Climate Change in Columbus Ohio

An Assessment of Columbus' Key Climate Changes, Impacts, and Vulnerabilities of Concern

Report prepared by the Great Lakes Integrated Sciences and Assessment (GLISA) and the University of Michigan Climate Center
March, 2016

Executive Summary

Mayor Andrew J. Ginther and the City of Columbus are committed to sustainability and to understanding the impacts of climate change to the community. In fact, the City of Columbus has a long history of leadership in sustainability. In 2005, the City launched the Get Green Columbus initiative with the issuance of a policy document entitled "Green Memo". The purpose of the initiative was to reduce impacts to the environment and demonstrate that economic prosperity and environmental protection are co-dependent objectives. The Columbus Green Community Plan: Green Memo III, was developed with input from over 1,000 stakeholders and recognizes that much progress has been made towards sustainability efforts in Columbus. The plan also lays out a community-wide sustainability framework of goals, objectives and actions to be implemented starting in 2015 and continuing through 2020. One of the plan's eight goal areas is to mitigate and adapt to climate change.

In 2015, the City of Columbus began work with city representatives and key city stakeholders to gather critical climate-related data and information. This process involved working with the NOAA-funded Great Lakes Integrated Sciences + Assessments program (GLISA) to identify key climate changes for Columbus and an eight month long vulnerability and risk assessment process that involved over 90 participants. Other key partners in this process included The Ohio State University, the Natural Resource Defense Council, and the University of Michigan Climate Center.

As a result of the initial step of working with GLISA to identify key climate concerns, two major climate changes and eight climate impacts were identified for Columbus:

Rising Temperatures
- Longer Growing Season
- Deteriorated Air Quality
- Extreme Heat
- Shifting Natural Resources

Increasing Precipitation
- Deteriorated Water Quality
- Increased Flood Risk
- Changing Seasonal Precipitation
- Changes to Water Availability

These climate changes and impacts were used as the basis for a vulnerability and risk assessment process in which city partners and stakeholders identify fourteen priority vulnerabilities related to these impacts that represent the biggest risks for the City of Columbus. These priority vulnerabilities provide decision makers with the necessary context to understand what populations, sectors, and resources would be most at risk to the City's primary climate concerns.

The results of this year-long process are intended to lay the foundation for the city's preparedness efforts and should inform city staff, decision makers, and stakeholders as they craft effective climate change communication initiatives and develop strategies to increase community resilience. The cross-cutting nature of the climate changes and associated vulnerabilities will require collaborative approaches on scales that range from neighborhoods to the region. While the ultimate goal is long-term resiliency, a combination of near-term actionable projects and long-term policy and regulation solutions will be essential.

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I. INTRODUCTION

Columbus Green Community Plan and Process

Former Columbus Mayor Michael B. Coleman launched the Get Green Columbus initiative in 2005 with the issuance of a policy document entitled "Green Memo". The purpose of the initiative was to reduce impacts to the environment and demonstrate that economic prosperity and environmental protection are co-dependent objectives. The Columbus Green Community Plan: Green Memo III, was developed with input from over 1,000 stakeholders and recognizes that much progress has been made towards sustainability efforts in Columbus, and the plan also lays out a community-wide sustainability framework of goals, objectives and actions to be implemented starting in 2015 and continuing through 2020. One of the plan's eight goal areas is to mitigate and adapt to climate change. In 2015, the City of Columbus, with the support of the partners listed below, began work with city representatives and key city stakeholders to gather critical climate-related data and information to inform the city's preparedness efforts. This year-long process involved working with the NOAA-funded Great Lakes Integrated Sciences + Assessment (GLISA) program to identify key climate changes for Columbus and an eight month long vulnerability and risk assessment process that involved over 90 participants. The result of these efforts is the identification of two primary climate changes, eight related climate impacts, and fourteen priority vulnerabilities associated with these impacts, all specific to the City of Columbus.

Partners and Roles

This effort was made possible due the collaboration among the City of Columbus, the Natural Resources Defense Council, The Ohio State University, The Columbus Foundation, the City's Green Team and Climate Change Working Group, the University of Michigan Climate Center, and GLISA. Their roles are discussed below:

- **The City of Columbus (the City)**: The Office of Environmental Stewardship ensured the vision of the Green Memo III was upheld while playing a key role in identifying and gathering information from participating stakeholders, ensuring representation from across the city, and identifying vulnerable communities as well as providing funding towards to the project.
- **The Ohio State University (OSU):** Faculty and staff members from OSU participated in various parts of the vulnerabilities assessment (Kirwan Institute; School of Environment and Natural Resources; Glenn College of Public Affairs; College of Food, Agricultural, and Environmental Sciences). Researchers at the Byrd Polar and Climate Research Center and members of the State Climate Office of Ohio provided technical expertise. Undergraduate students helped organized meeting results and prepare materials for various presentations.
- **Natural Resource Defense Council (NRDC):** The organization served as a catalyst for this project by providing the much needed funding to make it possible. NRDC also provided guidance and experience on local climate adaptation based on its work across the country.
- **The Columbus Foundation:** The foundation provided necessary funding towards the project.
- **The Green Team and Climate Change Working Group**: The Green Team served in an advisory role to the project. It was composed of subject matter experts, community leaders, and representatives from the private sector.
- **The University of Michigan Climate Center:** Faculty and staff from the University of Michigan provided expert advice on the development and implementation of the vulnerability assessment process. Based on previous efforts with cities throughout the region, the Climate Center designed and coordinated the

vulnerability and risk assessment process. The Climate Center also provides a platform for sharing outcomes from this engagement with cities across the Great Lakes region and beyond.

- **Great Lakes Integrated Sciences and Assessments (GLISA):** Housed at the University of Michigan's Climate Center, GLISA is the NOAA-funded Regional Integrated Sciences and Assessments program for the Great Lakes. GLISA resources contributed historic and future climatological data for Columbus and Ohio that underpinned the key impact areas this project addressed.

Climate concerns

The 2014 National Climate Assessment (Melillo et al, 2014) describes some of the impacts the Midwest is expected to face during the 21st century, including increased frequency of heat waves, degraded air quality, extreme rainfall events and flooding. It further notes particular vulnerabilities associated with cities, including flooding, heat waves, stressed urban vegetation, heat island effects, new disease vectors, and increased atmospheric pollution. It predicts that average temperatures will increase 3.8-4.9 degrees Fahrenheit by mid-century (for scenarios with "substantial emissions reductions" to "business as usual").

Locally, Columbus can expect higher temperatures and increased precipitation (GLISA, Appendix B). In the absence of appropriate adaptation measures, these changes will result in deteriorating air quality, deadly heat waves, more flooding (especially flash flooding) and more combined sewer overflows. Columbus' climate has warmed faster than national and global rates over the past 65 years. Annual average temperatures warmed by 2.3°F from 1951-2012, while average low temperatures warmed much faster, by 3.6°F. Late winter and early spring temperatures have risen faster than other parts of the year, with a change of 3.1°F seen during the spring. These trends are generally expected to continue or accelerate into the future, with approximately 3-5°F expected through mid-century. Beyond mid-century, benefits such as a longer growing season will be offset by increased summer drought risk and more extreme heat days. (More information on Columbus' anticipated climate impacts are provided in Section 2.)

Action at the state and local levels in Ohio

According to the Yale Project on Climate Change Communication (YPCC), public belief that climate change is happening in Ohio meets or lags national opinion. Nonetheless, surveying conducted by YPCCC in 2013 found that 57% of Columbus residents surveyed thought that the city needed to do "more" or "much more" to address global warming versus those who felt the city was "doing the right amount" or should do "less" or "much less." Those surveyed also thought that citizens and corporation/industry should be doing "more" or "much more" at 66% and 68% respectively (Leiserowitz et al, 2013). While many Great Lakes states, such as Minnesota and Michigan, undertake climate adaptation through state-level agencies or departments, such as natural resources, environmental protection or health and human services, there has been minimal state level action in Ohio. This creates a vacuum for cities to fill with local climate adaptation activities.

The lack of state-level leadership emphasizes the importance of Columbus embarking on its own adaptation process. Several other cities in Ohio have begun adaptation efforts, including Cleveland, Toledo, Cincinnati and Dayton. (See examples in Section 4.).

Integrating climate information into decision making

Most climate impacts exacerbate existing risks or present new challenges to Columbus, although a few present new opportunities (e.g. a longer growing season). This changing context undermines a business-as-usual approach to government operations and decision making. Especially prominent is the need for infrastructure upgrades and advanced planning. Most capital projects have a lifespan of at least a few decades and climate change creates moving targets for infrastructure parameters such as heat stress and extreme precipitation event capacity. While this poses a challenge for decision makers who must balance competing priorities, such as immediate infrastructure and service needs with long-term investments, incorporating climate information allows for a more complete picture of these parameters so that costs and benefits can be more carefully weighed. Likewise, citizens expect that local government has adequately planned for and is prepared to deal with significant events such as flooding and heat waves so that lives and property are protected and operations can return to normal soon after the event.

Other cities across the country have already recognized this and are beginning to incorporate climate into their decision making. New York City is updating its building regulations to account for a changing 100-year floodplain and working with utilities to protect electricity infrastructure from climate risks such as increased severity of storms. Baltimore included climate scientists on an Advisory Committee for its disaster risk preparedness planning alongside public officials, community and business leaders, and others to ensure climate predictions are considered. Chicago, which faces rising temperatures and more intense heat waves, is using satellite data to identify areas of the city where temperatures are highest and heat island reduction strategies, such as tree planting, will be most impactful.

Despite the characterization of climate change as a global issue, the impacts are highly localized. Likewise, each community has different risks associated with these impacts and assets that can be used to mitigate the risks. This combination of unique impacts, risks, and assets mean that each community is uniquely vulnerable to a changing climate and thus local adaptations should be tailored to a city's specific context. A vulnerability and risk assessment process is used by many cities to aid in the customized identification of climate vulnerabilities and risks. Through this process, cities collect data on ongoing and projected climate changes and impacts, as well as information about how these changes will affect the resources, infrastructure and residents of a municipality. Conducting a vulnerability and risk assessment process takes into account a city's vulnerabilities; the severity of particular impacts; consequences to city operations, citizens, and the business community; and the likelihood that expected impacts will occur. The process is iterative, relying on the input from many sectors and perspectives, in order to identify the city's most important climate impacts. The process and results of Columbus' vulnerability and risk assessment process are presented and discussed in Section III.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of both the sensitivity and the adaptive capacity of a given sector.

Risk: The possibility that impact may occur and the associated consequences. Risk is a function of both the likelihood an impact will occur and the severity of the consequences if it were to occur.

(Adapted from Melillo et al, 2014)

II. CLIMATE CONCERNS FOR COLUMBUS

Climate change will amplify existing weather-associated challenges to people, natural environments, and infrastructure in the Midwestern United States. Rising temperatures will lead to a greater probability of heat waves, a longer freeze-free period (growing season), and changing seasonality. Precipitation totals have increased dramatically during the wet seasons in many parts of the Midwest, including Ohio, and heavy precipitation events have become stronger and more frequent. The heaviest 1% of precipitation events are delivering 37% more precipitation in the Midwest than in the past (Melillo et al, 2014), with most of that change due to increases in the frequency of storms. Columbus is well-aligned with the broader regional trend, with 36.2% more precipitation falling in these heaviest precipitation events now compared to the the 1951-1980 period. The number of days exceeding 1.25 inches of precipitation also increased by 78% from 1951-2012 (GLISA, Appendix A).

Primary Projected Climate Changes and Impacts for Columbus

- Rising Temperatures
  - Longer Growing Season
  - Deteriorated Air Quality
  - Extreme Heat
  - Shifting Natural Resources
- Increasing Precipitation
  - Deteriorated Water Quality
  - Increased Flood Risk
  - Changing Seasonal Precipitation
  - Changes to Water Availability

These changes, when superimposed on rapidly shifting demographics, aging infrastructure, changing land use, the fragmentation of natural features, and increasing atmospheric pollution, create many potential impacts due to climate change. Stormwater management and treatment systems are already experiencing challenges during historically high-volume precipitation events. Numerous recent floods in many cities across, Iowa, Indiana, Illinois, Wisconsin, and Michigan are indicative of the types of events that will become more likely in the future. And, while flooding is a primary concern, seasonal summer drought, like the one experienced in 2012, may become more likely as summer precipitation levels remain stable and rising temperatures increase evaporation. Furthermore, drinking water supplies are impacted by harmful algal blooms (HAB), like the one that affected Toledo in August 2014, a phenomena that is exacerbated by warmer summer temperatures and inflow of nutrients during extreme precipitation events. Columbus has already invested $3 million over the past two years to protect its drinking water supplies from nutrients. Ecosystems unable to adapt to a rapidly shifting climate are losing their advantage over species traditionally found farther south. More resilient, adaptive invasive species may broaden their abundance and spatial extent, while pests and pathogens currently found elsewhere may be able to gain footholds in the region.

Social and Demographic Changes for Central Ohio

In their recent "Insight2050" report, the Mid-Ohio Regional Planning Commission (MORPC) found that Central Ohio's population is expected to grow by more than 500,000 additional people in the next 35 years, with more of the population being significantly younger (less than 35 years old) or significantly older (more than 65 years old). These trends, indicating that more of the population will be at a vulnerable age, highlight the need for planning that considers not only a changing climate but changing demographics.

(Source: Insight2050)

Methodology

To evaluate trends in climate already observed for the Greater Columbus region, observational data encompassing the eight Great Lakes states (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Pennsylvania, New York, and Ohio) were used to find a broad regional trajectory and to place changes observed near Columbus in the proper context. National Centers for Environmental Information (NCEI) nClimDiv divisional data were used

to evaluate the observed changes in seasonal and annual temperature and precipitation at the multi-county scale. Daily data, from NCEI's Global Historical Climate Network (GHCN-Daily, or GHCND) of weather observing stations, were used to identify local trends in long-term climate as well as changes in extreme events, such as days recording large precipitation totals or extreme temperatures. Data from GHCND were further quality-controlled so that only stations with reliable, continuous coverage over a long period of time were used in the analysis. This resulted in 32 stations of high quality across Ohio.

Historical climate observations

The average annual temperature for Columbus warmed by 2.3°F from 1951 through 2012, faster than the national and global rates. The early spring season has seen the greatest warming and winter temperatures have been highly variable, rising from the 1960s through the 1990s before declining sharply over the last decade. Perhaps most striking is that overnight low temperatures warmed four times as fast as mid-day high temperatures from 1951 through 2012. This likely means that temperatures have been cooling far less overnight than in the past.

With warming temperatures, the freeze-free season (growing season), lengthened by 25.5 days from 1951-2012, consistent with other large cities in Ohio. Both the average date of first freeze in the fall and last freeze in the winter changed by more than 10 days.

Annual precipitation totals rose 19.8% from 1951-2012, similar to other locations in Ohio. All seasons have seen an increase in precipitation, with fall seeing the greatest change both in actual volume and percentage change compared to the 1951-1980 average. Consistently, heavy precipitation events have increased in frequency and severity across Ohio. Columbus is no exception. The frequency of the heaviest 1% of precipitation events (defined by the 1951-1980 period) increased by 31.7% (41 storms from 1951-1980 to 54 storms from 1981-2010). The number of days exceeding 1.25" of total precipitation, a benchmark for when nuisance flooding occurs, increased by 78% (a change of 2.8 more days) from 1951 through 2012.

Projections

The Mid-Ohio Regional Planning Commission (MORPC) Sustaining Scioto project recently performed Projections of future climate for the Greater Columbus area in cooperation with the United States Geologic Survey (USGS). The MORPC-USGS team utilized Climate Model Intercomparison Project version 3 (CMIP3) model projections to inform how regional hydrology might respond to plausible changes in climate through the end of the 21st century. To remain consistent with their methodology, but to provide additional perspective on the probable future climate of Columbus, a dynamically downscaled regional climate model ensemble from the North American Regional Climate Change Assessment Program (NARCCAP) was used to describe relative changes from current climate conditions in annual and seasonal temperature and precipitation. NARCCAP data is available through the year 2070. Future changes in temperature and precipitation were calculated by taking averages over a 2° x 2° latitude-longitude area centered over Columbus.

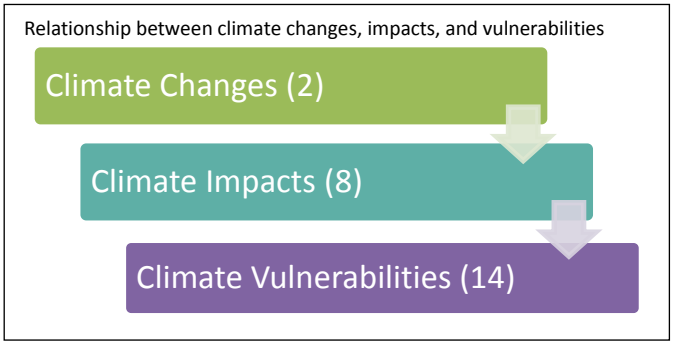
Although calculated using dynamically downscaled models from a different modeling framework, the results of the NARCCAP analysis align well with the previous CMIP3 results calculated by the MORPC team. While individual model projections vary in both the NARCCAP and CMIP3 analyses, the results of both are consistent with previous projections by the National Climate Assessment for the Columbus region. Annual average temperatures are generally projected to warm by 3-5°F in Columbus by mid-century and up to 10°F by

the end of the century. Total precipitation is projected to increase in all seasons, though summer precipitation may increase less, remain stable, or decline. This generally places Columbus, Ohio in warmer and wetter climate conditions for the majority of the year, with potentially warmer and drier summer conditions.

More detailed results of the climate change research and model analysis are included in Appendix A, the Historical Climatology for Columbus, and Appendix B, the Future Climate Change Impacts for Columbus.

III. COLUMBUS' VULNERABILITY AND RISK ASSESSMENT PROCESS

Process methodology



Over the course of 2015, the City of Columbus, in partnership with GLISA, NRDC, OSU, and U-M, carried out a vulnerability and risk assessment process to lay the groundwork for the city to integrate climate data into its emergency preparedness efforts. This process, which was adapted from ICLEI's Local Governments for Sustainability "Building Adaptive and Resilient Communities" program, allowed the City to not only better understand its key climate concerns, but provided decision makers with the necessary context to understand what populations, sectors, and resources would be most at risk due to these impacts. This process was primarily carried out by the "Core Team," with representatives from the City of Columbus, The Ohio State University's Byrd Polar and Climate Research Center, the Natural Resources Defense Council, the University of Michigan Climate Center, and GLISA. The Core Team was responsible for coordinating and administering the vulnerability and risk assessment process and identified key stakeholders to participate in the process. Core Team members were the primary facilitators for meetings that occurred throughout the process. The Core Team consisted of:

- Erin Miller, City of Columbus, Office of Environmental Stewardship
- Richard Hicks, City of Columbus, Public Health Department
- Jason Cervenec, The Ohio State University, Byrd Polar and Climate Research Center
- Theo Spencer, Natural Resources Defense Council
- Jen Lynch, Remington Road Group
- Ashlee Grace, University of Michigan Climate Center
- Elizabeth Gibbons, University of Michigan Climate Center/GLISA
- Dan Brown, University of Michigan Climate Center/GLISA
- Matthew Bishop, University of Michigan Climate Center

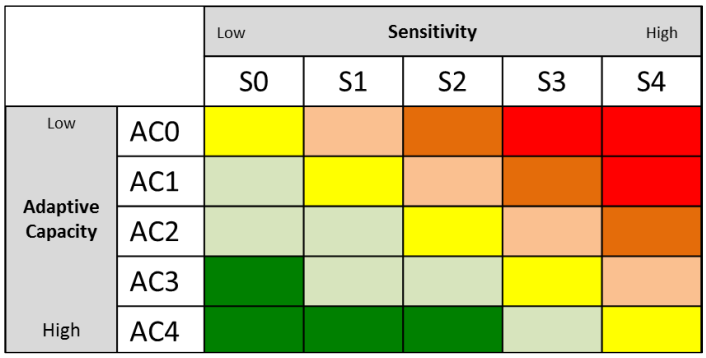
From February through April, the Core Team met routinely to review climatological data and prepare for the larger working group meetings. The Core Team invited over 40 local stakeholders and city employees to the initial Climate Working Group meeting in early May 2015 to review the eight major climate impacts of concern (as noted in section II) and identify climate vulnerabilities faced by the City. A second purpose of the meeting was to gauge interest and expertise as it related to the process. This first meeting generated 79 climate vulnerability statements based on sector-specific expertise and identified numerous resources for the Core Team to investigate further.

The Core Team studied the resources identified by the Climate Working Group, edited and organized the 79 identified climate vulnerability statements into a working list and, in early July 2015, invited a smaller, select Climate Working Group (based on their interest and relevant expertise) to refine the list, reducing it to 59. Then, aided by sector experts including MORPC and the Franklin County Office of Emergency Management, the Core Team further refined the list to 43 vulnerability statements, which were used in the vulnerability assessment process that occurred throughout September.

Vulnerability Assessment

Sensitivity: The degree to which a given system is directly or indirectly affected (either adversely or beneficially) by climatic conditions (i.e. temperature increases) or a specific climate change impact (i.e. increased flooding).

Adaptive Capacity: The ability of built, natural and social systems to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.



Scoring Matrix for Vulnerability Assessment
SO (low sensitivity): No, functionality will stay the same
S4 (high sensitivity): Yes, functionality will become unmanageable

AC0 (low adaptive capacity): No. Will require substantial costs ($$$$$) and staff intervention.
AC4 (high adaptive capacity): Yes. No too little costs ($) and staff intervention necessary.

Adapted from ICLEI's Local Governments for Sustainability "Building Adaptive and Resilient Communities" program

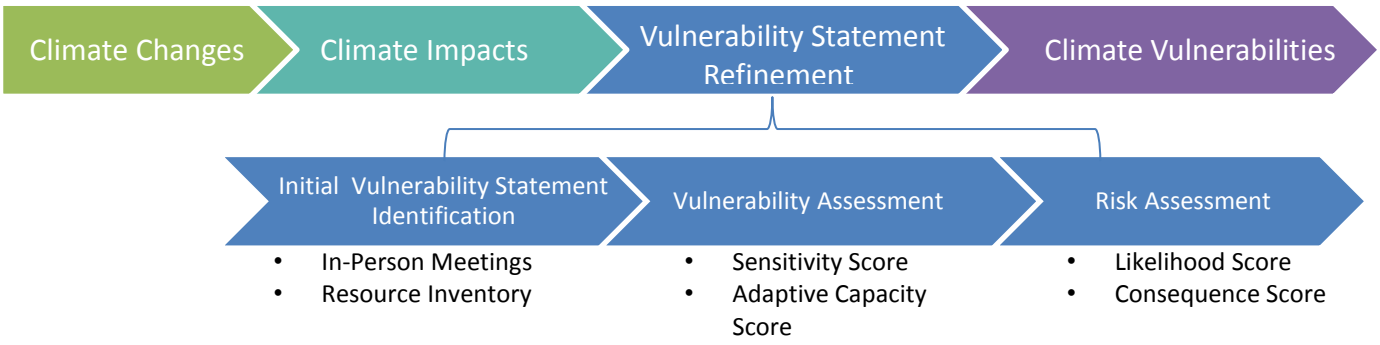
The vulnerability assessment process was carried out in two parts. First, the 43 vulnerability statements were released to sector-specific stakeholders in a customized online survey to identify initial scores for how sensitive Columbus is to each impact ("sensitivity") and how easily Columbus can respond to each impact ("adaptive capacity"). After the survey was completed, eight sector-specific Green Team Working Groups met in person to review these results and recommend edits or alterations as needed. The resulting sensitivity and adaptive capacity scores mapped to a single vulnerability score per group for each statement, which were then averaged to create a single vulnerability score per statement. The overall goal of this step was to further refine and prioritize the list of climate vulnerabilities of concern to Columbus to help the City focus its preparedness efforts.

Vulnerability statements receiving vulnerability scores above a threshold (totaling 21 statements) became part of the next step: the risk assessment process which took place in November, 2015. In the risk assessment process, Climate Center staff assigned a "likelihood" score to each vulnerability statement and city decision makers and key stakeholders identified "consequence" scores for five different topic areas. These topic areas included: Public Health and Safety; Environment and Sustainability; Public Administration; Local Economy

and Growth; and Community and Lifestyle. This initial scoring was again collected through an online survey. On a scale of 1-5, likelihood scores provided a standardized assessment of how likely each impact is by midcentury in the absence of adaptation activity. Consequence scores were specific to each of five sectors and were also rated on a scale of 1-5 (Appendix F). The average for each consequence score was then summed and multiplied by the likelihood score to obtain the final risk assessment score per vulnerability statement.

At the end of this process, the City of Columbus had identified 21 key climate impacts of concern that could be organized by primary climate impact (e.g. water quality and availability, flood risk and seasonal precipitation, air quality and extreme heat, and natural resources and growing season) and were further ranked by their overall risk score. Of the 21 statements, 14 were identified as the highest priority based on their overall score. The Core Team reviewed the results and shared them with key stakeholders for final approval in December, 2015.

Process for identifying climate vulnerabilities



Findings

The following tables include the list of key climate impacts and related priority vulnerabilities that were identified through this process. Priority vulnerabilities are organized by the primary climate change driver and impact that they relate to and key sectors impacted are indicated to the right of each vulnerability statement. This final list of impacts and vulnerabilities is anticipated to serve as the foundation for Columbus' upcoming communication efforts and adaptation strategies planning that will occur throughout 2016-2017.

Key Climate Changes, Impacts, and Priority Vulnerabilities

Climate Changes ***Priority Vulnerabilities***
Climate Impacts ***Impacted Sectors***

Increasing Temperatures	**Extreme Heat/Dangerously Hot Days** Rising temperatures increase the risk of extremely hot days. By mid-century, Columbus could see an additional 3 to 7 weeks per year of high temperatures exceeding 90°F, and an additional 1 to 2 weeks exceeding 95°F.	
	Increased demand for water and energy for agricultural, cooling purposes, and hydration due to heat waves and extended growing season.	*Public Health* *Emergency Services* *Energy Providers/Utilities* *Water Providers* *Natural Resource Managers* *Agriculture*
	Increased need for cooling centers for the elderly, very young and low income community during extended heat waves and extreme heat events.	*Public Health/Local Hospitals and Medical Providers* *Nursing Homes* *Public Schools* *Parks and Rec/Community Centers*

		Homeless Shelters
	Increased heat-related illnesses and fatalities due to increase in heat waves and extended heat waves.	*Public Health/Local Hospitals and Medical Providers*
	Increased stress on vegetation, possibly resulting in increased erosion, due to extended periods of warm temperatures and more extreme heat events.	*Parks and Rec* *Public Works/ROW Construction/Maintenance* *Natural Resource Managers*
	Increased economic hardship for low income communities and small, local businesses due to longer, more intense heat waves. (possibly caused by increasing use of AC for cooling and heat keeping people indoors)	*Department of Economic Development* *Small Business Bureau* *Energy Provider/Utilities*
	Deteriorated Air Quality Air quality deteriorates with warmer temperatures, increasing the risk of serious public health consequences. A greater incidence of asthma attacks and other respiratory conditions is anticipated.	
	Increased respiratory problems from deteriorated air quality.	*Public Health/Local Hospitals and Medical Providers* *Division of Environmental Health*
	(Temporarily) Extended Growing Season/Agriculture Through mid-century, some crop types may flourish in a warmer climate. Beyond mid-century, those benefits will likely be negated by heat stress, more frequent droughts, and a greater risk from pests.	
	Increased risk to freshwater ecosystems as more local streams and water bodies are used to water crops during extended seasons.	*Division of Environmental Health* *Agriculture* *Natural Resource Managers*
	Increased risk of harmful algal blooms (HABs) due to longer use of fertilizer and more frequent intense precipitation events leading to related run-off in addition to warmer temps and longer heat waves.	*Division of Environmental Health* *Agriculture* *Natural Resource Managers* *Water Providers/Utilities*
	Shifting Natural Resources Rising temperatures will alter the habitats of fish and wildlife, forcing plants and animals to migrate or adapt. Those unable to migrate with the pace of climate change will lose their advantage over other species, reducing ecosystem diversity.	
	Loss of native biodiversity due to changing and/or migrating aquatic and terrestrial ecosystems.	*Parks and Rec* *Natural Resource Managers* *Division of Environmental Health*

Increasing Precipitation	**Greater Flood Risk** Ohio has seen large increases in heavy storms that can lead to flooding. Models project those trends will continue, increasing flood damage risks to infrastructure and public health.	
	Increased risk of damage to energy and water infrastructure due to increased frequency of flood events and changing floodplain. (roads, floodwalls, dams, electric grid, water intakes, etc.)	*Public Works/Capital Projects* *Transportation/Bridges* *Energy Provider/Utility* *Water Providers/Utilities*
	Increased incidence of health risks associated with a flood. (mold, exposure to chemicals and waterborne pathogens, vector control, drinking water and food contamination)	*Public Health/Local Hospitals and Medical Providers* *Division of Environmental Health*
	Increased transportation issues during/following a flood. (causing major disruptions to local economy, difficult for police and ambulances to respond to emergencies when areas are flooded)	*Emergency Services* *Transportation* *Public Works*

Changing Seasonal Precipitation As temperatures warm and precipitation increases, the form and timing of precipitation will likely change. The number of days dry enough to plant crops in the spring may be reduced, and the potential for rain on semi-frozen ground may increase.	
Increased infrastructure and property damage due to extreme weather. (ice, floods, strong winds, heavy/wet snow impacting power lines, roads, roofs, etc.)	*Public Works/Capital Projects* *Transportation* *Energy Providers/Utilities* *Water Providers/Utilities* *Insurance Companies* *Homeowner Groups/Associations*
Reduced Water Quality With stronger storms come flashier flows, more runoff , and greater chances of sewer overflows that can contaminate water supplies.	
Increased need for water treatment due to deteriorated water quality. (more air pollution settling in water, more runoff containing pollutants during major precipitation events, higher turbidity, more fertilizers and pesticides used for longer growing season, harmful algal blooms, etc.)	*Water Providers/Utilities* *Division of Environmental Health* *Agriculture*
Summer Water Availability Many models project summer precipitation will decline even as precipitation increases during other seasons. This raises the potential for summer droughts and seasonal water shortages, particularly for agricultural and industrial use.	
No priority vulnerabilities related to this climate impact were identified during the vulnerability assessment	

IV. NEXT STEPS

Communication of the vulnerability and risk assessment results

Beginning in 2016, the City of Columbus will undertake a public awareness campaign with OSU to educate residents and member of the business community about the greatest climate risks and build support for adaptation strategies. This campaign will provide a diverse array of stakeholders with climate knowledge and demonstrate that the city is proactively addressing these risks. Already, this project has raised awareness across the community through the number and diversity of stakeholders engaged. The involvement of city staff and community stakeholders will continue to be an important part of the planning process.

Creating an adaptation strategy

The final priority vulnerabilities, which represent the top tier of risks posed to Columbus, will guide the strategies developed in 2016 for the city's efforts. The format and authority of the plan depends on the needs, expectations, and buy-in from city staff, decision makers, and community members. Dependent on what best meets the City's needs, the plan may take the form of a stand-alone document or information from this report and future preparedness planning efforts may be woven into existing plans, policies, or strategies.

While every city's context is uniquely dependent on its geography and demographics, there are valuable examples, both within and beyond Ohio, of how incorporating climate impacts into planning benefits cities. The sections below explore climate adaptation efforts across Ohio, as well as in Baltimore and Chicago, serving as examples of ways that Columbus can utilize the information presented in this report to move forward with actions to benefit of the community.

Adaptation in Other Ohio Cities

- **Cleveland**

  Cleveland Climate Action Plan

  The Cleveland Climate Action Plan was implemented in 2013 by a Climate Action Advisory Committee comprised of people from commercial, industrial, educational, governmental, and non-profit sectors. The goal of the Climate Action Plan was to reduce greenhouse gas (GHG) emissions by 80 percent by 2050 (using 2010 as the baseline year). Adaptation goals for the Climate Action Plan include planting 75 acres of trees by 2020 and 150 acres by 2030, reducing impervious surfaces by 10 percent by 2030, and installing stormwater control measures on redevelopment projects. In addition, Cleveland has objectives to engage Cleveland neighborhoods, beginning with two sustainable EcoDistricts and the Greater University Circle.

  Sustainable Cleveland 2019

  Sustainable Cleveland 2019 is a 10-year initiative to make Cleveland a more resilient community in terms of economic, social, and environmental health. An annual Sustainability Summit is held by Mayor Jackson to generate public input and support for a particular topic each year such as energy efficiency or local foods. Each topic is supported by 2-3 organizations that provide outreach to communities and demonstrate ways of making Cleveland more sustainable. The initiative's website, www.SustainableCleveland.org, features a "Get Involved" tab that gives specific actions for individuals, offices, and communities to implement.

- **Toledo**

  Seeking strategic partnership support

  Toledo has partnered with several organizations, companies, and decision makers to generate and implement climate adaptation measures. Toledo was one of six case studies featured by the UM Climate Center's Great Lakes Adaptation Assessment for Cities (GLAA-C). GLAA-C provided Toledo with updated, locally-relevant climate data and involved staff from diverse sector backgrounds at climate-oriented conferences and workshops. GLAA-C also worked with city staff and decision makers to identify adaptation needs, opportunities for action, and relative costs of different response options.

  Focus on Stormwater

  Through its partnership efforts, Toledo has identified stormwater management as its primary climate impact of concern. To address this, the city has recently invested in green infrastructure, worked to revise their stormwater credit program, and engaged the private sector.

  - **INVESTING IN GREEN INFRASTRUCTURE**: The EPA invested $500,000 in Toledo in 2014 for the construction of green infrastructure. The goal of this project was to reduce the volume of untreated stormwater entering Lake Erie after large precipitation events.
  - **REVISING STORMWATER CREDIT PROGRAM:** Toledo implemented a stormwater credit program in 2001 to combat runoff generated by impervious surfaces on non-residential properties. In fall 2013, University of Michigan graduate students worked with the City of Toledo to update the stormwater credit system. Following City Council approval, Toledo's Public Utilities Department released the updated stormwater credit program in April 2015.

- **ENGAGING THE PRIVATE SECTOR**: The City of Toledo has recently focused on a concerning area in the north side of the city that frequently experiences standing water after small and large interval storms, leading to property damage within and adjacent to the floodplain. Public utilities staff worked with three major businesses to encourage creation of green infrastructure on their properties and lessen the burden on stormwater infrastructure in highly vulnerable areas. All three properties have completed assessments to determine green infrastructure opportunities that are best suited to their needs and finances. Several easy fixes were identified, such as converting unused parking lots into permeable surfaces, while other strategies are more expensive and require further analysis.

- **Dayton**

Strategic partnerships

Dayton partnered with University of Michigan, regional partners, and local universities to increase research, funding, education, and public support for climate adaptation plans. Also a case study city for the UM Climate Center's Great Lakes Adaptation Assessment for Cities (GLAA-C), Dayton worked with the GLAA-C team to identify strategies to combat the City's increasingly frequent wind storms, heat events, and ice storms. As a part of this work, UM graduate students produced a report about climate adaption in Dayton. This report outlines best practices and recommendations for the City's adaptation efforts. Sustainability projects in Dayton include a geothermal energy project, an urban forestry program, and a well-field protection (aquifer protection) program.

The UM Climate Center helped the City of Dayton hold their first Climate Change Adaptation and Resiliency Workshop in 2013. The workshop involved city staff, elected officials, and key community stakeholders who discussed steps that the City could take to create a more economically vibrant and resilient community.

Climate Change Survey

In collaboration with Wright State University (WSU) , the City of Dayton conducted a survey to assess community beliefs, attitudes, knowledge, and behaviors as they relate to climate change to inform future awareness efforts. The city collected responses from 516 participants and summarized the findings in a technical report. The survey team consisted of city staff, the Miami Conservancy District (MCD), The Miami Valley Regional Planning Commission (MVRPC), and WSU. The survey findings will be used to develop a persuasive messaging campaign designed to increase community engagement and behaviors that provide personal and regional resilience to climate change.

Survey results:
69% Believe climate change is important
71% Believe people can reduce climate change
77% Believe climate affects human health

- **Cincinnati**

Green Cincinnati Plan

The Green Cincinnati Plan was adopted in 2008 and gave 80 recommendations including reducing GHG emissions by 2 percent per year, ultimately reaching a reduction in GHG emissions by 84 percent by 2050 (42 years). In 2013, the Plan met its goal of reducing GHG emissions by 10 percent over 5 years.
The Plan also made recommendations for adaptation strategies to deal with prolonged heat, changes in growing zones, the urban heat island effect, and extreme weather impacts on infrastructure.

Tax Abatement for LEED standards

Property tax abatement exists in Cincinnati for new or renovated residential, commercial, and industrial properties that meet the U.S. Green Building Council LEED (Leadership in Energy and Environmental Design) standards for sustainable buildings. Credits are given towards LEED certification for buildings with certain adaptations such as green infrastructure, water efficiency, and use of sustainable materials. LEED-certified buildings are eligible for full property tax abatement in the City for 15 years on new construction and 10-12 years on renovated property.

City-Wide Adaptation Strategies in Baltimore and Chicago

- **Baltimore, MD: Disaster Preparedness and Planning Project**

FEMA requires all local jurisdictions to adopt an All Hazards Mitigation Plan, updated every 5 years, to be eligible for disaster-related assistance funds. In 2013, Baltimore used this requirement as an opportunity to integrate climate change adaptation planning into its traditional hazard mitigation planning. The result was the innovative Disaster Preparedness and Planning Project (DP3), a joint effort through Baltimore's Department of Planning and Office of Sustainability. Through the DP3, Baltimore integrated hazard mitigation planning, floodplain mapping, and climate adaptation planning into a comprehensive risk preparedness system for addressing both existing and future impacts.

The DP3 process included 6 main steps: hazard identification, inventory assessment, modeling for identification of risk, vulnerability analysis of assets, identification of mitigation and adaptation actions, and creation of implementation plans. Incorporating climate adaptation-related hazards early in the process enabled planners to incorporate more health-related risks than would otherwise have been included. Baltimore is one of the first and largest cities in the United States to propose this framework for forward-thinking hazard mitigation planning, which has since been approved by FEMA

In creating the DP3, Baltimore sought to implement a collaborative process that went beyond FEMA's public outreach requirements. To gather data and draft recommendations for the DP3 in 2013, the Department of Planning assembled a 47 member Advisory Committee made up of city agency directors, community and business leaders, climate scientists, and representatives from state and federal agencies, academic institutions, and utilities. Rather than focusing on risk type, stakeholders in the committee were divided into subcommittees focused on infrastructure, buildings, natural systems, and public services. This helped to further target the committee's recommendations to sector-specific and actionable strategies. The city also held two town hall meetings and seven small community meetings, as well as presented to special interest groups throughout the community on the importance of understanding climate vulnerabilities and adaptation. These public engagement efforts helped the city better identify vulnerable communities and incorporate citizen feedback.

The final DP3 report is found on Baltimore's Office of Sustainability website at baltimoresustainability.org/disaster-preparedness-and-planning-project. Baltimore also created a blog for the DP3 and the city's other climate change planning efforts at baltimorehazards.wordpress.com. The site includes extensive preparedness and adaptation strategies for the public in an accessible format and also publishes news updates.

The final DP3 includes 50 strategies and 231 actions, each with specific lead actors and timeframes identified. The subgroups established in the committee process serve as the primary drivers for carrying out these actions. One key benefit of the DP3 is that it ensures adaptation strategies are incorporated into Baltimore's Capital Improvement Planning process: when departments apply for this funding they must explain how their project takes climate change resiliency into account. Baltimore has also used the DP3's

recommendations to adopt a new floodplain code, make and distribute over 1,200 emergency planning kits that increase community awareness, and create a training program for developers, contractors, and architects to understand how climate change will impact built and natural environments and strategies to prepare for and adapt to these impacts.

- **Chicago, IL: Chicago Climate Action Plan**

  A key climate change hazard Chicago faces is increased heat risk, through both rising temperatures in general and more frequent and intense heat waves, This in turn will deteriorate air quality and increase heat-related illness, while also putting increased stress on power plants to meet increased demand for cooling needs. Due to shifts in the plant hardiness zones in Chicago, the city faces declining health of its urban forests and their ability to mitigate urban heat island effects. Increased intensity and frequency of rain and snowstorms in winter and spring also present a significant risk to city infrastructure (Melillo et al, 2014).

  In response to these concerns, former Chicago Mayor Daley announced the Chicago Climate Action Plan (CCAP) in 2008. The CCAP includes 5 overarching strategies for addressing climate change in Chicago: energy efficient buildings, clean and renewable energy sources, improved transportation options, reduced waste and industrial pollution, and adaptation. While the CCAP focuses most heavily on climate change mitigation strategies, Chicago was unique in being the first United States city whose plan addressed both mitigation and adaptation in its planning efforts. The CCAP includes 35 actions related to mitigation and adaptation, with a goal of 25% reductions from 1990 levels by 2020.

  The CCAP creation process was divided into 3 phases: research, planning, and implementation. City officials initially reached out to the Chicago-based nonprofit Global Philanthropy Partnership (GPP) with their idea for the CCAP, which helped city officials gain better access to the expertise of Chicago's nonprofit and community stakeholder networks. The Mayor's Office and Department of the Environment created and led the Chicago Climate Task Force. The task force was a group of 19 leaders from business, civic, environmental, foundational, and nonprofit organizations throughout the city whose expertise provided input for initial mitigation and adaptation actions. The Task Force, Department of Environment, and GPP also coordinated large forums for invited community members to learn about climate change and provide their own suggestions for the CCAP. Finally, the Department of Environment created sector-specific groups, comprised of city staff and stakeholders, to provide feedback on the plan's implementation challenges.

  The CCAP is available online at chicagoclimateaction.org. Chicago continually reviews progress on the CCAP's recommendations and publishes progress updates every 2 years, with the first update published on the CCAP's website in 2010. As of 2010, Chicago had developed 456 city initiatives in 16 city departments based on the CCAP's recommendations.

  Chicago created a Green Ribbon Committee of national and local leaders to monitor and guide implementation of the plan, and especially to provide focus for parts of the CCAP that are progressing more slowly. In the year succeeding CCAP's publication, Chicago focused on creating implementation plans for each section in the adaptation plan, to provide roadmaps for each city agency to prioritize their work. One result of the CCAP is an update to the Chicago building code, the IECC 2006 energy code, that also includes a reflective roofing component to address the urban heat island effect. Chicago has also created a new green stormwater infrastructure strategy to address the recommendations in the CCAP.

Finally, Chicago created the Adaptation Advisory Group to provide high-level aid and guidance to the city's adaptation efforts, specifically implementation, monitoring, and communications. Chicago continues to foster public engagement in its climate change adaptation planning efforts. One example is through the online Chicago Community Action Climate Toolkit. Created by the Field Museum in partnership with four Chicago neighborhoods, the toolkit offers guidance and resources for community groups to develop and implement local climate action projects. The Chicago Conservation Corps, a 20-hour training program for Chicago residents, empowers community leaders to enact environmental change and has already trained over 250 individuals. In 2009, 40 building managers and 150 companies participated in the Green Office Challenge, which offers strategies for office tenants and property owners to reduce waste and energy usage.

V: CONCLUSION

This well-researched and prioritized list of key vulnerabilities to the City of Columbus should inform city staff, decision makers, and stakeholders as they craft effective climate change communication initiatives and develop strategies to increase community resilience. The cross-cutting nature of the impacts will require collaborative approaches on scales that range from neighborhoods to the region. While the ultimate goal is long-term resiliency in the face of a changing climate, a combination of near-term actionable projects and long-term policy and regulatory solutions will be essential.

Acknowledgements

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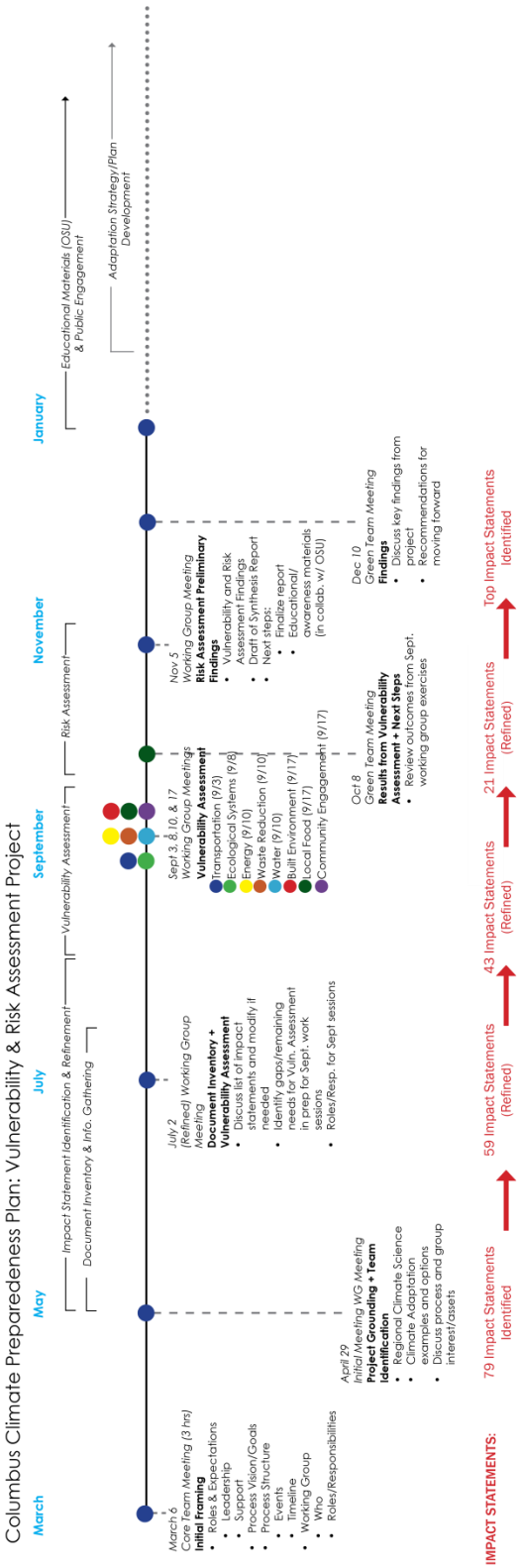
APPENDIX

APPENDIX A: Historical Climatology

APPENDIX B: Projected Impacts

APPENDIX C: Project Timeline



APPENDIX D: All Identified Vulnerability Statements

	Vulnerability Statement	Refinement Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	Vulnerability Score	Risk Score
Extreme Heat				
1	Increase in heat-related illnesses (heat-stroke, heat stress and heat exhaustion; and for older adults, fluid and electrolyte disorders, renal failure, urinary tract infection and septicemia) due to increase in heat waves	Increase in heat-related illnesses and fatalities (vector-borne illnesses, heat-stroke, heat stress and heat exhaustion; and for older adults, fluid and electrolyte disorders, renal failure, urinary tract infection and septicemia) due to increase in heat waves	4	54.8
2	Increase in vector-borne disease to people and animals due to increased habitat of disease-carrying insects and ticks. (Merged with #1 moving forward)			
3	Increase in mortality rates during summer season heatwaves, especially for the elderly	X	X	X
4	Increase in brown-outs and energy services interruptions due to increases in energy demand during extreme hot/cold weather events	Increase risk on existing infrastructure such as transportation and utilities	3.3	X
5	Higher incidence of crime due to longer, more intense heat waves	Higher incidence of crime due to longer, more intense heat waves	2.75	X
6	More variability in seasonal supply of natural gas as winters warm (currently, natural gas supply geared towards big winter peaks)	More variability in seasonal supply of natural gas as winters warm (currently, natural gas supply geared towards big winter peaks)	1.75	X
7	Increasing economic hardship for low income communities and businesses due to increased use of AC for cooling during major heat events or heat for extreme cold events	Increasing economic hardship for low income communities and businesses due to increased use of AC for cooling during major heat events or heat for extreme cold events	4.5	51.2
8	Decline in local, small-business economy during major heat waves that keep people indoors	Decline in local, small-business economy during major heat waves that keep people indoors	X	X
9	Heat stressed livestock, fish, and wildlife populations during major heat events and/or extended periods of warm days (decreased food supply, warmer water temps, etc)	Heat stressed livestock, fish, and wildlife populations during major heat events and/or extended periods of warm days (decreased food supply, warmer water temps, etc)	2.5	X
10	Increased water demand for cooling purposes and hydration	Increased water demand for agricultural, cooling purposes and hydration	4.33	74
11	Increase in unplanned water withdrawal, such as opening of fire hydrants, for cooling purposes			
12	Increase in water use for agricultural purposes			
13	Increased stress on vegetation, which may lead to more erosion issues, during extended periods of warm temperatures	Increased stress on vegetation, which may lead to more erosion issues, during extended periods of warm temperatures	4	53.6
14	Decline in worker productivity, especially in outdoor jobs, during major or extend	Decreased worker productivity, especially in outdoor jobs, during major or extended heat events and/or during air quality alert days.	2.75	X
15	Increase in fire risk as vegetation dries out which may be made worse by the large amount of crude oil that passes through the region	Increase in fire risk as vegetation dries out	3.25	X

16	Increased burden on homeowners to water street trees may make city-wide tree canopy harder to manage and expand.	X	X	X
17	Increased food insecurity as prices rise due to crop shortages related to more extreme heat days and related drought	Increased food insecurity as prices rise due to crop shortages related to more extreme heat days and related drought	3.75	31
18		Increased food storage burdens and accessibility (affecting pricing and availability) (Added in July)	3	X
19		Increased demand on health care facilities (staffing and locations).	3.25	X
20		Increased need for cooling centers for the elderly, very young and low income community during extended heat waves and extreme heat events.	3.67	57.2

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Deteriorated Air Quality				
21	Increase in respiratory problems from deteriorated air quality	Increased respiratory problems from deteriorated air quality (breathing in dirty air and decrease in physical activity as more people (esp. young and elderly) unable to go outside due to increased respiratory risks and extreme heat	4	57.47
22	Increase in cost of health insurance as more people have health issues			
23	Decrease in physical activity as more people (esp. young and elderly) unable to go outside due to increased respiratory risks, allergies from longer growing seasons and extreme heat			
24	Increased water treatment needed as air pollution settles in water sources and increases acidity	Increased water treatment needed as air pollution settles in water sources	X	X
25	Potential loss of federal funding from falling out of compliance with air quality standards	Increased regulatory and economic burden to comply with air quality standards.	3.5	35.8
26	Increase in difficulty for industry to receive air permits if the region is out of air quality attainment standards			

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Longer Growing Season				
27	Changing seasonality of energy use and energy source	Increased demand of resources (ie. energy, water) related to lengthened seasonal activities (ie. agriculture/lawn care)	X	X
28	Changing seasonality of water demand due to shorter winters and longer growing seasons			
29	Increased opportunity for carbon sequestration with longer growing season	Increased opportunity for carbon sequestration	X	X
30	Increased risk of harmful algal blooms (HABs) with increased use of fertilizer and plantings	Increased risk of harmful algal blooms (HABs) due to longer use of fertilizer and more frequent intense precipitation events leading to related run-off in addition to warmer temps and longer heat waves.	4.5	62.13

31	Decline in water delivery to streams/local water bodies as more being used for crops, etc.	Increased risk to freshwater ecosystems as more local streams and water bodies are used to water crops during extended seasons.	4	68.67
32	Increase in landscaping and maintenance costs as the need for mowing and pest control increases	Increase in landscaping and maintenance costs	2	X
33	Opportunity for second harvest with longer growing seasons	Opportunity for second harvest with longer growing seasons	X	X
34	Opportunity for increased crop diversity	Opportunity for increased crop diversity	X	X
35	Longer season for building, construction and outdoor work	Longer season for building, construction and outdoor work	X	X
36		Increased seasonal allergy issues with longer pollen season and as more carbon dioxide fuels greater pollen production from plants such as ragweed	3.25	X

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Shifting/Migrating Natural Resources				
35	Changing fish populations due to changing stream temperatures.	Loss of native biodiversity due to changing aquatic and terrestrial ecosystems	4	60.83
36	Increased ecosystem vulnerability to invasive species due to changing temperatures.	Increased ecosystem vulnerability to invasive species due to changing temperatures.	4.5	49.33
37	Increased incidence of pests and diseases due to vector migration.	Increased incidence of pests and diseases due to vector migration.	3.56	41
38	Changes in land use demands and management due to shifting natural resources.	Changes in land use	X	X
39	Loss of native trees and reduction of canopy.	X	X	X
40	Decline in birding recreational options and tourism as bird migrations shift, following food sources shift.	Decreased recreational options and tourism impacting quality of life and the business sector that supports outdoor activities. (forest composition changing, bird population migrating, etc.)	2.75	X
41	Change in forest and plant species composition	X	X	X
42	Increase in presence of zebra mussels in water infrastructure disrupting water systems and requiring more frequent maintenance	Increase in presence of invasive species in water infrastructure disrupting water systems and requiring more frequent maintenance	3.42	X
43		Increased human population due to migration related to climate change impacts.	X	X

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Greater Flood Risk				
44	Increased damage to dam infrastructure due to flash floods.	Increased risk of damage to energy and water infrastructure due to increased frequency of flood events and changing floodplain. (roads, floodwalls, dams, electric grid, water intakes, etc.)	4.25	82
45	Increased damage to bridges and other infrastructure due to scouring from flooding.			
46	Increased damage to underground infrastructure and corrosion of underground power grid due to			

	increased flooding			
47	Increased maintenance costs for water intake due to greater flood risk			
48	Increased cost of water treatment due to increased runoff and thus higher turbidity.	Increased cost of water and wastewater treatment due to increased volume of runoff containing pollutants (ie. higher turbidity, phosphates, nitrates, endocrine disruptors, sediments) (MOVED TO WATER QUALITY)	X	X
49	Increased incidence of CSO events.	Increased incidence of Combined Sewer Overflows (CSOs) events due to greater flood risk.	3.33	X
50	Increased incidence of SSO events	Increased incidence of Sanitary Sewer Overflows (SSOs) events due to greater flood risk.	3.33	X
51	Increased pollution and sedimentation in streams and reservoirs due to increased erosion.	Decreased storage volume of reservoirs due to flood-related erosion and sedimentation.	2.92	X
52	Increased pollution in streams and water bodies due to more runoff	X	X	X
53	Increased construction runoff due to major precipitation events.	X	X	X
54	Increased flooding in basements of homes and businesses.	Increased damage to infrastructure and structures in the new floodplain due to changing floodplains. (COVERED IN OTHER INFRASTRUCTURE DAMAGE IMPACT STATEMENT)	X	X
55	Increased damage to infrastructure and structures in the floodplain due to changing floodplains.			
56	Increased flooding of roads causing damage to infrastructure and vehicles.	Increased risk for population displacement, mortality, and costs associated to property owners due to flood events.	3.83	42.6
57	Increased flood damage to vacant properties, requiring additional inspection and clean-up cost.			
58	Increase in extended power outages during major storm events (trees falling on power lines, etc)	X	X	X
59	Increase in insurance premiums due to greater flood risk (to both homeowners and business owners)	Increase in insurance premiums due to greater flood risk (to both homeowners and business owners)	3.42	X
60	Increased cost to move operations as a result of potential flood issues	X	X	X
61	Increased consumer and food traffic during/following a flood	Increased demand/consumer traffic for food and other goods during/following a flood. (Residents wanting to stock up on food and water and other basic needs)	2.88	X
62	Increased transportation issues during a flood.	Increased transportation issues during/following a flood. (causing major disruptions to local economy, difficult for police and ambulances to respond to emergencies when areas are flooded)	3.5	76
63	Increased incidence of mold following a flood.	Increased incidence of health risks associated with a flood (mold, exposure to chemicals and waterborne pathogens, vector control, drinking water and food contamination)	3.5	76.83

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Changing Season Precipitation				
64	Increased property damage due to extreme winter weather (ice, strong winds, and heavy/wet snow)	Increased infrastructure and property damage due to extreme weather (ice, strong winds, heavy/wet snow, strong/more frequent tornadoes)	4	83.5

65	Increased damage to the power grid leading to brown or blackouts due to freezing rain, wet snow, extreme thunderstorms.			
66	Changes to crops or drainage strategies due to cold, wet springs.	Decrease in drainage capacity of soils due to changing seasonality and type of precipitation (cold, wet springs)	2.5	X
67	Decrease in winter plant crops due to poor drainage during wetter winters			
68	Increased difficulty in planning planting/crop schedules due to uncertainty of seasonal change.	Increased difficulty in planning planting/crop schedules due to uncertainty of seasonal change.	2.5	X
69	Increased need for broader awareness and education among farmers as uncertainty in water availability increases, especially during summer months.	X	X	X
70	More school days cancelled due to disruptive cold temperatures	More school days cancelled due to extreme weather	2	X
71		Decrease in local economic activity due to ice and heavy/wet snow making it difficult for workers to get to work and for consumers to travel local business	2.67	X
72		Increased difficulty in planning for proper salt allocation due to uncertainty of seasonal change.	2.67	X

	Vulnerability Statement	**Refinement** Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Vulnerability Score**	**Risk Score**
Deteriorated Water Quality				
73	Increased risk of toxic algal blooms, especially in reservoirs, due to decreasing water quality.	Increased need for water treatment due to deteriorated water quality (more air pollution settling in water, more runoff containing pollutants during major precipitation events, higher turbidity, more fertilizers and pesticides used for longer growing season, harmful algal blooms, etc)	4.17	88
74	Increased cost of water treatment			
75	Decrease in water-based recreation, such as fishing, due to decreased water quality	Decrease in water-based recreation, such as fishing and swimming.	3.83	45.33
76	Increased risk of waterborne disease due to decreased water quality.	Increased risk of waterborne disease	X	X
77	Reduced access to drinking water for businesses, especially restaurants, due to decreasing water quality	Reduced Access to potable water	X	X
78	Increase in water quality issues in upground reservoirs constructed for additional water supply when water is pumped to fill them during high flows.	Increase in water quality issues in upground reservoirs constructed for additional water supply when water is pumped to fill them during high flows.	X	X
79	Increased difficulty for industry to receive water pollution discharge permits if TMDL levels are already exceeded.	Increased regulatory and economic burden to comply with water quality standards	X	X

	Vulnerability Statement	**Refinement**	**Vulnerability**	**Risk**

		Based on Document Inventory and Research; Meetings with Key Stakeholders (MORPC and Franklin County Office of Emergency Management); grey boxes indicate that the impact statement did not move to the next round	**Score**	**Score**
Summer Water Availability				
80	More water storage needed due to increased risk of drought coupled with increased water usage	Increased risk of drought due to low precipitation coupling with increased water usage	X	X
81	Potential need to prioritize water use between human and natural system during the summer/extended times of low water availability			
82	Power plant operations impacted by increased temperatures and low water availability	Increased risk to power plant operations impacted by increased temperatures and low water availability.	3	48.7
83	Higher turbidity in streams and water bodies due to decreased water flows and greater variability in precipitation	Higher turbidity in streams and water bodies due to decreased water flows and greater variability in precipitation	X	X
84	More periods below mandated or healthy minimum flows for water withdrawal due to greater variability in flows	More periods below mandated or healthy minimum flows for water withdrawal due to greater variability in flows	3.25	X

APPENDIX D: Existing Resource Inventory

Sector	Resource	Link/Location
Community Public Safety	2014 IAB Annual Report (Police Report)	http://www.columbuspolice.org/FormsPublications/2015/2014%20IAB%20Annual%20Report.pdf
Comprehensive	Franklin County Natural Hazard Mitigation Plan	http://fcemhs.com/Portals/0/Planning/Documents/Franklin_Plan_FINAL%202012.pdf
Comprehensive	FEMA Hazus	https://www.fema.gov/hazus
Emergency Services Public Health	Franklin County Extreme Heat Plan	http://fcemhs.com/portals/0/news/documents/2010/FC_Extreme_Heat_Plan_FINAL_08102010.pdf
Infrastructure/Water	Franklin County Floodplain Management	http://development.franklincountyohio.gov/planning/floodplain/index.cfm
Community	The Ohio Poverty Report	
Economic Infrastructure	NOAA 2012 Derecho Report	http://www.development.ohio.gov/files/research/P7005.pdf
Natural Systems Infrastructure/Water	EPA National Lakes Assessment	http://water.epa.gov/type/lakes/lakessurvey_index.cfm
Comprehensive	Sustaining Sciota_Adaptation Strategies	PDF in Drive
Infrastructure/Water Natural Systems	Greenways and Water Quality, Sustaining Scioto	http://www.morpc.org/Sustainability/greenways-water-quality/sustaining-scioto/index
Infrastructure/Water	Hydrologic Effects of Potential Changes in Climate, Water Use, and Land Cover in the Upper Scioto River Basin, Ohio	http://dx.doi.org/10.3133/sir20155024
Natural Systems	Audubon Christmas Bird Count	http://netapp.audubon.org/CBCObservation/
Natural Systems	Audubon Ohio	http://oh.audubon.org/index.html
Natural Systems	iTree Reports	https://www.itreetools.org/resources/reports.php
Natural Systems	Why Trees Matter	http://treesmatter.osu.edu/resources.html
Natural Systems	Columbus Urban Forestry	https://columbus.gov/recreationandparks/Urban-Forestry/
Natural Systems	Urban Tree Canopy Assessment	http://www.nrs.fs.fed.us/urban/utc/
Community Natural Systems	The Role of Public Gardens in Sustainable Community Development	http://www.publicgardens.org/files/files/Sustainable_Communities_11_26_2012_final.pdf http://www.publicgardens.org/
Economic	Clean Energy Opportunities for Ohio's Small Businesses	PDF in Drive
Economic	Small Business Clean Energy Poll Report 112513	PDF in Drive
Economic	Small Business Energy Poll Report Ohio 060712	PDF in Drive
Economic Public Health	Temperature, Physiology, and the Wealth of Nations	PDF in Drive; https://wpcarey.asu.edu/sites/default/files/uploads/department-economics/heal-paper.pdf
Economic Public Health	OSHA Heat Stress - information and guidelines for worker safety	https://www.osha.gov/SLTC/heatstress/
Infrastructure	2013 Public Utilities Annual Report	PDF in Drive; http://columbus.gov/Templates/Detail.aspx?id=65640
Infrastructure/Energy	AEP Response to the Carbon Disclosure Project	https://www.aepsustainability.com/fastfacts/CarbonDisclosureProject.aspx
Infrastructure/Energy	AEP 2013 Carbon Disclosure Project	PDF in Drive; https://www.aepsustainability.com/fastfacts/docs/AEP_2013-CDP-Response.pdf
Infrastructure/Energy	Natural Gas Data, U.S. Energy Information (Consumption and Price info for Ohio)	http://www.eia.gov/naturalgas/data.cfm
Infrastructure/Transportation	Federal Highway Administration Hydraulic Engineering	http://www.fhwa.dot.gov/engineering/hydraulics/scourtech/
Infrastructure	US EPA	http://www.epa.gov/groundlevelozone/actions.html / http://www.puco.ohio.gov/puco/index.cfm/media-room/media-releases/puco-files-comments-with-ferc-regarding-winter-weather-operations/#sthash.yUO57sS5.dpbs

Infrastructure/Energy	PUCO	http://elibrary.ferc.gov/idmws/file_list.asp?document_id=14216416
Infrastructure/Energy	PUCO	http://www.puco.ohio.gov/puco/index.cfm/media-room/2014-end-of-year-review/#sthash.57lomGsz.dpbs
Infrastructure/Water	Project Dry Basement	http://columbus.gov/Templates/Detail.aspx?id=37989
Infrastructure/Water	OARS Deep Sewer Tunnel	https://columbus.gov/Templates/Detail.aspx?id=38013
Infrastructure/Water	USEPA Federal Regulatory Programs	http://water.epa.gov/infrastructure/greeninfrastructure/gi_regulatory.cfm
Infrastructure/Water	Sewer Overflow Discharge Information	http://eapp.columbus.gov/ssocso/
Infrastructure/Water	Blueprint Columbus	http://www.columbus.gov/Templates/Detail.aspx?id=62706 http://www.epa.state.oh.us/dsw/cso/columbus_ltcp.aspx
Infrastructure/Water	OH EPA Harmful Algal Blooms	http://epa.ohio.gov/ddagw/HAB.aspx
Infrastructure/Water	Wet Weather Managment Plan	http://www.columbus.gov/uploadedFiles/Public_Utilities/Projects/WWMPbro10-07.pdf http://www.columbus.gov/uploadedFiles/Public_Utilities/Document_Library/Publications/Sewer/WetWaterManagementPlanFactSheet.pdf http://www.epa.state.oh.us/dsw/cso/columbus_ltcp.aspx
Public Health	Cause-Specific Risk of Hospital Admission Related to Extreme Heat in Older Adults	PDF in Drive; http://jama.jamanetwork.com/article.aspx?articleid=2084889
Public Health	West Nile Maps and Data (CDC)	http://www.cdc.gov/westnile/statsmaps/index.html
Public Health	2013 Vector Control Report for City of Columbus	PDF in Drive; https://columbus.gov/WorkArea/DownloadAsset.aspx?id=71992
Public Health	Operation Cool Down - Press Release from Mayor Coleman	https://columbus.gov/Templates/Detail.aspx?id=52472

APPENDIX E: Consequence Ranking Descriptions

Consequence Rating	Public Health & Safety	Local Economy & Growth	Community & Lifestyle	Environment & Sustainability	Public Administration
5 Catastrophic	Large numbers of serious injuries or loss of lives	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective
4 Major	Isolated instances of serious injuries or loss of life	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen to be in danger of failing completely
3 Moderate	Small number of injuries	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts
2 Minor	Serious near misses or minor injuries	Individually significant but isolated areas of reduction in economic performances relative to current forecasts	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure
1 Negligible	Appearance of a threat but no actual harm	Minor shortfall relative to current forecasts	There would be minor areas in which the region was unable to maintain its current services	No environmental damage	There would be minor instances of public administration being under more than usual stress but it could be managed

Consequence Rankings from ICLEI's "Municipal Climate Adaptation Guide and Workbook"