

SUMMARY

Wisconsin's climate is changing. A wealth of temperature and precipitation data provide evidence that on average our state has become warmer and wetter over the past 60 years. Scientists project that the decades ahead will bring changes in climate much more profound than those already observed; in some cases those changes could occur more rapidly than plant or animal species can adapt. This first report from the Wisconsin Initiative on Climate Change Impacts (WICCI) seeks to identify the impacts of those changes as well as the strategies needed to adapt to them.

Historical temperature and precipitation patterns have varied widely across regions of the state, especially when seasonal differences are factored in. For instance, in the 1950-2006 period used in this report, **winter** temperatures increased significantly in northwestern Wisconsin, and these increases extended into the central part of the state. Springtime temperature increases also occurred in the same regions. During winter, nighttime minimum temperatures warmed at a faster rate than daytime maximum temperatures, and the number of very cold nights declined significantly. Northwestern and central Wisconsin experienced 14 to 21 fewer nights with temperatures below zero degrees Fahrenheit. Other areas of the state saw reductions in subzero nights of seven days or less.

During **summer** months, daytime maximum temperatures across the state changed little from 1950 through 2006, but nighttime minimum temperatures warmed significantly in the northwestern and central regions. Similarly, the number of days when temperatures exceeded 90° F did not increase throughout the state. Autumn temperatures did not warm statewide; northeastern and southwestern Wisconsin actually cooled slightly during the fall.

Precipitation also varied widely across the state, with localized drought in some northern regions and much wetter conditions in western and south central Wisconsin. Statewide, average annual precipitation increased by about 15 percent from 1950 through 2006. In some

regions, including south central and western Wisconsin, annual precipitation increased by as much as seven inches. In areas of northern Wisconsin, however, declines of up to four inches were recorded.

Future projections of temperature and precipitation patterns for Wisconsin were created by University of Wisconsin-Madison climate scientists using 14 “down-scaled” global circulation models. Their work indicates that **Wisconsin's warming trend will continue and increase considerably** in the decades ahead. By the middle of the century, statewide annual average temperatures are likely to warm by 6-7° F.

By mid-century, seasonal temperature increases (above current conditions) are projected to be greatest in winter, followed by spring and fall, then by summer. For example, wintertime temperatures are likely to increase by about 8° F, with slightly warmer temperature increases in northwestern Wisconsin. Summertime average temperatures are likely to rise 5-6° F statewide, with the greatest warming in northern Wisconsin. In addition to this warming, the number of summer days that exceed 90° F is projected to increase statewide. Southern and western regions of Wisconsin could see three or more weeks per year of these very hot days, while northern regions are likely to see an increase of about two weeks. A smaller increase in the number of hot days is projected for the areas along Lake Superior and for Wisconsin's “thumb” in Lake Michigan due to the cooling effect of the Great Lakes. Consistent with these warming trends, the number of winter nights below 0° F is projected to decrease significantly across the state by mid-century. A decline of about three weeks of these cold nights is expected in northern Wisconsin, with about one fewer week in the southeastern counties.

While our future precipitation patterns are more difficult to discern than temperature, the state is likely to continue its trend toward more precipitation overall, with the most probable increases in winter, spring and fall. Large storm events are also likely to increase in frequency during spring and fall. Statewide, the amount of precipitation that falls as rain rather than

snow during the winter is also projected to increase significantly, and freezing rain is more likely to occur.

Rising air temperatures, shifting precipitation patterns and increases in heavy rain events lead to a variety of secondary effects on our natural and built environments. These changes bring impacts at both broad and local levels, affecting the state as a whole as well as individual species of plants, fish and wildlife, and human communities.

The **quantity and quality of Wisconsin's water resources** are influenced by climate change. For example, we are seeing a decrease in the length of time that ice covers our lakes. A detailed examination of ice records for Lake Mendota in Dane County shows that the annual duration of ice cover has declined by about a month over the last 150 years. Water levels are higher in many areas due to increased precipitation but lower in the north due to a prolonged drought. With evapotranspiration rates projected to increase in the future, water levels in northern lakes and wetlands could decline further during future periods of drought, such as the droughts that have occurred periodically during the past century. More runoff from projected heavy seasonal rainfalls will likely increase sediment and nutrient inputs to lakes and wetlands, leading to more blue-green algal blooms in lakes and loss of biodiversity in wetlands. Changes in the timing and amount of rainfall influence groundwater recharge, and any decrease in groundwater recharge could be compounded by increased demand for irrigation due to an extended growing season, shifts in the timing of precipitation, and high temperatures or regional droughts.

Natural habitats respond to a changing climate in many ways, with impacts seen in wildlife, forests and plant communities. Plant hardiness zones are shifting; consequently, the ranges for many plant and animal species are expanding northward. An earlier onset of spring will disrupt relationships between plants and pollinators and could cue reproduction or other lifecycle events at non-ideal times. Species currently found in northern Wisconsin at the southern edge of their range may no longer be able to survive in the state, while more southerly species, including those not currently present in the state, will expand northward. Animals like the American marten, spruce grouse and

snowshoe hare may disappear from Wisconsin. Boreal tree species such as black spruce, balsam fir and paper birch may no longer grow in the state by the end of century, resulting in a dramatic change in the tree composition of our northern forests. Due to slow dispersal rates or fragmented habitat, migration of certain species to fill these northern voids is not certain.

Rising stream temperatures, which result from rising air temperatures and other factors, will lead to reduced habitat for native brook trout that require cold water. Scientists project that if summer air temperatures rise by 5° F, brook trout habitat will decline by 95 percent across the state. However, a warming climate will benefit other species, including the gray squirrel, white-tailed deer, European starling and Canada goose, with potential negative impacts on the environment resulting from increases in their populations.

Lower soil moisture levels are another change related to increased temperatures and evapotranspiration rates. Reductions in soil moisture affect numerous amphibians across the state such as frogs and salamanders that need moist conditions to survive. All of these changes could reduce biodiversity in Wisconsin and weaken the resilience of many ecosystems.

Wisconsin's agriculture will also be affected by climate change. In general, research suggests that warming temperatures in spring and fall would help boost agricultural production by extending the growing season across the state. However, increased warming during the summer months could reduce yields of crops such as corn and soybeans, with studies suggesting that every 2° F of warming could decrease corn yields by 13 percent and soybean yields by 16 percent.

The projected precipitation trends of more annual rainfall and more intense storms heighten the potential for significant **soil erosion**. Most soil erosion occurs during the few heavy rainfall events that occur each season, and an increasing number of these storms are likely in our future. This is especially true during the spring months, when cultivated fields are mostly bare with little plant cover to reduce soil erosion. Without appropriate adaptation measures, future precipitation patterns could double soil erosion rates by 2050 compared to 1990 rates. The good news is that Wisconsin

farmers and natural resource managers have effective conservation practices at hand, and widespread implementation has the potential to counter the threat of soil loss from climate change.

Wisconsin's **coastal regions** face new challenges as reduced ice cover, declining lake levels and increasing wind strength over the Great Lakes will bring impacts including increased shoreline erosion and recession and an increase in the vulnerability of shoreline infrastructure. Coastal wetlands face increased sedimentation from runoff and flooding and greater threats from invasive species that take hold when an ecosystem is disrupted or warmed. Lake Michigan's average water levels are expected to decline by about a foot by the end of the century. However, both high and low water levels will continue to impact coastal wetlands, bluffs and beaches due to natural fluctuations in water levels that occur every few decades.

Climate change also affects **society and the built environment**. New or more severe public health challenges arise as heat waves become more frequent and climatic conditions boost air pollutants such as smog and particulate matter. In the Chicago area, not far from several southeastern Wisconsin counties, occurrences of ground-level ozone exceeding current air quality standards are expected to increase from the present average of about two days per summer to about 17 days per summer by the end of the century. Pollen production is increasing, as well. All of these air pollutants worsen asthma and other respiratory diseases.

Waterborne diseases may multiply because human pathogens are introduced into the environment when combined and sanitary sewers overflow as a result of heavy rainfall or groundwater infiltration exceeding the capacity of wastewater treatment systems. In many places, current infrastructure is not equipped to handle the projected increases in frequency of heavy storms and subsequent runoff. This increases the risk that stormwater management and drinking water systems will fail and flooding will damage bridges, roadways and urban areas.

Adapting to impacts requires us to take a comprehensive view of climate change in Wisconsin. Adapta-

tion strategies presented in each chapter of this report illustrate alternative ways to avoid some of the worst outcomes and take advantage of benefits where possible. They are provided to help stakeholders take action to create resilience within natural and built environments, build capacity to make better decisions, improve the communication of climate science and projected impacts to stakeholders, and fill gaps in our knowledge of how natural and human systems respond to climate change.

As stakeholders determine which strategies will best achieve their goals, several **adaptation principles** may apply. These principles help identify which actions to implement first, the degree to which flexibility can be built into resource management practices, and whether some strategies will bring benefits regardless of how the climate continues to change. For example, they suggest that when vulnerability is high, it may be wiser to be safe rather than sorry. They remind us that variability in both time and space needs to be recognized; even within Wisconsin, changes and responses to impacts will differ across the state. Many place-based impacts present unique restrictions and circumstances for adaptation. For example, large cities and tribal lands cannot be moved to more favorable climates, and designated natural areas may no longer protect the species they were originally designed to protect.

This report is the first in a series that will provide an ongoing assessment of climate change impacts and adaptation strategies in Wisconsin. Even as we present this synthesis of the findings of the 15 contributing working groups, the groups continue to move forward with vulnerability assessments and identification of adaptation strategies, while WICCI continues to identify topics and areas in need of future attention.

If Wisconsin is to adapt successfully to current and future climate change, information about climate science, predicted impacts, types of adaptation strategies and means of implementing those strategies must reach local and state decision-makers. WICCI envisions a climate adaptation outreach model that supports managers of natural and human systems and other decision-makers in assessing vulnerabilities and evaluating risks from climate impacts. WICCI will

continue to engage Wisconsin academic institutions, state agencies, local governments, professional associations, businesses and other organizations in a process of identifying climate adaptation strategies. Outreach activities will also provide information on climate risk and adaptation to communities to support implementation of climate adaptation strategies. This report builds a foundation for long-term integration of climate risk education into Wisconsin's professional and community development efforts. To meet these objectives, WICCI will collaborate with existing education and outreach groups and support integration of information about climate impacts and adaptation into existing and new outreach programs.

An appendix includes the executive summaries of the technical, scientific working group reports, which are available in full on the Web at www.wicci.wisc.edu. The executive summaries contain the main findings of each working group along with key figures. Please see the full working group reports for information on methods, results and citations.