OHIO

Ohio, like its neighboring states in the Great Lakes region, already is experiencing increases in temperature and precipitation. Further temperature increases, changes in the seasonality of precipitation, and more extreme precipitation events from climate change are likely. One of the state's most valuable water resources, Lake Erie, will not be immune to the impacts of climate change. Between 2010 and 2050, the state could lose up to $27 billion in GDP and 167,000 jobs from reduced water availability due to climate change and subsequent impacts on economic sectors, employment, personal income, and interstate migration.[1] Despite these grave risks, the state has yet to develop strategies to reduce statewide greenhouse gas pollution or to adapt to potential climate change impacts. **Ohio should seek to assess the state's vulnerability to climate change and implement measures to reduce statewide greenhouse gas pollution and to prepare for inevitable climate impacts.**

Water Resources Background

Ohio is affected by air masses from both Canada and the tropics. This results in a wide range of climates in the state, with cold, dry winters and hot, humid summers. In addition, northern parts of the state experience lake-effect weather from Lake Erie, particularly during the winter. Annual average precipitation ranges from 32 to 42 inches across the state, with greater amounts in the southern portion of the state, which is more strongly influenced by the climate of the Gulf of Mexico.[2] The extreme northeastern counties, whose climate is influenced by Lake Erie, remain an exception to this geographic distribution and receive on average 40 to 42 inches annually.[3] The driest months are typically October and January/February, and the wettest months are April through July.[4] Precipitation between October and March generally results from mid-latitude low-pressure systems; during the remainder of the year, rainfall is associated with thunderstorms.[5] Snowfall varies across the state, with as little as 16 inches a year in the south to more than 90 inches a year in the northeast, which is dominated by lake-effect snow from Lake Erie.[6]

The state's water resources are dominated by Lake Erie to the north and the Ohio River to the south. The state's eight coastal counties have 312 miles of coastline along Lake Erie, which is the most biologically productive of all the Great Lakes.[7] The lake supplies drinking water for three million people in the state.[8] It is also an important part of Ohio's economy, with tourism bringing in almost $11 billion per year, commercial fisheries valued at $800 million annually, and lakefront ports handling important commodities like steel, iron ore, and coal.[9] In between the two dominant water sources, the state has 29,000 miles of perennial streams and rivers and almost 120,000 acres of publicly owned lakes.[10] Ohio's 10 major watersheds drain into either Lake Erie or the Ohio River.[11] In addition, Ohio has three major types of aquifers: sand and gravel, sandstone, and carbonate.[12] Sandstone aquifers are generally found in the eastern half of the state and carbonate aquifers in the western half, while sand and gravel aquifers are found throughout the state.[13]

In Ohio, electrical generation and public supply are the dominant water withdrawers.[14] In 2009 total withdrawals were approximately 3.5 billion gallons (approximately 10.6 million acre-feet).[15] Thermoelectric power plant withdrawals made up approximately 79 percent of this total, and public supply accounted for approximately 14 percent.[16] Agriculture and irrigation are not as predominant water users in Ohio as they are in other midwestern states, representing only 0.5 percent of total withdrawals.[17] Additionally, groundwater usage makes up only approximately 9 percent of total withdrawals in the state, although it is an important source of drinking water for 5.7 million Ohioans.[18] The remainder is withdrawn from surface water resources.[19]

The Great Lakes Compact

The Great Lakes contain six quadrillion gallons of water (about 18.4 billion acre-feet), more than one-fifth of the world's surface supply of freshwater and more than 95 percent of the surface freshwater supply in the U.S.[20] Although the volume of the Great Lakes is vast, less than 1 percent of its waters are renewed annually through

precipitation, runoff, and infiltration.[21] The Great Lakes Basin ranks third in terms of total freshwater use out of the 21 major watersheds in the U.S.[22] Lake levels are expected to decline over the next century in each of the Great Lakes, from 1 foot on Lake Superior to as much as 3 feet on Lakes Michigan and Huron.[23] Management and use of water in the eight Great Lakes states is governed by the Great Lakes-St. Lawrence River Basin Water Resources Agreement and Compact.[24] In ratifying the Compact, each state agreed to undertake a series of actions, including the establishment of thresholds governing new or increased withdrawals of water; implementation of a permitting process for new withdrawals; development of water conservation and efficiency programs, including the establishment of state-specific goals and objectives to guide individual states' programs; and improved data gathering and sharing across the basin. In addition, the Compact directs states to "[g]ive substantial consideration to climate change or other significant threats to Basin Waters and take into account the current state of scientific knowledge, or uncertainty,"[25] and to take appropriate measures, such as adaptive management, to address these threats.

Climate Change Impacts on Water Resources

The climate of Ohio has changed measurably over the past several decades. In the past century, annual average temperature in the state has increased by 0.8°F, with most of this warming occurring during the winter and spring seasons.[26] As the result of these warmer temperatures, the melting of ice and snow is occurring earlier in the spring.[27] Under high-emissions scenarios, summer temperatures are projected to rise 2°F to 4°F by 2040 and 5°F to 12°F by the end of this century.[28] Average annual precipitation has also increased in Ohio at a rate of 2.7 inches over the past century.[29] In addition, heavy rainfalls are already twice as frequent in the Midwest as they were a century ago.[30] Cincinnati could experience an increase of 30 percent in the frequency of these events over the next few decades, and a doubling of these events by the end of the century under a high-emissions scenario.[31] Additionally, winters and springs in Ohio are projected to become wetter, with models showing 30 percent more precipitation during these seasons by the end of the century.[32] These changes could increase flooding risks to communities and agricultural areas in floodplains.[33] In contrast, summers are projected to receive 5 percent less rain and are likely to be drier because of higher temperatures.[34] This decrease in rainfall is expected to lead to decreases in soil moisture, indicating that drought could be more common in Ohio's future.[35] River, stream, and lake levels are expected to drop during summer months because of anticipated warming, further contributing to drought conditions.[36] Overall, short-term droughts are projected to increase in frequency while long-term droughts, those lasting several years, are expected to decline.[37]

Climate change is also likely to present challenges to water quality. A projected increase in heavy rainfalls could lead to increased overflows from wastewater treatment systems and the release of untreated sewage into receiving water bodies, which could increase public health risks for waterborne diseases.[38,39] Cincinnati typically experiences overflows of approximately 14 billion gallons a year, and this figure is likely to increase in the future as severe rain events occur more frequently.[40] In addition, runoff from urban and agricultural areas transports pollutants into neighboring waterbodies. This is also likely to increase in the future with increased precipitation and more heavy-rainfall events.[41] These changes in water quality, in addition to warmer water temperatures, are likely to have an impact on aquatic species. Warmer water temperatures could prolong the stratification of some lakes and lead to oxygen-poor conditions in the bottom layers.[42] Warmer water temperatures and increases in nutrient runoff also may lead to increases in harmful algal blooms, which can cause human illness and contaminate seafood.[43] Furthermore, populations of coldwater fish, such as brook trout and lake trout, are likely to decline as suitable habitats disappear while warmwater species, such as smallmouth bass, expand.[44]

The impacts of climate change on agriculture, a $7 billion annual industry in Ohio, could be particularly profound. One in every seven people in Ohio is employed in the agricultural sector, and more than half the state is designated prime farmland.[45] Although the growing season is expected to lengthen by three to seven weeks, depending on the emissions scenario, the longer growing season will be accompanied by higher temperatures, decreased soil moisture, and increased extreme weather events.[46] These changes will result in heat stress for crops and an increase in the

quantity of irrigation water needed.[47] This could present numerous challenges, as less than 1 percent of crops in Ohio are currently irrigated.[48] Therefore, irrigation infrastructure will likely need to be expanded.

Lake Erie also will be impacted by climate change. Toward the end of the century, water levels in Lake Erie are projected to decline, from less than 1 foot under a low-emissions scenario to almost 1.5 feet under a high-emissions scenario, as a result of greater evaporation during the summer and reduced ice cover in the winter.[49] Lower water levels would impair commercial shipping in the Great Lakes, with an estimated load reduction of 99 to 127 tons for a cargo ship for every 1-inch decline in lake level.[50] Lower lake levels could also affect tourism and recreation by limiting access to docks, boat ramps, and ferry landings.[51] In addition, reduced winter ice cover would increase coastal shoreline erosion risks from wave action, especially during storms.[52] Warmer water temperatures associated with climate change are also expected to change the distribution of fish species in the Great Lakes, with some warmwater species moving 400 miles northward while other species disappear entirely.[53] Invasive species could also expand since they are more adaptive to a wider range of environmental conditions.[54]

Greenhouse Gas Pollution Reduction

Ohio has not adopted greenhouse gas pollution reduction targets or developed a plan for reducing statewide greenhouse gas pollution. To reduce the state's contribution to climate change, **Ohio should adopt a greenhouse gas pollution reduction goal and develop and implement a strategy to achieve it.**

State Adaptation Planning

Ohio does not have a state climate adaptation plan, nor does adaptation planning appear to be under way in any state regulatory agency. Considering the potential impacts of climate change on Ohio, **the state should be actively assessing its vulnerabilities and developing and implementing strategies to adapt to climate change impacts.** The Ohio Sea Grant, however, is addressing some climate change issues. Building hazard resilience in coastal communities is one of the key focus areas in the Sea Grant's 2010-2014 Strategic and Implementation Plan.[55] To achieve this goal, the Sea Grant is educating communities about coastal hazards (including climate change), developing tools to determine how climate change might impact communities, and training communities on mitigation and adaptation planning. The Ohio Sea Grant also hosts Ohio State University's Changing Climate website, which contains climate change research information.[56] The website also offers webinars on climate change topics, such as a recent one titled "Climate Change Impacts on Great Lakes Water Levels," to help inform the community about climate change issues.

While the state's hazard mitigation plan notes that climate change may lead to more frequent and severe drought and flood events, the plan neglects to include flexible and adaptive strategies to reduce flood vulnerability and does not contain any strategies to reduce drought vulnerability.[57] **Because green infrastructure can substantially reduce the volume of stormwater runoff and consequently decrease flooding risks, Ohio should encourage widespread adoption of green infrastructure as a flood mitigation technique**. **The state also should work to encourage the widespread implementation of water conservation and efficiency measures.** This could be accomplished by adopting a permitting program requiring facilities that currently must report water usage annually to the Department of Natural Resources (those capable of withdrawing more than 100,000 gallons per day)[58] to meet conservation and efficiency metrics—which also would help to meet the state's obligations under the Great Lakes Compact.

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[1] George Backus, Thomas Lowry, Drake Warren, Mark Ehlen, Geoffrey Klise, Verne Loose, Len Malczynski, Rhonda Reinert, Kevin Stamber, Vince Tidwell, Vanessa Vargas, and Aldo Zagonel, "Assessing the Near-Term Risk of Climate Uncertainty: Interdependencies Among the U.S. States" (2010), 22, Sandia National Laboratories, cfwebprod.sandia.gov/cfdocs/CCIM/docs/Climate_Risk_Assessment.pdf.

[2] National Climatic Data Center (NCDC), National Oceanic and Atmospheric Administration, "Climate of Ohio" (undated), 3, geography.osu.edu/faculty/rogers/OOC.pdf.
[3] NCDC at 4.
[4] NCDC, note 2.
[5] NCDC, note 2.
[6] NCDC, note 3. Snowfall is converted into water equivalent values and included in the average annual precipitation numbers.
[7] Office of Coastal Management (OCM), Ohio Department of Natural Resources (ODNR), "Duties, Functions, 2010 Year in Review & the Status of Ohio's Lake Erie Coastal and Watershed Resources" (2011), 6, ohiodnr.com/LinkClick.aspx?fileticket=WhzRgxtY4zE%3d&tabid=9261.
[8] OCM 2011 at 10.
[9] OCM, note 8.
[10] Ohio Environmental Protection Agency (OH EPA), "Section B: Ohio's Water Resources," *2010 Integrated Water Quality Monitoring and Assessment Report* (2010), B-2, epa.state.oh.us/portals/35/tmdl/2010IntReport/Section_B.pdf.
[11] Randall E. Sanders, ed., "Major Ohio Watersheds," *A Guide to Ohio Streams* (Columbus, OH: Ohio Chapter of the American Fisheries Society, 2001), 10.0, dnr.state.oh.us/portals/0/streams/chapter10.pdf.
[12] OH EPA, "Ground Water in Ohio" (February 2010), 3, epa.state.oh.us/portals/28/documents/gwqcp/gwfactsht.pdf.
[13] OH EPA, note 12.
[14] ODNR Water Division, "2009 Water Withdrawal Summary Report" (2010), 1, dnr.state.oh.us/Portals/7/pubs/reports/2009WWFRAnnualRpt.pdf.
[15] ODNR Water Division, note 14.
[16] ODNR Water Division, note 14.
[17] ODNR Water Division, note 14.
[18] OH EPA, note 12.
[19] ODNR Water Division, note 14.
[20] "Great Lakes Facts and Figures," Great Lakes Information Network, great-lakes.net/lakes/ref/lakefact.html.
[21] Dave Dempsey, Jane Elder, and Donald Scavia, "Great Lakes Restoration and the Threat of Global Warming" (2008), 14, snre.umich.edu/scavia/wp-content/uploads/2009/11/how-global-warming-report-08_final.pdf.
[22] Michigan Department of Environmental Quality (MDEQ) Water Bureau, "Water Withdrawals for Major Water Uses in Michigan 2004" (2006), 1, deq.state.mi.us/documents/deq-wd-wurp-report04.pdf.
[23] Dempsey et al. 2008 at 3.
[24] Karen Hobbs and Ed Osann, "Protecting a Shared Future: Assessing and Advancing the Sustainable Management of the Great Lakes through Water Conservation and Efficiency" (June 2011), 3, Natural Resources Defense Council (NRDC), nrdc.org/water/files/greatlakescompact.pdf.
[25] "Great Lakes-St. Lawrence River Basin Water Resources Compact," Section 4.15.1.b, December 13, 2005, glslregionalbody.org/Docs/Agreements/Great_Lakes-St_Lawrence_River_Basin_Water_Resources_Compact.pdf.
[26] "Climate Change & Variability in the Midwest," Midwestern Regional Climate Center, mrcc.isws.illinois.edu/climate_midwest/mwclimate_change.htm#.
[27] Union of Concerned Scientists (UCS), "Confronting Climate Change in the U.S. Midwest—Ohio" (2009), 1, ucsusa.org/assets/documents/global_warming/climate-change-ohio.pdf.
[28] UCS, note 27.
[29] "Climate Change," note 26.
[30] UCS 2009 at 6.
[31] UCS, note 30.
[32] UCS, note 30.
[33] UCS, note 30.
[34] UCS, note 30.
[35] UCS 2009 at 7.
[36] UCS, note 35.
[37] UCS, note 35.
[38] UCS, note 35.

[39] U.S. Global Change Research Program (USGCRP), "Regional Climate Impacts: Midwest," *Global Climate Change Impacts in the United States* (2009), 120, downloads.globalchange.gov/usimpacts/pdfs/midwest.pdf.
[40] UCS, note 35.
[41] UCS, note 35.
[42] USGCRP 2009 at 122.
[43] Kim Knowlton, "Tides of Trouble: Increased Threats to Human Health and Ecosystems from Harmful Algal Blooms" (2010), Natural Resources Defense Council, nrdc.org/health/files/HABs6pgr_07hr.pdf.
[44] USGCRP, note 42.
[45] UCS 2009 at 8.
[46] UCS, note 45.
[47] UCS, note 45.
[48] "State Fact Sheets: Ohio," U.S. Department of Agriculture, ers.usda.gov/StateFacts/OH.htm#FC.
[49] UCS, note 35.
[50] Noah D. Hall and Bret B. Stuntz, "Climate Change and Great Lakes Water Resources" (2007), 12, prepared for the National Wildlife Federation, online.nwf.org/site/DocServer/Climate_Change_and_Great_Lakes_Water_Resources_Report_FI.pdf.
[51] Stephen Saunders, Dan Findlay, Tom Easley, and Theo Spencer, "Great Lakes National Parks in Peril: The Threat of Climate Disruption" (July 2011), 17, Rocky Mountain Climate Organization and NRDC, rockymountainclimate.org/images/GreatLakesParksInPeril.pdf.
[52] Saunders et al. 2011 at 16.
[53] Saunders et al. 2011 at 27 (citing Jay Austin and Steven Colman, "Lake Superior Summer Water Temperatures Are Increasing More Rapidly Than Rregional Air Temperatures: A Positive Ice-Albedo Feedback," *Geophysical Research Letters*, 34 [2007]: 2-3).
[54] USGCRP 2009 at 122.
[55] Ohio Sea Grant College Program, "2010-2014 Strategic and Implementation Plan" (undated), 72, ohioseagrant.osu.edu/_documents/publications/TB/TB-096%20Ohio%20Sea%20Grant%20Strategic%20and%20Implementation%20Plan%202010%202014.pdf.
[56] "Changing Climate," Ohio Sea Grant College Program, changingclimate.osu.edu.
[57] Ohio Emergency Management Agency, "State of Ohio Hazard Mitigation Plan 2011" (2011), 218-219, 272-276, ohiosharpp.ema.state.oh.us/OhioSHARPP/Planning.aspx#shmp.
[58] Ohio Revised Code, Section 1521.16.