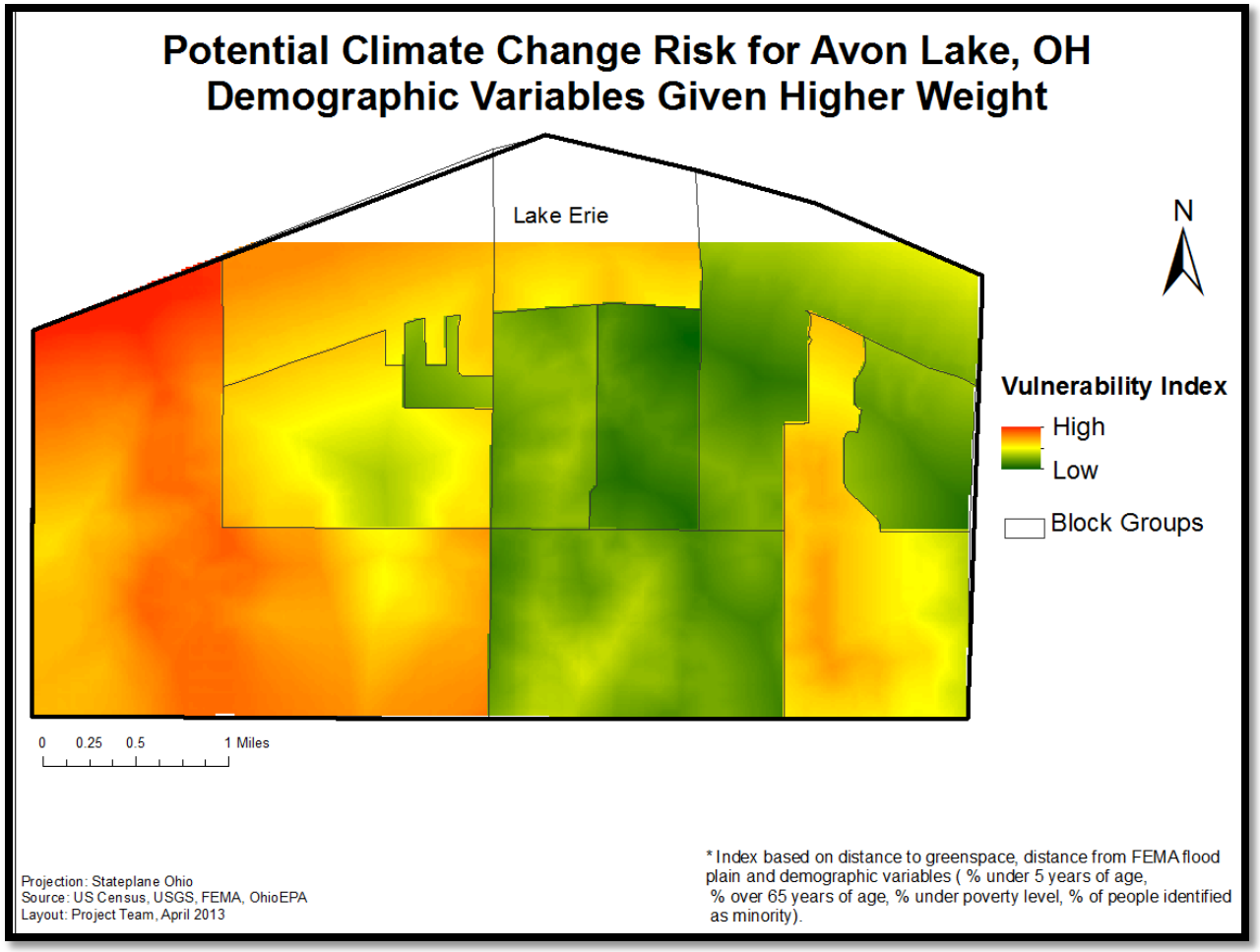
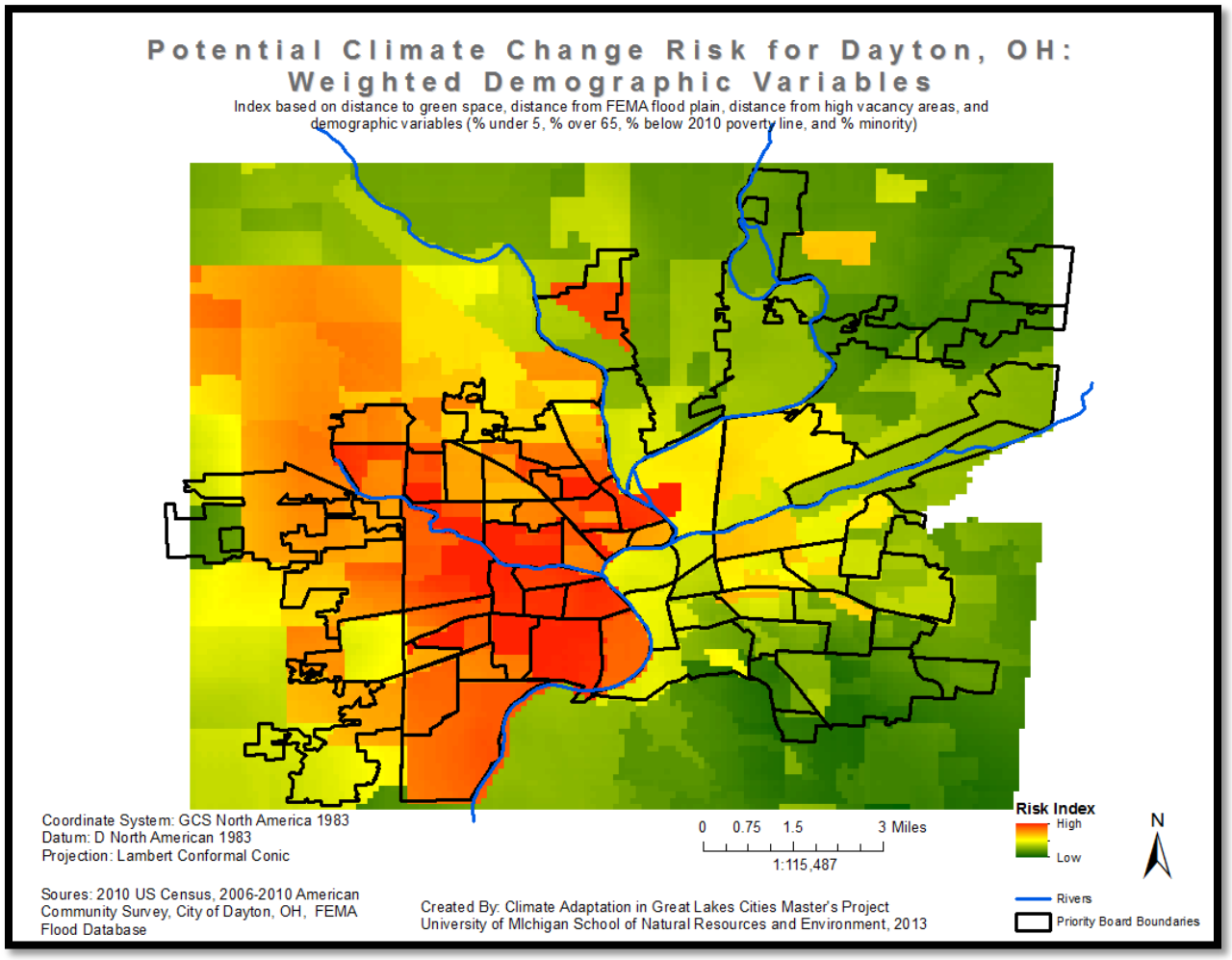
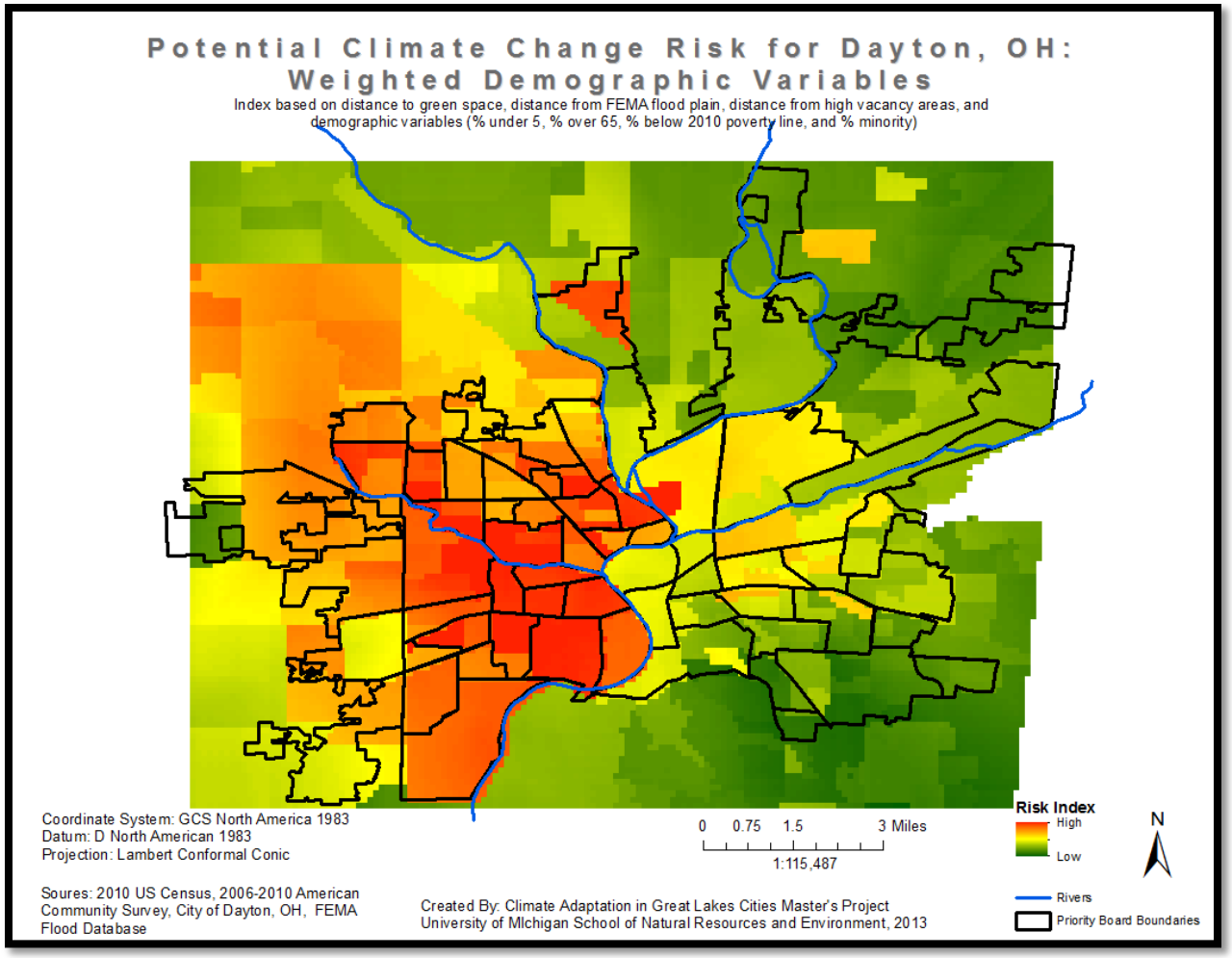

Potential Climate Change Risk for Avon Lake, OH
Equally Weighted
Lake Erie
N
Vulnerability Index
High
Low
Block Groups
0 0.25 0.5 1 Miles
Projection: Stateplane Ohio
Source: US Census, USGS, FEMA, OhioEPA
Layout: Project Team, April 2013
* Index based on distance to greenspace, distance from FEMA flood plain and demographic variables (% under 5 years of age, % over 65 years of age, % under poverty level, % of people identified as minority).


Potential Climate Change Risk for Avon Lake, OH
Flood Hazard Given Higher Weight
Lake Erie
N
Vulnerability Index
High
Low
Block Groups
0 0.25 0.5 1 Miles
Projection: Stateplane Ohio
Source: US Census, USGS, FEMA, OhioEPA
Layout: Project Team, April 2013
* Index based on distance to greenspace, distance from FEMA flood plain and demographic variables (% under 5 years of age, % over 65 years of age, % under poverty level, % of people identified as minority).


Potential Climate Change Risk for Avon Lake, OH
Green Space Given Higher Weight
Lake Erie
N
Vulnerability Index
High
Low
Block Groups
0 0.25 0.5 1 Miles
Projection: Stateplane Ohio
Source: US Census, USGS, FEMA, OhioEPA
Layout: Project Team, April 2013
* Index based on distance to greenspace, distance from FEMA flood plain and demographic variables (% under 5 years of age, % over 65 years of age, % under poverty level, % of people identified as minority).


Potential Climate Change Risk for Avon Lake, OH
Demographic Variables Given Higher Weight
Lake Erie
N
Vulnerability Index
High
Low
Block Groups
0 0.25 0.5 1 Miles
Projection: Stateplane Ohio
Source: US Census, USGS, FEMA, OhioEPA
Layout: Project Team, April 2013
* Index based on distance to greenspace, distance from FEMA flood plain and demographic variables (% under 5 years of age, % over 65 years of age, % under poverty level, % of people identified as minority).


Potential Climate Change Risk for Dayton, OH:
Weighted Demographic Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:115,487
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Demographic Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
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Created By: Climate Adaptation in Great Lakes Cities Master's Project
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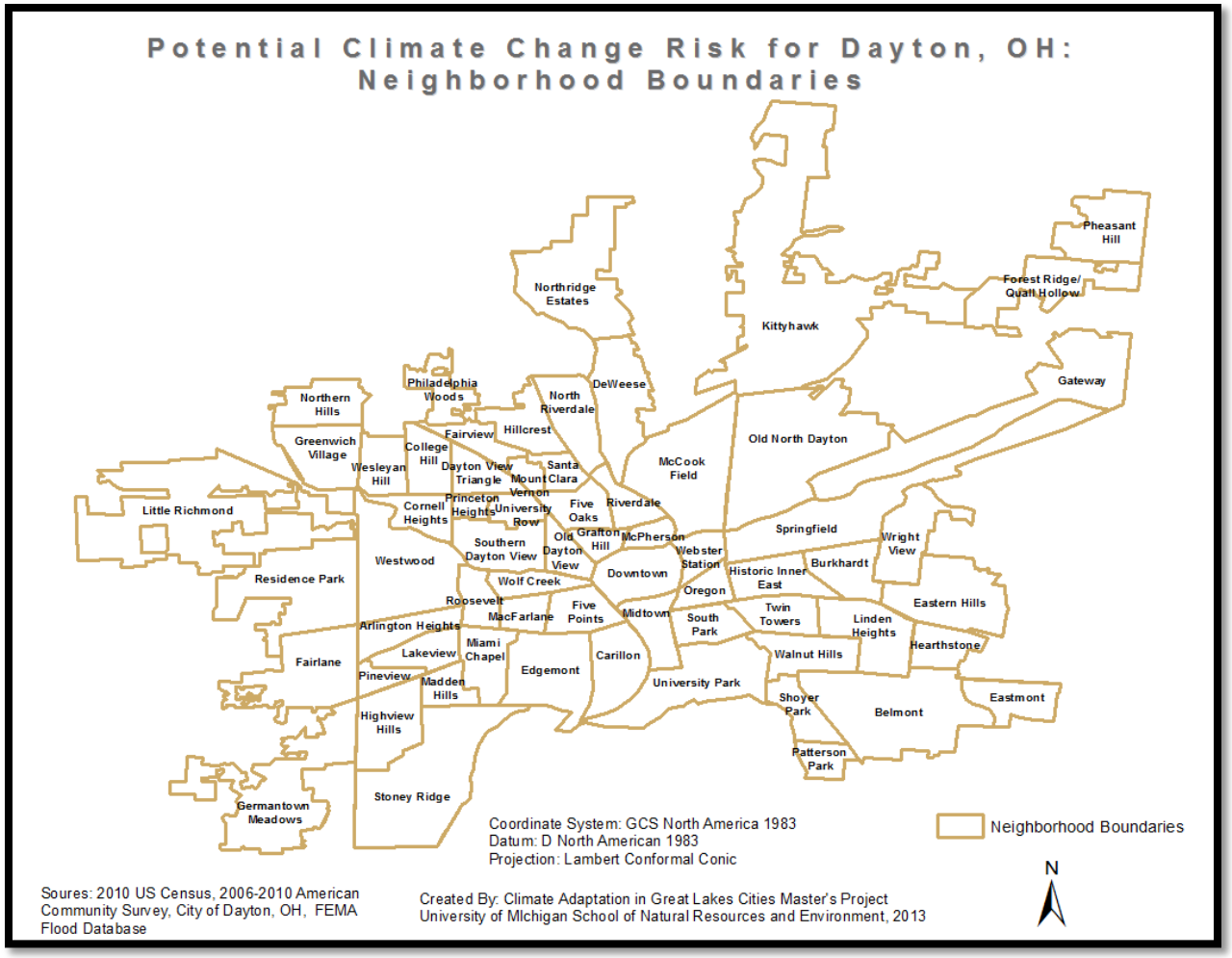
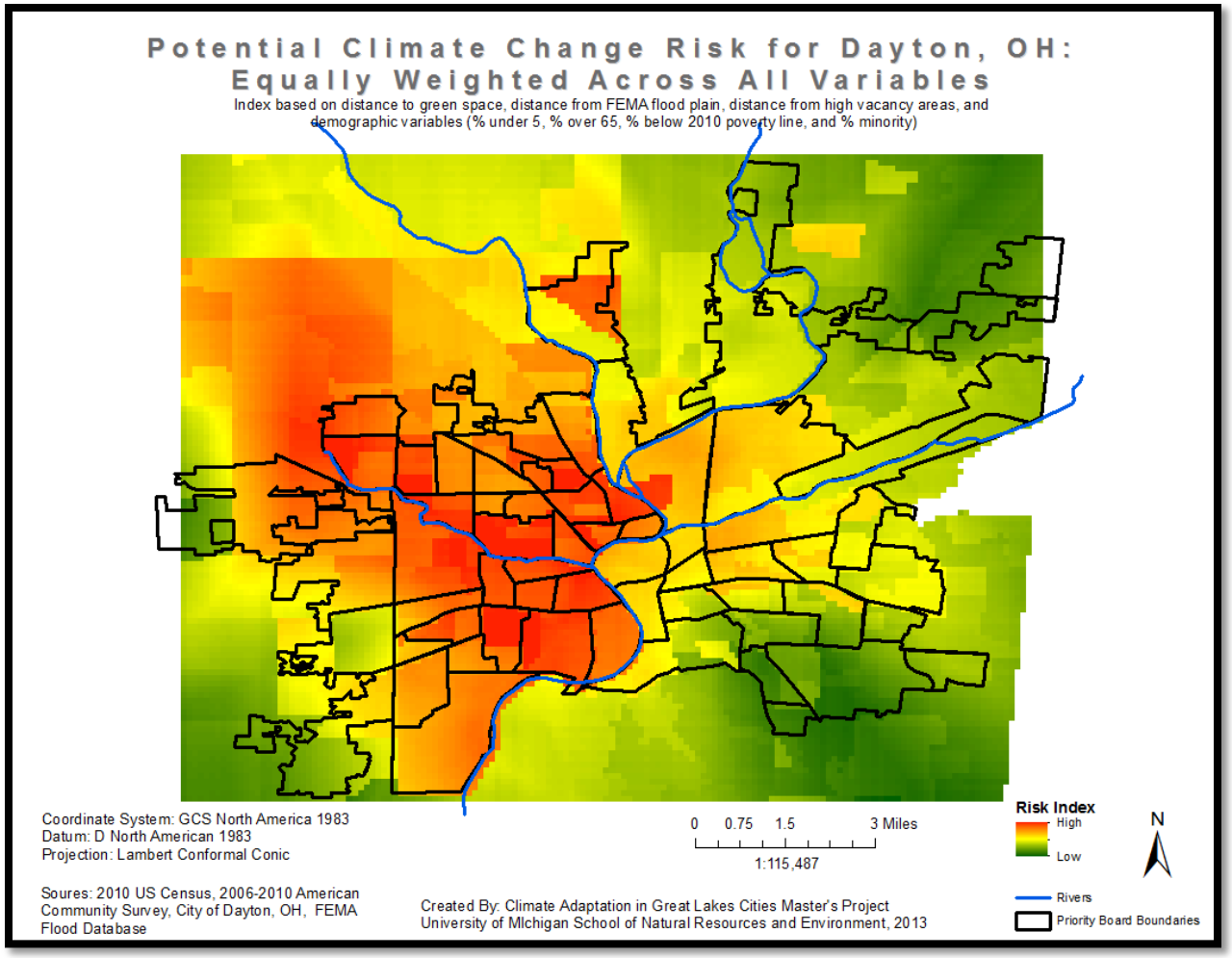
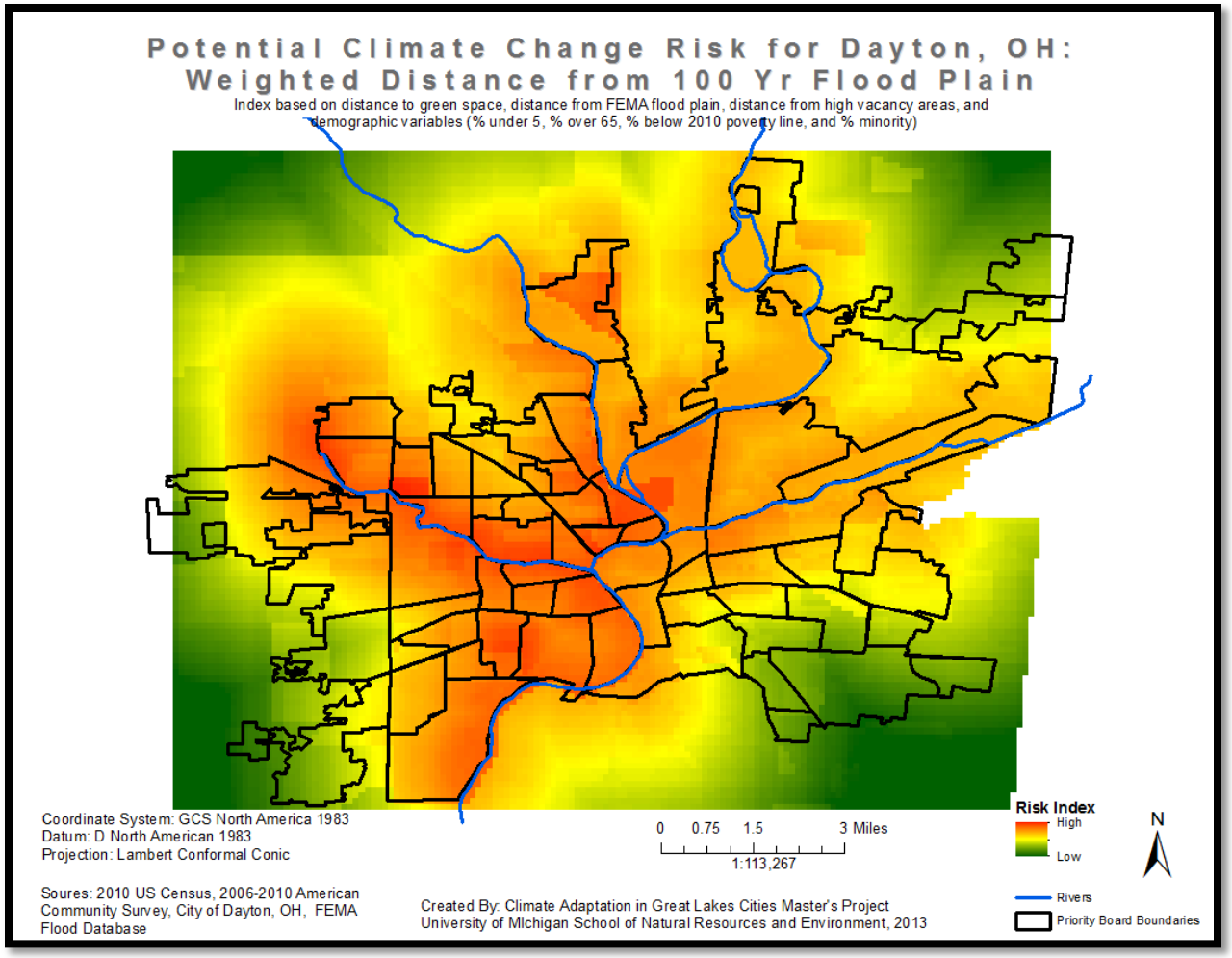
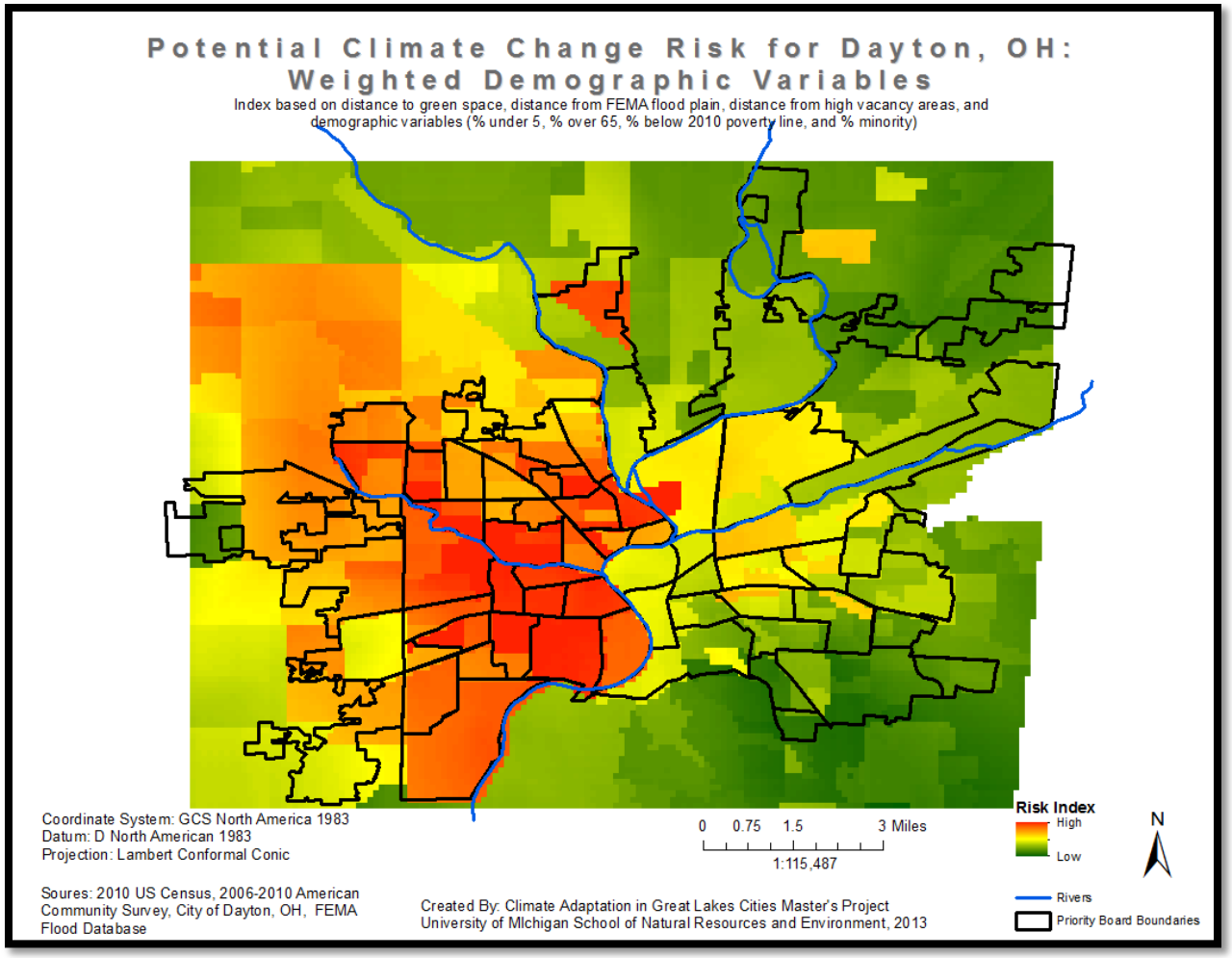
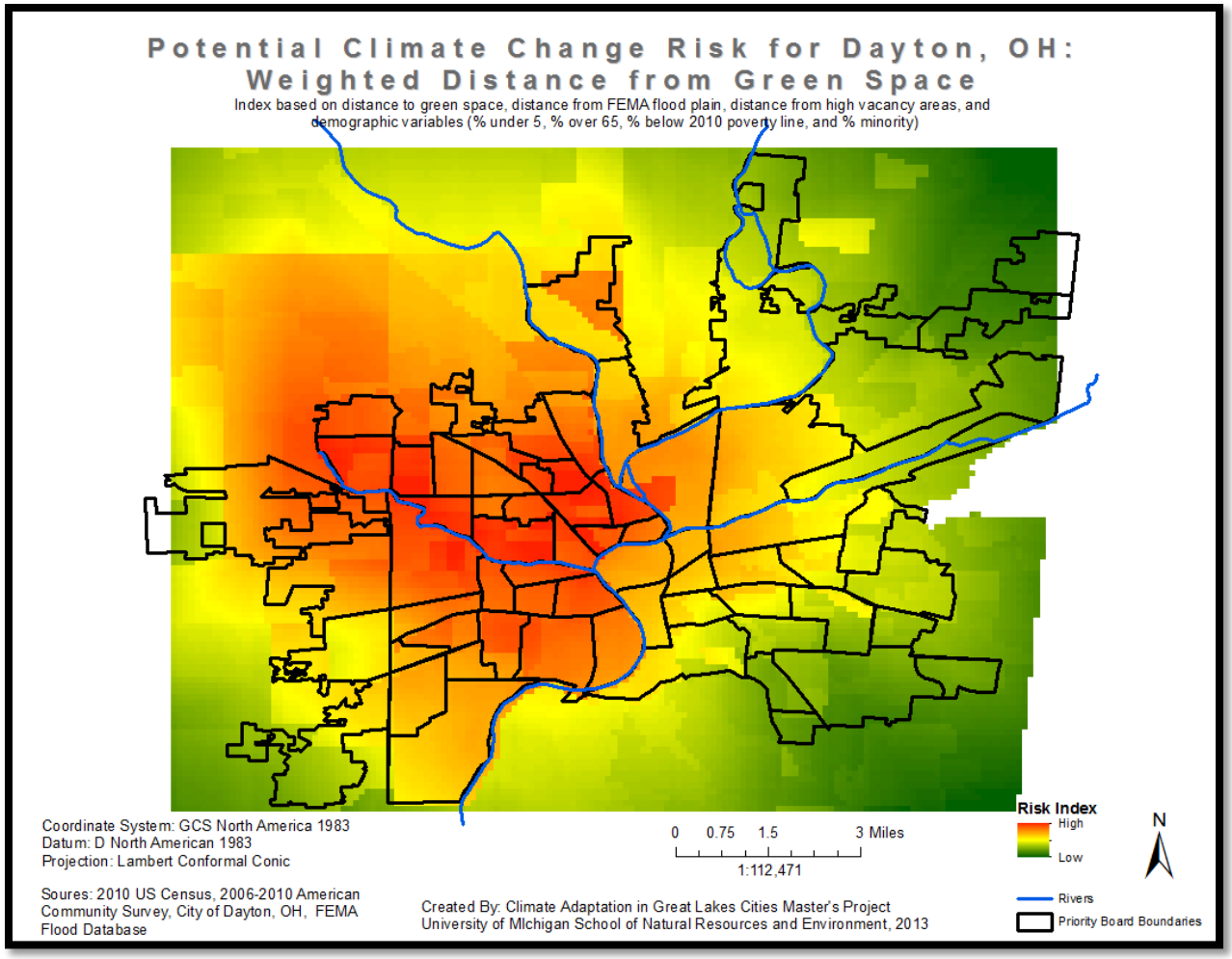
Risk Index
High
Low
N
Rivers
Priority Board Boundaries

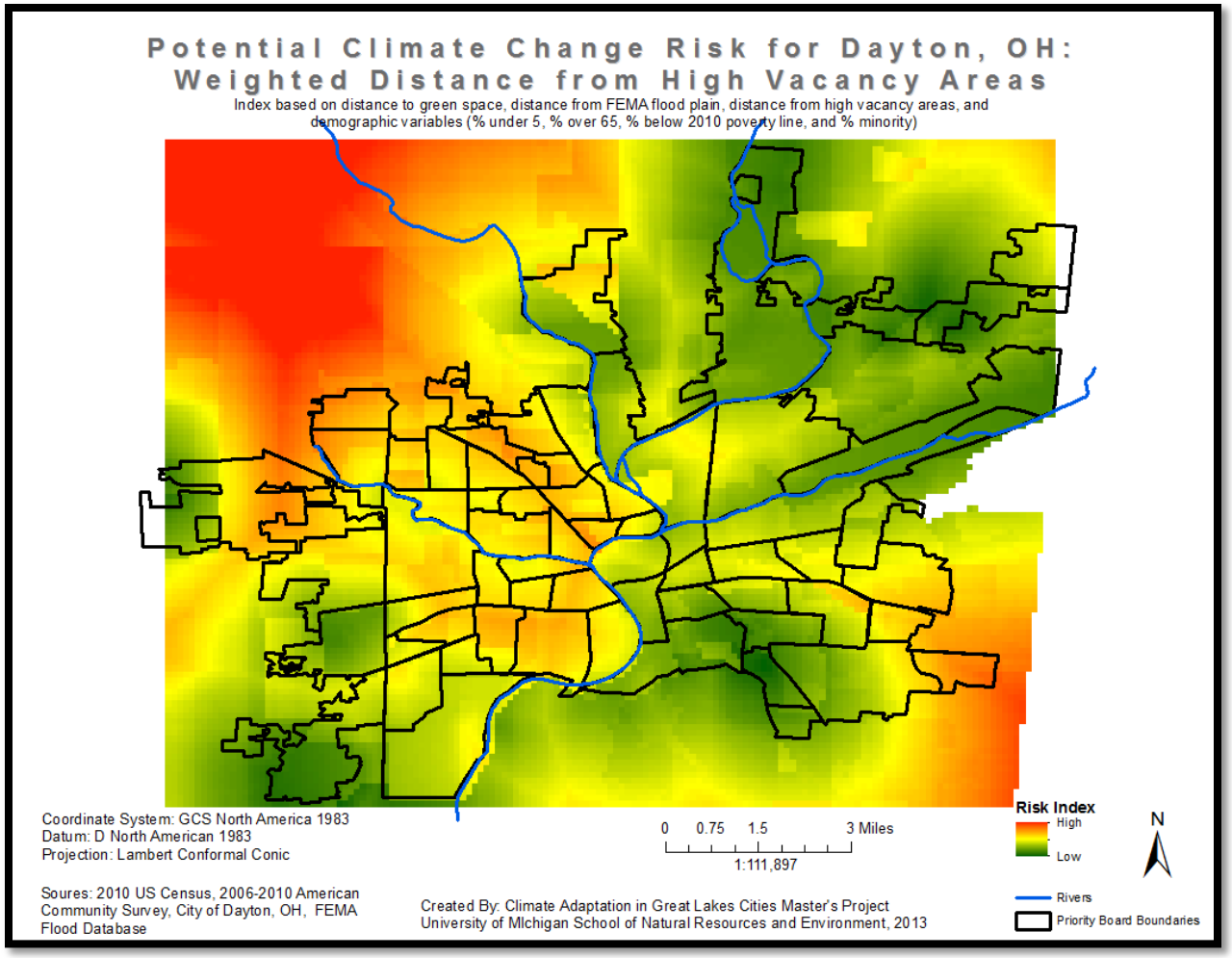

Potential Climate Change Risk for Dayton, OH:
Neighborhood Boundaries
Pheasant Hill
Forest Ridge/ Quail Hollow
Northridge Estates
Kittyhawk
Gateway
Philadelphia Woods
DeWeese
North Riverdale
Northern Hills
Hillcrest
Fairview
Old North Dayton
Greenwich Village
College Hill
McCook Field
Wesleyan Hill
Dayton View Triangle
Santa Clara
Mount Vernon
Princeton Heights
University Row
Five Oaks
Riverdale
Little Richmond
Cornell Heights
Springfield
Wright View
Grafton Hill
McPherson
Old Dayton View
Southern Dayton View
Webster Station
Burkhardt
Westwood
Historic Inner East
Downtown
Residence Park
Wolf Creek
Oregon
Roosevelt
Five Points
Midtown
Twin Towers
Eastern Hills
MacFarlane
South Park
Linden Heights
Arlington Heights
Miami Chapel
Hearthstone
Lakeview
Carillon
Walnut Hills
Fairlane
Edgemont
Pineview
Madden Hills
University Park
Shoyer Park
Eastmont
Belmont
Highview Hills
Patterson Park
Stoney Ridge
Germantown Meadows
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Neighborhood Boundaries
N
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of MIchigan School of Natural Resources and Environment, 2013


Potential Climate Change Risk for Dayton, OH:
Equally Weighted Across All Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:115,487
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from 100 Yr Flood Plain
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:113,267
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Demographic Variables
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:115,487
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from Green Space
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Risk Index
High
Low
Rivers
Priority Board Boundaries
N
0 0.75 1.5 3 Miles
1:112,471
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013


Potential Climate Change Risk for Dayton, OH:
Weighted Distance from High Vacancy Areas
Index based on distance to green space, distance from FEMA flood plain, distance from high vacancy areas, and demographic variables (% under 5, % over 65, % below 2010 poverty line, and % minority)
Coordinate System: GCS North America 1983
Datum: D North American 1983
Projection: Lambert Conformal Conic
Soures: 2010 US Census, 2006-2010 American Community Survey, City of Dayton, OH, FEMA Flood Database
0 0.75 1.5 3 Miles
1:111,897
Created By: Climate Adaptation in Great Lakes Cities Master's Project
University of Michigan School of Natural Resources and Environment, 2013
Risk Index
High
Low
N
Rivers
Priority Board Boundaries