Appendix A

Climate Change Impacts

Comments of the Attorneys General of California, Connecticut, Delaware, Illinois, Iowa, Maine, Maryland, Massachusetts, Minnesota (by and through its Minnesota Pollution Control Agency), New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, Washington, and the District of Columbia, the Maryland Department of the Environment, and the cities of Boulder, Chicago, Los Angeles, New York, Philadelphia, and South Miami, and Broward County

on

the Environmental Protection Agency's Proposed Review of Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units, 83 Fed. Reg. 65,424 (Dec. 20, 2018)

Docket ID No. EPA–HQ–OAR–2013–0495

March 18, 2019

Our States and Cities have already begun to experience adverse impacts from climate change. Based on the overwhelming scientific evidence, those harms are likely to increase in number and severity unless aggressive steps are taken to reduce emissions of carbon dioxide and other greenhouse gases. Summarized below are some of those most significant threats being faced by our States and Cities.

California

Climate change's adverse effects have become impossible to ignore in California. The state weathered a historic five-year drought only to face record-setting fire seasons and a variety of other unprecedented phenomena increasingly harming the health and prosperity of Californians from all walks of life and all parts of the state, as described in more detail in a recent report of the California Air Resources Board.[1]

Drought conditions beginning in 2012 left reservoirs across the state at record low levels, often no more than a quarter of their capacity. The Sierra snowpack—critical to California's water supply, tourism industry, and hydroelectric power—was the smallest in at least 500 years.[2] The resulting cutbacks threatened the livelihoods of farmers and fishermen alike. In the Central Valley, the drought cost California agriculture about $2.7 billion and more than 20,000 jobs in 2015 alone.[3] In addition, the drought led to land subsidence, due to reduced precipitation and increased groundwater pumping, and the death of 129 million trees throughout the state.[4]

Even prior to the drought, the U.S. Forest Service had found that California was at risk of losing 12 percent—over 5.7 million acres—of the total area of forests and woodlands in the state due to insects and disease thriving in a hotter climate.[5] Several pine species are projected to lose around half of their basal area.[6] And a majority of the ponderosa pine in the foothills of the central and southern Sierra Nevada Mountains has already died, killed by the western pine beetle and other bark beetles.[7] The increasing threat from these insects is driven in large part by warmer

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[1] *See generally* California Air Resources Board, *California's 2017 Climate Change Scoping Plan Update: The Strategy for Achieving California's 2030 Greenhouse Gas Target*, (Nov. 2017), https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

[2] *See* NOAA, National Centers for Environmental Information: "Multi-Century Evaluation of Sierra Nevada Snowpack," https://www.ncdc.noaa.gov/news/multi-century-evaluation-sierra-nevada-snowpack.

[3] *California's 2017 Climate Change Scoping Plan Update*, *supra*, at 7.

[4] U.S Forest Service, *Record 129 Million Dead Trees in California* (2017), https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd566303.pdf.

[5] *California's 2017 Climate Change Scoping Plan Update*, *supra*, at 7.

[6] *Id*.

[7] *Id*.

summer temperatures attributable to climate change.[8] The very high levels of tree mortality led Governor Brown to issue an Emergency Proclamation on October 30, 2015, directing state agencies to identify and take action to reduce wildfire risk through the removal and use of the dead trees.[9]

Notwithstanding the Governor's Proclamation, the hotter, drier weather and millions of dead trees have increasingly accelerated the damage from wildfires. The 2017 season—the worst on record—killed dozens of people, destroyed thousands of homes, forced hundreds of thousands to evacuate, and burned more than half a million acres.[10] Prior to 2017, the worst year on record was 2015. In between, California faced the most expensive wildfire in U.S. history, the Soberanes fire, which burned for three months in 2016 and cost more than $250 million to put out.[11] Climate change is expected to make longer and more severe wildfire seasons "the new normal" for California.[12] Besides the immediate threats they pose to life and property, wildfires significantly impair both air quality (via smoke and ash that can hospitalize residents) and water quality (via the erosion of hillsides stripped of their vegetation).

Off the coast, rising ocean temperatures and ocean acidification have spurred toxic algal blooms, resulting in high levels of the neurotoxin domoic acid.[13] This toxin has hit California's economically valuable Dungeness crab fishery particularly hard. From 2015 to 2017, domoic acid contamination forced California to close the fishery for parts of the season in order to protect consumers from serious health risks, with the 2015-16 season declared a federal disaster.[14] Other fisheries have suffered a similar fate. The Dungeness crab fishery is expected to decline significantly in the future as acidification increases.[15] In addition, high levels of domoic

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[8] Jeffry B. Mitton and Scott M. Ferrenberg, *Mountain Pine Beetle Develops an Unprecedented Summer Generation in Response to Climate Warming*, THE AMERICAN NATURALIST, Vol. 179, No. 5 (May 2012).

[9] "Proclamation of a State of Emergency," https://www.gov.ca.gov/wp-content/uploads/2017/09/10.30.15_Tree_Mortality_State_of_Emergency.pdf.

[10] Lauren Tierney, *The Grim Scope of 2017's California Wildfire Season Is Now Clear. The Danger's Not Over.*, WASH. POST (Jan. 4, 2018), https://www.washingtonpost.com/graphics/2017/national/california-wildfires-comparison/.

[11] Lyndsey Gilpin, *The 10 Most Expensive Wildfires in the West's History*, HIGH COUNTRY NEWS (Oct. 5, 2016), https://www.hcn.org/articles/the-10-most-expensive-wildfires-in-the-wests-history.

[12] California Department of Forestry and Fire Protection, *California's Forests and Rangelands: 2010 Assessment*, Ch. 3-7 (2010).

[13] S. Morgaine McKibben et al., *Climatic Regulation of the Neurotoxin Domoic Acid*, 114 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 2 (2007).

[14] See Tara Duggan, *Toxin again an issue as Dungeness crab season nears*, S.F. CHRONICLE (Oct. 30, 2017), https://www.sfchronicle.com/food/article/Dungeness-crab-season-could-be-delayed-again-by-12318483.php; Mary Callahan, *California's crab fleet awaits share of $200 million in disaster relief*, SANTA ROSA PRESS-DEMOCRAT (Feb. 15, 2018), http://www.pressdemocrat.com/news/7996795-181/californias-crab-fleet-awaits-share?sba=AAS.

[15] Marshall, K.N. et al.. *Risks of Ocean Acidification in the California Current Food Web and Fisheries: Ecosystem Model Projections*, 21 GLOB. CHANGE BIOL. 4 (2017).

acid are poisoning marine mammals, and have been linked to reproductive failure (including high rates of miscarriage and premature birth) among California sea lions.[16]

California's many miles of coastline, particularly coastal bluffs, make it uniquely vulnerable to sea-level rise and more intense storms. Even if storms do not become more intense or frequent, sea-level rise itself will magnify the adverse impact of any storm surge and high waves on the California coast. Some observational studies report that the largest waves are already getting higher and winds are getting stronger.[17] California is likely to face greater than average sea-level rise, because of gravitational forces and the rotation of the Earth. Recent projections indicate that if no significant greenhouse gas mitigation efforts are taken, the San Francisco Bay Area may experience sea level rise between 1.6 to 3.4 feet, and in an extreme scenario involving the rapid loss of the Antarctic ice sheet, sea levels along California's coastline could rise up to 10 feet by 2100.[18]

In addition to damage to the physical environment, increased temperatures California will experience due to climate change will put the health of state residents at risk. Increased hospitalizations for multiple diseases, including cardiovascular disease, ischemic heart disease, ischemic stroke, respiratory disease, pneumonia, dehydration, heat stroke, diabetes, and acute renal failure are associated with increases in same-day temperature.[19] Such temperature increases have also been found to be associated with increased risk of preterm delivery[20] and stillbirths.[21] Recent California studies suggest increased mortality risk not only with extreme heat, but also with increasing ambient temperature.[22]

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[16] T. Goldstein et al., *The Role of Domoic Acid in Abortion and Premature Parturition of California Sea Lions (Zalophus californianus) on San Miguel Island, California*, JOURNAL OF WILDLIFE DISEASES. 45(1): 91-108 (2009).

[17] National Research Council of the National Academy of Sciences, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future*. National Academies Press (2012).

[18] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). *Rising Seas in California: An Update on Sea-Level Rise Science*. California Ocean Science Trust, April 2017.

[19] Green R, Basu R, Malig B, Broadwin R, Kim J and Ostro B (2010). *The Effect of Temperature on Hospital Admissions in Nine California Counties.* INTERNATIONAL JOURNAL OF PUBLIC HEALTH 55(2): 113-121. *See also* Basu R, Pearson D, Malig B, Broadwin R and Green S (2012). *The effect of elevated ambient temperature on emergency room visits in California.* EPIDEMIOLOGY 23(6):813-20; Sherbakov T, Malig B, Guirguis K, Gershunov A, Basu R. (2018) *Ambient temperature and added heat wave effects on hospitalizations in California from 1999 to 2009*. ENVIRON RES. 160:83-90.

[20] Basu R, Malig B and Ostro B (2010). *High ambient temperature and the risk of preterm delivery*. AM J EPIDEMIOLOGY 172(10): 1108-1117.

[21] Basu R, Sarovar V, Malig BJ (2018) *Association Between High Ambient Temperature and Risk of Stillbirth in California*. AM J EPIDEMIOL. 183(10):894-901.

[22] Basu R and Ostro BD (2008a). *A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California*. AM J EPIDEMIOL. 168(6): 632-637; Basu R, Feng W and Ostro B (2008b). *Characterizing temperature and mortality in nine California counties, 1999-2003*. EPIDEMIOLOGY 19(1): 138 -145; Basu R and Malig B (2011). *High ambient*

California 2018 Supplement

In 2018, the State of California produced two substantial reports on the impacts of climate change in California, which incorporate the latest scientific research on the impacts of climate change in California.

The first report, published May 2018 titled "***Indicators of Climate Change in California***" examines thirty-six separate indicators and reflects the contributions of dozens of scientists from California's universities, and state agencies, as well as the U.S. National Oceanic and Atmospheric Administration and the U.S. Department of Energy's Lawrence Berkeley National Laboratory.[23] A copy of the full "Indicators" report is included in the attachments to the States' comments.

The second report, published August 2018 titled "***California's Fourth Climate Assessment***" includes thirty-three papers from State-funded research, and eleven papers from externally funded researchers, as well as regional summaries and a statewide summary of climate vulnerabilities, and a key findings paper.[24] A copy of selected research papers and the regional and statewide summaries and key findings reports are included in the attachments to the States' comments.

Key findings from those reports and other sources include the following:

Temperature Changes and Air Quality Impacts

> "Since 1895, annual average air temperatures have increased throughout the state, with temperatures rising at a faster rate beginning in the 1980s. The last four years were notably warm, with 2014 being the warmest on record, followed by 2015, 2017, and 2016. Temperatures at night have increased more than during the day: minimum temperatures (which generally occur at night) increased at a rate of 2.3 degrees Fahrenheit (°F) per century, compared to 1.3°F per century for maximum temperatures."[25]

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temperature and mortality in California: Exploring the roles of age, disease, and mortality displacement. ENVIRONMENTAL RESEARCH 111(8): 1286-1292.

[23] *See* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). *Indicators of Climate Change in California*. Available at www.oehha.ca.gov/climate-change/document/indicators-climate-change-california (last visited October 24, 2018) (hereinafter "California Climate Indicators 2018").

[24] *See* California Natural Resources Agency, *California's Fourth Climate Change Assessment* (2018), *available at* www.ClimateAssessment.ca.gov (last visited October 24, 2018) (hereinafter "California 4th Assessment").

[25] California Climate Indicators 2018 at S-4.

> "Extremely hot days and nights — that is, when temperatures are at or above the highest 2 percent of maximum and minimum daily temperatures, respectively — have become more frequent since 1950. Both extreme heat days and nights have increased at a faster rate in the past 30 years. Heat waves, defined as five or more consecutive extreme heat days or nights, are also increasing, especially at night. Nighttime heat waves, which were infrequent until the mid-1970s, have increased markedly over the past 40 years."[26]

> In addition, rising temperatures "could lead to increases in ground-level ozone and reduce the effectiveness of emission reductions taken to achieve air quality standards…."[27]

> "A recent detailed analysis suggests that adoption of low-carbon energy in California to reduce GHG emissions 80 percent below 1990 levels would lead to a 55 percent reduction in air pollution mortality rates relative to 2010 levels (Zapata et al., 2018). These public health improvements have a value of $11-20 billion/year in California (Zapata et al., 2018)."[28]

Human Health Impacts

Climate change poses direct and indirect risks to public health, as people will experience earlier death and worsening illnesses.

> "Nineteen heat-related events occurred from 1999 to 2009 that had significant impacts on human health, resulting in about 11,000 excess hospitalizations. However, the National Weather Service issued Heat Advisories for only six of the events. Heat-Health Events (HHEs), which better predict risk to populations vulnerable to heat, will worsen drastically throughout the state: by midcentury, the Central Valley is projected to experience average Heat-Health Events that are two weeks longer, and HHEs could occur four to ten times more often in the Northern Sierra region."[29]

> "The 2006 heat wave killed over 600 people, resulted in 16,000 emergency department visits, and led to nearly $5.4 billion in damages. The human cost of these events is already immense, but research suggests that mortality risk for those 65 or older could increase ten-fold by the 2090s because of climate change."[30]

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[26] *Id.* at S-5.

[27] California's Fourth Climate Change Assessment, California's Changing Climate 2018: Statewide Summary Report at 40 (Aug. 2018), *available at* http://www.climateassessment.ca.gov/state/docs/20180827-StatewideSummary.pdf. (hereinafter "California Statewide Summary").

[28] *Id.* at 71.

[29] *Id.* at 10.

[30] *Id.*

Environmental Justice Impacts

"Multiple studies of vulnerability and climate impacts indicate that existing inequities can be exacerbated by climate change. For example, the consequences of climate-related water impacts are particularly acute for communities already dealing with a legacy of inequalities. A recent study on drought and equity in California found that low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts caused by water supply shortages and rising cost of water (Feinstein et al., 2017). In a report prepared as part of the Fourth Assessment, Ekstrom et al. (2018) found that while all water districts faced similar challenges during the drought, small water districts (defined as those serving less than 10,000 people or less than approximately 3,300 connections) were less likely to have the resources and capacity to overcome those challenges. These districts are most likely to serve small, rural communities in California. Furthermore, for marginalized populations in rural areas of the state, agricultural actions in response to the drought, including increases in groundwater pumping and crop choices, are increasing and reshaping their vulnerability to drought and water shortage (Greene, 2018).[31]

"Inequities not only exist in varying exposures to climate risk, but also in the availability and implementation of potential adaptation or resilience solutions. Recent research analyzed differences in tree canopy, an important tool for adapting to the effects of extreme heat, at the census block group scale in coastal Los Angeles and found disparities between canopy in high-income and low-income neighborhoods (Locke et al., 2017). This disparity can have implications for communities because of the benefits tree canopy provides in reducing the negative effects of extreme heat events. A study prepared for the Fourth Assessment provides one of the first estimates of these benefits in one location (Taha et al., 2018)."[32]

Tribal and Indigenous Communities Impacts

"Tribes and Indigenous communities in California face unique challenges under a changing climate. Tribes maintain cultural lifeways and rely on traditional resources (e.g., salmon fisheries) for both social and economic purposes. However, tribes are no longer mobile across the landscape. For many tribes in California, seasonal movement and camps were a part of living with the environment. Today these nomadic options are not available or are limited. This is the result of Euro-American and U.S. policy and actions and underpins several climate vulnerabilities. Tribes with reservations/Rancherias/allotments are vulnerable to climate change in a specific way: tribal lands are essentially locked into fixed geographic

[31] California Statewide Summary at 36-37.

[32] *Id.* at 37.

locations and land status. Only relatively few tribal members are still able to engage in their cultural traditions as livelihoods."[33]

Precipitation and Water Supply Impacts

"California has the highest variability of year-to-year precipitation in the contiguous United States."[34] By 2050, "the average water supply from snowpack is projected to decline by 2/3 from historical levels."[35]

> "Statewide precipitation has become increasingly variable from year to year. In seven of the last ten years, statewide precipitation has been below the statewide average (22.9 inches). In fact, California's driest consecutive four-year period occurred from 2012 to 2015. In recent years, the fraction of precipitation that falls as rain (rather than snow) over the watersheds that provide most of California's water supply has been increasing — another indication of warming temperatures."[36]

> "Spring snowpack, aggregated over the Sierra Nevada and other mountain catchments in central and northern California, declines substantially under modeled climate changes (Figure 6). The mean snow water equivalent (SWE) declines to less than two-thirds of its historical average by 2050, averaged over several model projections under both RCP 4.5 and 8.5 scenarios. By 2100, SWE declines to less than half the historical median under RCP 4.5, and less than one-third under RCP 8.5. Importantly, the decline in spring snowpack occurs even if the amount of precipitation remains relatively stable over the central and northern California region; the snow loss is the result of a progressively warmer climate. Furthermore, while the models indicate that strong year-to-year variation will continue to occur, the likelihood of attaining spring snowpack that reaches or exceeds historical average is projected to diminish markedly (Pierce et al., 2018) (Figure 6)."[37]

Agriculture Impacts

> "Agricultural production could face climate-related water shortages of up to 16% in certain regions. Regardless of whether California receives more or less annual precipitation in the

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[33] *Id.* at 10.

[34] *Id.* at 24.

[35] California's Fourth Climate Change Assessment, California's Changing Climate 2018: A Summary of Key Findings from California's Fourth Climate Change Assessment 6 (Aug. 2018), *available at* http://www.climateassessment.ca.gov/state/docs/20180827-SummaryBrochure.pdf. (hereinafter "California Key Findings") at 5.

[36] California Climate Indicators at S-5.

[37] California Statewide Summary at 27.

future, the state will be dryer because hotter conditions will increase the loss of soil moisture."[38]

"Winter chill has been declining in certain areas of the Central Valley. This is the period of cold temperatures above freezing but below a threshold temperature needed by fruit and nut trees to become and remain dormant, bloom, and subsequently bear fruit. When tracked using "chill hours," a metric used since the 1940s, more than half the sites studied showed declining trends; with the more recently developed "chill portions" metric, fewer sites showed declines."[39]

"[I]t is evident from recent droughts that agricultural production will be challenged by water shortages, higher temperatures, changing atmospheric conditions, and conversion of agricultural land to developed uses (Medellín-Azuara et al., 2018; Wilson et al., 2017). Agriculture is the economic foundation for many of California's communities, particularly rural communities where other employment opportunities are limited. Roughly 6.7 percent of jobs statewide are generated by farms and farm processing, and in the Central Valley the figure is much higher (22 percent) (UC Agricultural Issues Center, 2012). This means that climate change impacts to agriculture, and even nuanced impacts such as shifting cropping patterns, may create hardships in the rural communities where agriculture is foundational. Different crops have different labor demands (Medellín-Azuara et al., 2016), and shifting crop patterns may result in changes in employment throughout the agricultural sector (Greene, 2018; Villarejo, 1996). A Fourth Assessment study found that in the 2012-2016 drought, to access higher market prices and compensate for the higher cost of water, many farms switched to higher value crops, for which cultivation and harvesting could be largely automated— leaving agricultural workers with employment shortages beyond the drought (Greene, 2018). A report by the University of California found that in 2016, the drought resulted in a $603 million loss to the economy and the loss of 4,700 jobs due to the impacts on agriculture (Medellín-Azuara et al., 2016)."[40]

Forest Impacts

A new paper published on October 18, 2018, estimates that "human-caused climate change caused over half of the documented increase in fuel aridity since the 1970s and doubled the cumulative forest fire area since 1984," contributing an additional 4.2 million ha [hectares] of forest fire.[41] As the paper notes, "[i]ncreased forest fire activity across the western United States

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[38] *Id.*

[39] California Climate Indicators at S-5.

[40] California Statewide Summary at 59.

[41] John T. Abatzoglou and A. Park Williams, Impact of Anthropogenic Climate Change on Wildfire Across the Western U.S. Forests, *Proceedings of the National Academy of Science*, vol. 113, no.

in recent decades has contributed to widespread forest mortality, carbon emissions, periods of degraded air quality and substantial fire suppression expenditures."[42]

> "A changing climate combined with anthropogenic factors has already contributed to more frequent and severe forest wildfires in the western U.S. as a whole (Abatzoglou & Williams, 2016; Mann et al., 2016; Westerling, 2016)."[43]

> "One Fourth Assessment model suggests large wildfires (greater than 25,000 acres) could become 50% more frequent by the end of century if emissions are not reduced. The model produces more years with extremely high areas burned, even compared to the historically destructive wildfires of 2017 and 2018."[44]

> "By the end of the century, California could experience wildfires that burn up to a maximum of 178% more acres per year than current averages."[45] Increased wildfire smoke will also lead to more respiratory illness.[46]

> In addition, the changes in climate make trees more vulnerable to pest infestations.

> "Moisture stress in conifer forests enhances tree vulnerability to insect infestation, particularly by bark beetles (Anderegg et al., 2015; Bentz et al., 2010; Berryman, 1976; Gaylord et al., 2013; Hart et al., 2014; Kolb et al., 2016; Raffa et al., 2008). Between 2010 and 2017, an estimated 129 million trees have died (Young et al., 2017). Bark beetle outbreaks may be promoted by warming for multiple reasons (Bentz et al., 2010). Warming may promote successful beetle overwintering (Weed et al., 2015) and may also promote earlier timing of adult emergence and flight in spring/early summer, which may enable beetles to increase the frequency at which they can mate, lay eggs, and emerge as adults (Bentz et al., 2016)."[47]

Drought and Land Subsidence Impacts

> "The recent 2012-2016 drought was exacerbated by unusual warmth (Williams, Seager, et al., 2015), and disproportionately low Sierra Nevada snowpack levels (Dettinger & Anderson, 2015). This drought has been described as a harbinger of projected dry spells in

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42 (Oct. 18, 2018), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5081637/pdf/pnas.201607171.pdf.

[42] *Id.*

[43] California Statewide Summary at 28.

[44] California Key Findings at 6.

[45] *Id.*

[46] *Id.* at 8.

[47] California Statewide Summary at 64.

future decades, whose impacts will likely be worsened by increased heat (Mann & Gleick, 2015). A very wet winter in 2016-2017 followed this drought, a further indication of potential continued climate volatility in the future (Berg & Hall, 2015; Polade, et al., 2017; Swain et al., 2018)."[48]

> "Warming air temperatures throughout the 21st century will increase moisture loss from soils, which will lead to drier seasonal conditions even if precipitation increases (Thorne et al., 2015). Warming air temperatures also amplify dryness caused by decreases in precipitation (Ault et al., 2016; Cayan et al., 2010; Diffenbaugh et al., 2015). These changes affect both seasonal dryness and drought events. Climate projections from the previous and present generation of GCMs (e.g. Pierce et al., 2014; Swain et al., 2018) show that seasonal summer dryness in California may become prolonged due to earlier spring soil drying that lasts longer into the fall and winter rainy season. The extreme warmth during the drought years of 2014 and 2015 intensified some aspects of the 2012-2016 drought (Griffin & Anchukaitis, 2014; Mao et al., 2015; Stephenson et al., 2018; Williams, Seager, et al., 2015) and may be analogous for future drought events (Diffenbaugh et al., 2015; Mann & Gleick, 2015; Williams, Seager, et al., 2015)."[49]

In addition, a "secondary, but large, effect of droughts is the increased extraction of groundwater from aquifers in the Central Valley, primarily for agricultural uses. The pumping can lead to subsidence of ground levels, which around the San Joaquin-Sacramento Delta has been measured at over three-quarters of an inch per year."[50]

> "This subsidence compounds the risk that sea-level rise and storms could cause overtopping or failure of the levees, exposing natural gas pipelines and other infrastructure to damage or structural failure. At this rate of subsidence, the levees may fail to meet the federal levee height standard (1.5 ft. freeboard above 100-year flood level) between 2050-2080, depending on the rate of sea-level rise."[51]

Sea-Level Rise, Coastal Erosion and Infrastructure Impacts

> "Along the California coast, sea levels have generally risen. Since 1900, mean sea level has increased by about 180 millimeters (7 inches) at San Francisco and by about 150 millimeters (6 inches) since 1924 at La Jolla. In contrast, sea level at Crescent City has declined by about 70 millimeters (3 inches) since 1933 due to an uplift of the land surface from the movement

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[48] *Id.* at 13.

[49] *Id.* at 26.

[50] *Id.* at 14.

[51] California Statewide Summary at 12.

of the Earth's plates. Sea level rise threatens existing or planned infrastructure, development, and ecosystems along California's coast."[52]

"If emissions continue at current rates, Fourth Assessment model results indicate that total sea-level rise by 2100 is expected to be 54 inches, almost twice the rise that would occur if greenhouse gas emissions are lowered to reduce risk."[53]

"31 to 67% of Southern California beaches may completely erode by 2100 without large-scale human interventions."[54]

"Flooding from sea-level rise and coastal wave events leads to bluff, cliff, and beach erosion, which could affect large geographic areas (hundreds of kilometers). In research conducted for the Fourth Assessment, Erikson et al. (2018) found that if a 100-year storm occurs under a future with 2m (6.6 feet) of SLR, resultant flooding in Southern California could affect 250,000 people and lead to damages of $50 billion worth of property and $39 billion worth of buildings."[55]

In addition, airports in major urban areas will be susceptible to major flooding from sea-level rise and storm surge by 2040-2080, and 370 miles of coastal highway will be susceptible to coastal flooding by 2100.[56]

Ocean Acidity and Health Impacts

"Increasing evidence shows that climate change is degrading California's coastal and marine environment. In recent years, several unusual events have occurred along the California coast and ocean, including a historic marine heat wave, record harmful algal bloom, fishery closures, and a significant loss of northern kelp forests."[57]

In addition:

"[o]cean acidification … is predicted to occur especially rapidly along the West Coast (e.g., Gruber et al., 2012). Ocean acidification presents a clear threat to coastal communities through its significant impacts on commercial fisheries and farmed shellfish (Ekstrom et al., 2015) as well as to ocean ecosystems on a broader scale. Ocean acidification affects many shell-forming species, including oysters, mussels, abalone, crabs, and the microscopic

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[52] California Climate Indicators at S-7.

[53] California Key Findings, at 6.

[54] *Id.* at 15.

[55] California Statewide Summary at 31.

[56] *Id.* at 54-55.

[57] *Id.* at 12.

plankton that form the base of the oceanic food chain (Kroeker et al., 2013; Kroeker et al., 2010). Significant changes in behavior and physiology of fish and invertebrates due to rising CO2 and increased acidity have already been documented (e.g., Hamilton et al., 2017; Jellison et al., 2017; Kroeker et al., 2013; Munday et al., 2009). Species vulnerable to ocean acidification account for approximately half of total fisheries revenue on the West Coast (Marshall et al., 2017)."[58]

Connecticut

In April 2010, the Governor's Steering Committee on Climate Change produced a report that predicted the impact of climate change on Connecticut's agriculture, infrastructure, natural resources and public health.[59] In general the report concluded that the impact of climate change on these four areas would be largely negative; Connecticut crops such as maple syrup, apple and pear production, and shellfish will suffer; infrastructure to control coastal flooding and storm water could be substantially damaged; rare habitats and critical species face elimination; and Connecticut's public health, particularly of the most vulnerable communities, is threatened by a decrease in air quality, extreme heat and the favorable conditions for increased disease.

The Connecticut Institute for Resilience and Climate Adaptation or CIRCA, an institute housed at the University of Connecticut, has projected a rise in sea level of approximately twenty inches by 2050. In response to this latest analysis, Governor Malloy signed Public Act 18-82, *An Act Concerning Climate Change Planning and Resiliency*, into law which requires state and federally funded projects to plan for a scenario of 50 centimeters of sea level rise by 2050, ensuring the success of future projects undertaken in the state, the prudence of state investments, and the safety of those residing on or near the shoreline. In addition to preparations for the imminent rise in sea level, Public Act 18-82 sets an interim target of a 45% reduction in greenhouse gas emissions from a 2001 baseline by 2030, ensuring Connecticut remains on a path to achieve an 80% reduction in emissions by 2050 as mandated under the state's Global Warming Solutions Act.

Observed Change

Connecticut has already begun to experience the severe consequences of climate change induced by unchecked, increasing GHG emissions. Between 1895 and 2011, temperatures in the Connecticut increased by almost 2℉ (0.16℉ per decade), and precipitation increased by

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[58] *Id.* at 66-67.

[59] Adaptation Subcommittee to the Governor's Steering Committee on Climate Change, *The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health* (2010), *available at* http://www.ct.gov/deep/lib/deep/climatechange/impactsofclimatechange.pdf.

approximately five inches, or more than 10% (0.4 inches per decade).[60] Between 1980 and 2018, average annual temperature in Connecticut has risen by over 2^{o} F. Over the same period, winter temperatures have warmed by 3^{o} F.

The Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States; between 1958 and 2010, Connecticut saw more than a 70% increase in the amount of precipitation falling in very heavy events. In 2011 Hurricane Irene caused power outages affecting 754,000 customers and over $1 billion in damage, and in 2012 Hurricane Sandy caused power outages affecting more than 600,000 customers and over $360 million in damage. The latter forced thousands of Connecticut residents evacuate, saw thousands apply for FEMA assistance, damaged roads and infrastructure, and took nine days for utilities to restore power.[61] Many of Connecticut's coastal communities and assets remain at risk to more frequent future storm events exacerbated by climate change.

Projections

Connecticut is highly vulnerable to changes in mean and extreme climate due to regional characteristics like a dense population and aging infrastructure. In conservative estimates, climate projections for Connecticut robustly indicate that annual mean temperature will rise by 5-10^{o}F by the end of the 21st Century.

Mean annual precipitation is also likely to increase, particularly in winter and spring seasons, contributing to increased flooding risk through the region. Additionally, weather and climate extremes are projected to be more frequent and intense which will impact both natural and socioeconomic sectors. As temperatures increase along the coast, humidity will also rise, resulting in amplified heat stress during summer months. For inland areas, drought events will become more severe and longer-lived, causing increased competition for limited water resources, agricultural crop damage, ecosystem stress, and risk of wildfire. Communities in Connecticut should expect that coastal flooding intensity and frequency to increase in coming decades due to accelerating trends in coastal erosion, extreme precipitation, and storms.

Sea Level

Direct and remotely sensed measurements of sea level have shown that the annual mean level of the ocean surface is rising. In the Northeast, coastal flooding has increased due to approximate one foot rise in sea level since 1900. This rate of sea level rise exceeds the global average of approximately eight inches, due primarily to land subsidence and thermal expansion

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[60] Horton, R., Yohe, G., Easterling, W., Kates, R., Matthias, R., Sussman, E., Whelchel, A., Wolfe, D., and Lipschultz, F. (2014). Ch. 16: Northeast. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn.

[61] Burgeson, John, *Rising Above the Tide: 5 Years Since Sandy*, CTPost, (Oct. 28, 2017), https://www.ctpost.com/local/article/Rising-above-the-tide-5-years-since-Sandy-12313727.php

(of ocean water) along the Northeastern coast. In moderately conservative estimates, sea level rise along the Connecticut coast is projected to be ~0.76 ft (0.23 meters) higher than 2000 levels by 2050.[62] And according to a report released in late March 2018 by the Connecticut Institute for Climate and Resilience (CIRA), sea level rise is anticipated to rise by 2 feet by 2050 and over 3 feet by 2100.[63] This will strongly impact the many coastal communities and businesses in Connecticut.

Delaware

As a low-lying state with 381 miles of coastline, Delaware is vulnerable to coastal storms, sea level rise, and flooding exacerbated by climate change. Sea levels around Delaware have already risen 13 inches this century.[64] This means that storm surges come further inland and coastal towns flood more frequently, jeopardizing infrastructure, and leading to costly repairs. Towns like Slaughter Beach are partnering with the state to build climate adaption plans, recognizing that these events will only get worse and more expensive. As climate change exacerbates sea level rise, over 17,000 homes and almost 500 miles of roadway in Delaware are at risk of permanent inundation from sea level rise by the end of the century.[65]

In addition, rising temperatures and extreme heat events as a result of climate change threaten public health and especially Delaware's most vulnerable citizens – young children, the elderly, outdoor workers, and individuals with underlying health conditions. Extreme heat days and extended heat waves can exacerbate poor air quality and unhealthy outdoor conditions, especially in urban areas like Wilmington. Extreme heat, saltwater intrusion from sea level rise, and changes in precipitation also threaten Delaware's $8 billion agricultural industry, which is strongly ingrained in both the state's economy and culture.

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[62] O`Donnell, J., *Sea Level Rise in Connecticut*. Draft Report, Connecticut Institute for Resilience and Climate Adaptation (March 27, 2018), *available at* https://circa.uconn.edu/wp-content/uploads/sites/1618/2017/10/SeaLevelRiseConnecticutFinalDraft-Posted-3_27_18.pdf.

[63] See https://circa.uconn.edu/2018/03/27/sea-level-rise-projections-for-the-state-of-connecticut-webinar-recording-available/.

[64] Callahan, John A., Benjamin P. Horton, Daria L. Nikitina, Christopher K. Sommerfield, Thomas E. McKenna, and Danielle Swallow, *Recommendation of Sea-Level Rise Planning Scenarios for Delaware: Technical Report*, prepared for Delaware Department of Natural Resources and Environmental Control (DNREC) Delaware Coastal Programs (2017), *available at* http://www.dgs.udel.edu/sites/default/files/projects-docs/de%20slr%202017%20technical%20report%20final.pdf

[65] DNREC, *Preparing for Tomorrow's High Tide: Sea-Level Rise Vulnerability Assessment for the State of Delaware. Technical Report*, Prepared for the Delaware Sea Level Rise Advisory Committee by the Delaware Department of Environmental Control (2012), *available at* http://www.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/AssesmentForWeb.pdf.

Illinois

Climate change is affecting Illinois in a number of ways—both by fundamentally altering the state's environment in ways never seen before and by intensifying well-recognized weather hazards. The fundamental changes can be seen in Illinois' farming industry and in the state's greatest environmental asset, Lake Michigan.

The farming sector is particularly vulnerable to extreme precipitation caused by climate change. 2012 was Illinois' third driest summer on record. The very next year, heavy rainfall caused flooding in parts of the state that, together with the wettest January-to-June period ever recorded in Illinois, forced farmers to delay planting and lose revenue.[66] Heat waves during the crop pollination season may reduce future yield: hotter weather and altered rain patterns could cause 15% loss in the next 5 to 25 years and up to a 73% average loss by the end of the next century.[67] Milder winters will lead to more weeds, insects, and diseases surviving throughout winter, also hurting yield and quality.[68]

Climate disruption also contributes to whipsawing water levels on Lake Michigan. In January 2013, the lake fell to an all-time low water level. In 2015, it climbed to its highest level since 1998, the second-largest recorded gain over a 24-month span.[69] Rapidly swinging water levels hurt the commercial shipping industry, recreational boaters, wildlife, and beach-goers. For example, for every inch the lake loses, a freighter must forgo 270 tons of cargo. High water erodes beaches and damages property.[70]

Climate change has already turned up the volume on well-recognized catastrophic extreme weather events, causing stronger storms, increased precipitation, and higher average temperatures. In recent years, the state has been struck by deadly tornadoes in November 2013 and the 2014 polar vortex.[71]

Illinois also suffers from frequent flooding, and climate change has and will cause the frequency and strength of these floods to increase. For instance, flooding caused by increased

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[66] University of Illinois–Institute of Government & Public Affairs, *Preparing for Climate Change in Illinois: An Overview of Anticipated Impacts*, https://igpa.uillinois.edu/sites/igpa.uillinois.edu/files/reports/Preparing-for-Climate-Change-in-Illinois.pdf (last visited Oct. 11, 2018).

[67] *Id.*

[68] *Id.*

[69] Tony Briscoe, *Lake Michigan Water Levels Rising at Near Record Rate*, CHICAGO TRIBUNE (July 12, 2015), *available at* http://www.chicagotribune.com/news/local/breaking/ct-lake-michigan-water-levels-met-20150710-story.html.

[70] *Id.*

[71] National Weather Service, *Historic Tornado Outbreak of November 17, 2013*, https://www.weather.gov/ilx/17nov13 (last visited Oct. 11, 2018); National Weather Service, *The Bitterly Cold Air of January 27-28, 2014*, https://www.weather.gov/lot/2014jan28 (last visited Oct. 11, 2018).

precipitation causes dramatic damage to the lives and property of Illinois residents; this toll will increase as climate change intensifies. For example, in 2009, a freight train carrying ethanol derailed in Cherry Valley, Illinois due to washout of train tracks following heavy rains.[72] Fourteen of the tanker cars carrying ethanol caught fire, killing a woman in her car waiting for the train to pass. Seven other people were injured and about 600 nearby homes were evacuated.[73] A few days later, a 54-mile-long fish kill occurred on the Rock River when ethanol that was not consumed by the fire flowed downstream, killing over 70,000 fish.[74]

CHERRY VALLEY TRAIN DERAILMENT

Image from Rockford Register Star

In another instance, a major flood struck Jo Daviess County in northwestern Illinois in 2011 after 15 inches of rain fell during a 12-hour time period. The flood waters caused extensive damage to roads and train tracks and at least one fatality.[75] Illinois has also struggled with urban flooding caused by heavy rains falling on impervious surfaces.[76]

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[72] National Transportation Safety Board, *Derailment of CN Freight Train U70691-18 with Subsequent Hazardous Materials Release and Fire*, https://www.ntsb.gov/investigations/AccidentReports/Pages/RAR1201.aspx (last visited Oct. 11, 2018).

[73] CBC.ca, *CN Blamed for Fatal Train Derailment in Illinois*, https://www.cbc.ca/news/canada/cn-blamed-for-fatal-train-derailment-in-illinois-1.1139430 (last visited Oct. 12, 2018).

[74] Illinois Attorney General, *Attorney General Madigan Reaches Settlement to Recover Costs of Rockford Train Derailment, Ethanol Leak*, http://www.illinoisattorneygeneral.gov/pressroom/2015_03/20150305.html (last visited Oct. 12, 2018).

[75] *Crews Find Body of Woman Swept Away by Flood in Galena*, ROCKFORD REGISTER STAR (July 30, 2011), *available at* www.rrstar.com/x555032097/Crews-find-body-of-woman-swept-away-by-flood-in-Galena

[76] NOAA National Centers for Environmental Information, *State Climate Summaries: Illinois*, https://statesummaries.ncics.org/il (last visited Oct. 11, 2018).

2011 JO DAVIESS COUNTY FLOOD

Images from Rockford Register Star

Furthermore, rising average temperatures injures Illinois residents. Hotter weather will inevitably harm public health and lead to heat-related deaths. For instance, over 700 Illinois residents died due to the historically intense heat wave in July 1995.[77] Intensified drought conditions strengthen these impacts—the inverse of heavy precipitation.

Though catastrophes such as these have occurred from time to time throughout Illinois' history, climate change will cause them to happen more frequently and with more ferocity than ever before, at the cost of the lives and health of Illinois residents.

<u>Iowa</u>

Climate change increases Iowa's propensity for flooding and droughts, creates challenges for the state's agricultural economy, and poses risks to public health. While already experiencing

[77] Jan C. Semenza, *et al.*, *Heat Related Deaths During the 1995 Heat Wave in Chicago*, THE NEW ENGLAND JOURNAL OF MEDICINE (July 11, 1996), *available at* https://www.nejm.org/doi/full/10.1056/NEJM199607113350203.

some of climate change's adverse effects, Iowa will likely only become more susceptible to climate change-related harms as average temperatures continue to increase.

Climate change influences the frequency and duration of precipitation events, and Iowa is feeling the effects.[78] Over the past half century, Iowa has seen an increase in annual precipitation and a greater frequency of extreme rain events.[79] The latest science suggests that the increase in precipitation will continue, while Iowa will also continue experiencing more significant drought in some areas.[80] The increased rain events are due to higher surface evaporation from a warmer world, while dry spells are due to reduced evaporation stemming from a lack of moisture.[81] In other words, changes in Iowa's climate will likely continue to make wet seasons wetter and dry seasons dryer.

Extreme rain events have caused significant flooding throughout Iowa, and with Iowa's over 70 interior rivers,[82] the flooding has adversely affected much of Iowa's population. Since 1990, Iowa has had over 30 presidentially declared flood-related disaster declarations.[83] The flooding has caused an estimated 13.5 billion dollars worth of property-related damage.[84] In 2016, a presidential declaration identified 19 counties affected by severe flooding, many of which were also hit hard by flooding in 2008.[85] In 2018 alone, 30 counties have already been identified in presidential disaster declarations due to severe storms and flooding.[86]

Heavy rainfall and melting snow have also led to significant flooding in Iowa's bordering Mississippi and Missouri Rivers. In 2011, the high level of the Mississippi River forced navigation closures and caused billions of dollars in damage downstream.[87] That same year,

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[78] *Iowa Climate Statement 2017*, CTR. FOR GLOBAL & REGIONAL ENVTL. RES., 1 (2017), https://cgrer.uiowa.edu/sites/cgrer.uiowa.edu/files/wysiwyg_uploads/Iowa%20Climate%20Statement%202017_It's%20not%20just%20the%20heat,%20it's%20the%20humidity!_FINAL_August_10_2017.pdf.

[79] Iman Mallakpour & Gabriele Villarini, *The Changing Nature of Flooding Across the Central United States*, 5 NATURE CLIMATE CHANGE, 250, 250–54 (2015).

[80] *What Climate Change Means for Iowa*, EPA 1 (Aug. 2016), https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-ia.pdf.

[81] Chia Chou et al., *Increase in the Range Between Wet and Dry Season Precipitation*, 6 NATURE GEOSCIENCE, 263, 263–67 (2013).

[82] *Interior Rivers*, IOWA DEP'T OF NAT. RESOURCES, http://www.iowadnr.gov/Fishing/Where-to-Fish/Interior-Rivers (last visited Oct. 2, 2018).

[83] *Iowa Disaster History*, IOWA HOMELAND SECURITY & EMERGENCY MGMT., https://www.homelandsecurity.iowa.gov/disasters/iowa_disaster_history.html (last visited Oct. 2, 2018).

[84] *Iowa Flood Center: For Legislators*, U. IOWA, https://iowafloodcenter.org/resources/for-legislators/ (last visited Oct. 2, 2018).

[85] *Iowa Disaster History*, IOWA HOMELAND SECURITY & EMERGENCY MGMT., *supra.*

[86] *Id.*

[87] HENRY DEHAAN ET AL., USACE, MISS. VALLEY DIV., MISSISSIPPI RIVER AND TRIBUTARIES SYSTEM 2011 POST-FLOOD REPORT V-12 (2012).

flooding along the Missouri River led to hundreds of millions of dollars in damages[88] and also closed the river to navigation.[89] Iowa's Sioux City and Council Bluffs were two of the cities affected most by the flood, experiencing extensive property damage and crop loss.[90]

Iowa also has felt the impacts of climate change in its dry seasons. As recently as 2017, drought conditions throughout the state left locations with rainfall at less than 50 percent of normal precipitation.[91] In 2012, a prolonged drought cost the region more than $250 million when the scarcity of water led to narrowed navigation channels, forced lock closures, and dozens of barges running aground on the Mississippi River.[92]

Iowa has warmed between one-half to one degree in the last century, and a continued increase in temperature may lead to more challenges for Iowa's agricultural economy.[93] Iowa leads the nation in egg production, harvested acreage of principal crops, corn export value, corn for grain production, and hog and pig inventory.[94] Climate change may put additional heat stress on farmers' crops and livestock, posing a greater risk of substantial decreases in crop yields and livestock productivity.[95] Under some estimates, absent significant adaptation by Iowa farmers, the state could face declines in its corn crop of 18-77 percent—a significant blow to a corn industry currently worth nearly $10 billion.[96] Crop production can be inhibited by changing rain patterns such as wetter springs—which delay planting and increase flood risk—and less rain

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[88] DEP'T OF HOMELAND SEC., MISSOURI RIVER FLOOD COORDINATION TASK FORCE REPORT, 12, 39 (2011).

[89] David Bailey & David Hendee, *The Mighty Missouri River: The Flooding and the Damage Done*, (Sep. 3, 2011, 8:45 AM), http://www.reuters.com/article/us-missouri-flooding/the-mighty-missouri-river-the-flooding-and-the-damage-done-idUSTRE78213720110903.

[90] DEP'T OF HOMELAND SEC., MISSOURI RIVER FLOOD COORDINATION TASK FORCE REPORT, *supra,* at 39.

[91] Craig Cogil, *Extreme Drought Expands in Southern Iowa*, NAT'L WEATHER SERV. 1 (Sep. 18, 2017), https://www.weather.gov/media/dmx/Climate/Drought.pdf.

[92] U.S. ARMY CORPS OF ENG'RS, EVENT STUDY: 2012 LOW-WATER AND MISSISSIPPI RIVER LOCK 27 CLOSURES, 6–7, 37 (2013), http://www.lrd.usace.army.mil/Portals/73/docs/Navigation/PCXIN/Drought_2012_Report_-FINAL_2013-08-30.pdf; *See* Harry J. Hillaker, *The Drought of 2012 in Iowa*, IOWA DEP'T OF AGRIC. AND LAND STEWARDSHIP, http://www.iowaagriculture.gov/climatology/weatherSummaries/2012/DroughtIowa2012Revised.pdf (last visited Oct. 2, 2018).

[93] *What Climate Change Means for Iowa*, *supra*, at 1.

[94] *Iowa's Rank in United States Agriculture,* USDA (May 2018), https://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Rankings/IA-2018-Rankings.pdf.

[95] *What Climate Change Means for Iowa*, *supra*, at 2.; J. L. Hatfield et al., *Vulnerability of Grain Crops and Croplands in the Midwest to Climatic Variability and Adaptation Strategies*, 146 CLIMATIC CHANGE, 263, 263–64 (2018).

[96] Kate Gordon et al., *Heat in the Heartland: Climate Change and Economic Risk in the Midwest*, RISKY BUSINESS 33 (2015); http://riskybusiness.org/site/assets/uploads/2015/09/RBP-Midwest-Report-WEB-1-26-15.pdf

during the increasingly hot summers.[97] Farmers may also face the survival and spread of more unwanted pests because of warmer winters and a longer growing season.[98]

Climate change also puts Iowans' public health at risk. The higher temperatures can increase air pollutants such as ozone and fine particulates, which increase the risk of heart and lung-related illness.[99] Allergic diseases and asthma are expected to become more widespread and more severe due to exposure to new plants and increases in pollen counts.[100] The warmer, wetter climate can even increase the risk of infectious diseases transmitted by insects that will be better able to live in a more humid and warm Iowa environment.[101] Iowans' health risks will only likely increase as average temperatures continue to increase.

Maine

Maine is experiencing significant, negative effects of climate change through rising sea levels, ocean acidification, and invasive species that are expanding their range northward as the environment warms. By way of example, the Gulf of Maine is warming faster than 99% of the world's ocean waters.[102] These warmer waters have brought with them an invasion of non-native green crabs that are devastating soft-shell clam flats throughout southern and mid-coast Maine, and threaten Maine's $1.7 billion lobster industry.[103] At the same time, ocean waters globally have become approximately 30% more acidic over the last century, and features of the Gulf of Maine, including its extensive freshwater inputs, make it particularly vulnerable to acidification.[104] These symptoms of climate change threaten both the health of the State's marine ecosystem and a coastal economy that depends on it.

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[97] *What Climate Change Means for Iowa*, *supra*, at 1.

[98] Sara C. Pryor et al., *Midwest*, in CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT 418, 435 (J. M. Melillo et al. eds., 2014).

[99] *What Climate Change Means for Iowa*, *supra*, at 2.

[100] *Climate Change*, IOWA DEP'T OF NAT. RESOURCES , http://www.iowadnr.gov/Conservation/Climate-Change (last visited Oct. 2, 2018).

[101] *Id.*

[102] Woodard, C., *Mayday: Gulf of Maine in Distress*, Portland Press Herald, October 25, 2015, http://www.pressherald.com/2015/10/25/climate-change-imperils-gulf-maine-people-plants-species-rely/

[103] *Id.*; Dahlman, L, *Climate Change, Ocean Heat Content*, National Oceanic and Atmospheric Administration, https://www.climate.gov/news-features/climate-and/climate-lobsters; Hall, J., *From Bought to Caught, Lobsters all about Economics*, Portland Press Herald, August 11, 2012, http://www.pressherald.com/2012/08/11/market-forces-make-everyone-feel-the-pinch_2012-08-12/

[104] Gledhill, D.K., et al., Ocean and Coastal Acidification off New England and Nova Scotia. *Oceanography* 28(2):182–197, 2015, http://dx.doi.org/10.5670/oceanog.2015.41.https://climate.nasa.gov/evidence/; http://tos.org/oceanography/article/ocean-and-coastal-acidification-off-newengland-and-nova-scotia.

Similar changes are occurring in Maine's interior. Iconic species that drive the State's tourist economy are suffering from the effects of global warming. Longer, hotter summers and more frequent droughts are shrinking brook trout habitat[105] and undermining efforts to restore sea-run salmon in Maine's downeast rivers.[106] A plague of winter ticks brought on by decreased snowpack has taken a significant toll on Maine's moose population.[107] Milder winters have also hurt the ski industry,[108] while shorter and earlier springs are interfering with maple sugaring operations.[109]

Maryland

With more than 3,000 miles of coastline, Maryland's coast is particularly vulnerable to rising sea levels and the more extreme weather events associated with climate change: shoreline erosion, coastal flooding, storm surges, inundation, and saltwater intrusion into groundwater supplies.

In 2007, the Maryland Commission on Climate Change (MCCC) was established by Executive Order 01.01.2007.07 and was charged with evaluating and recommending state goals to reduce Maryland's greenhouse gas emissions to 1990 levels by 2020 and to reduce those emissions to 80 percent of their 2006 levels by 2050. The MCCC was also tasked with developing a plan of action that addressed the causes and impacts of climate change and included firm benchmarks and timetables for policy implementation. As a result of the work of more than 100 stakeholders and subject matter experts, the MCCC produced a climate action plan. That plan was the impetus for Maryland's Greenhouse Gas Emissions Reduction Act of 2009, an enhanced version of which became law in 2016.[110]

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[105] Pennsylvania State University, *For Trout Fishermen, Climate Change Will Mean More Driving Time, Less Angling*. ScienceDaily, August 20, 2015. www.sciencedaily.com/releases/2015/08/150820123648.htm.

[106] The National Academies Press, *Atlantic Salmon in Maine*, 2004, at 50-53, https://www.nap.edu/read/10892/chapter/5.

[107] Fleming, D., *Winter Ticks Raise Concerns about the Future of Maine's Moose Herd*, Portland Press Herald, June 14, 2014, http://www.pressherald.com/2014/06/14/winter-ticks-raise-concerns-about-future-of-maines-moose-herd/.

[108] Seelye, K., *Rising Temperatures Threaten Fundamental Change for Ski Slopes*, The New York Times, December 12, 2012, http://www.nytimes.com/2012/12/13/us/climate-change-threatens-ski-industrys-livelihood.html.

[109] Taylor, C., *How Climate Change Threatens Your Breakfast*, Science Friday, March 17, 2017, https://www.sciencefriday.com/segments/how-climate-change-threatens-your-breakfast/.

[110] Maryland Commission on Climate Change, 2016 Annual Report 7, http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MCCC_2016_final.pdf ("MCCC 2016 Annual Report").

As emphasized by the MCCC's Science and Technical Working Group, estimates show that "Maryland is projected to experience between 2.1 and 5.7 feet of sea level rise over the next century. In fact, sea level could be as much as 2.1 feet higher in 2050 along Maryland's shorelines than it was in 2000."[111]

Sea level rise could inundate some facilities of the Port of Baltimore, placing one of the most important ports along the East Coast at risk. In 2016, for instance, the Port generated nearly $3 billion in wages and salaries, supported over 13,000 direct jobs, and moved 31.8 million tons of international cargo.[112]

The state's tourism sector is also likely to feel the impact of climate change.[113] In 2015, for instance, tourism resulted in $2.3 billion in tax revenue, which directly supported more than 140,000 jobs with a payroll of $5.7 billion.[114] Rising sea levels, flooding, and heightened storm surges will place further strain on Maryland's low-lying urban and coastal lands, making tourism less feasible and increasing the costs of maintaining bridges, roads, boardwalks, and other tourism infrastructure.[115] Beaches, moreover, "will move inland at a rate 50 to 100 times faster than the rate of sea level elevation" and "the cost of replenishing the coastline after a 20-inch rise in sea level would be between $35 million and $200 million."[116]

Further, skiing and other snow sports "are at obvious risk from rising temperatures, with lower-elevation resorts facing progressively less reliable snowfalls and shorter seasons."[117] Wisp Mountain Park, for example, is a popular skiing destination in Western Maryland, and the only ski resort in the State. Even in late December of 2015, only one of the resort's 35 trails was open because of the difficulty keeping snow on the ground in above-freezing temperatures.[118]

Climate change may also adversely impact Maryland's agricultural industry, which employs some 350,000 people. [119] In 2015, the market value of agricultural products produced in

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[111] Maryland Commission on Climate Change, 2015 Annual Report 13, http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/MCCC2015Report.pdf ("MCCC 2015 Annual Report").

[112] Maryland Commission on Climate Change, 2017 Annual Report 12, http://www.mde.state.md.us/programs/Air/ClimateChange/MCCC/Documents/MCCC_2017_final.pdf ("MCCC 2017 Annual Report").

[113] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015, https://www.c2es.org/document/climate-change-the-cost-of-inaction-for-marylands-economy/.

[114] Maryland Office of Tourism Development, Fiscal Year 2016 Tourism Development Annual Report, 2016, available at: http://industry.visitmaryland.org/research/annual-reports/annual-reports-archive/.

[115] MCCC 2015 Annual Report 14, *supra*.

[116] MCCC 2017 Annual Report 16, *supra*.

[117] MCCC 2016 Annual Report 18-19, *supra*.

[118] MCCC 2017 Annual Report 15, *supra*.

[119] *Id.* at 13.

Maryland was $2.2 billion, with net farm income exceeding $500 million.[120] By 2050, absent additional action, rising summer temperatures could result in nearly $150 million in median annual losses for corn, soy, and wheat.[121] Increased flooding could adversely affect the stability, salinity, drainage, and nutrient balance of soil in low-lying areas, causing declines in crop production and making farming less viable. Rising seas could lead salt water to flow into aquifers used for irrigation. Livestock could suffer from higher temperatures, too, and would need more access to cooler areas. By causing soil erosion and nutrient runoff, moreover, increased rainfall could adversely affect water quality, including in the Chesapeake Bay.[122]

Climate change will have significant effects on forests, which contribute some $2.2 billion to the Maryland economy, as well as $24 billion in ecological services.[123] Climate change will exacerbate species' existing stressors and alter their distribution, with some species likely to leave or decline and others likely to arrive or increase. Further, the services that forests provide—such as temperature regulation and water filtration—may be affected by climate change.[124]

Climate change also threatens the Chesapeake Bay, the largest estuary in the United States. Development and pollution have made the Bay and its ecosystems more vulnerable to stressors, including those resulting from climate change. Already, the Bay has warmed by three degrees Fahrenheit. Further temperature increases could change the composition of commercial fisheries and deprive aquatic life of the oxygen needed to survive. Some species are likely to move north towards cooler waters and more suitable habitats. Other forms of aquatic life, including invasive pests and diseases, are likely to arrive or proliferate in the Bay's newly-warmed waters.[125]

In terms of health impacts, Maryland is likely to experience increasing numbers of 90-degree days, markedly exacerbating heat-related illnesses and mortality, particularly among the elderly.[126] A two-week heat wave in 2012, for instance, led to 12 deaths in Maryland.[127] By mid-century, rising temperatures could cause 27 additional deaths each summer in Baltimore alone.[128]

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[120] *Id.* at 14.

[121] MCCC 2015 Annual Report 15, *supra.*

[122] *Id.*

[123] *Id.*

[124] *Id.* at 15-16.

[125] *Id.* at 16.

[126] MCCC 2017 Annual Report 9, 17, *supra*.

[127] MCCC 2016 Annual Report 18-19, *supra*.

[128] *Id.*

Massachusetts

Temperatures in Massachusetts have warmed by an average of 1.3 degrees Celsius since 1895, almost twice as much as the rest of the contiguous 48 states. According to recent research by the University of Massachusetts, the Northeast, including Massachusetts, will continue to see temperatures rise higher more quickly than the rest of the United States and the world.[129]

Rising temperatures will result in milder winters with more freeze-thaw cycles and less precipitation falling as snow and instead as rain and freezing rain. Hotter summers will increase the number, intensity, and duration of heat waves and lead to poorer air quality.[130] Massachusetts already has the nation's highest incidence of pediatric asthma: among Massachusetts children in kindergarten to eighth grade, more than 12 percent suffer from pediatric asthma, and 12 percent of Massachusetts's adult population suffers from asthma.[131] Warmer temperatures increase ground level ozone, which impairs lung function and can result in increased hospital admissions and emergency room visits for people suffering from asthma, particularly children. Higher temperatures and carbon dioxide levels also will cause plants to produce more pollen, which can exacerbate asthma and other respiratory illnesses. More extreme heat also presents health hazards for people, including increased cardiovascular disease, Type II diabetes, renal disease, nervous disorders, emphysema, epilepsy, cerebrovascular disease, pulmonary conditions, mental health conditions, and death—especially for our most vulnerable residents.

The Northeast has seen the country's largest increases in heavy precipitation events (more than a 70-percent increase in the heaviest 1 percent of all events since 1958).[132] Some areas in Massachusetts have shown an increasing trend in the number of days with two inches of precipitation or more from 1970-2008. For example, over the last 60 years, the Connecticut River basin has experienced more than a doubling of heavy rainfall events. Regionally, the majority of heavy precipitation events have occurred during the summer months of May through September.[133] One hundred-year flood events are now occurring every 60 years, and 50-year floods are now occurring approximately every 30 years. Flooding has increased in association with extreme precipitation events, causing costly property damage and putting fish, wildlife, and their habitats at increased risk. Since 1990, Massachusetts has been affected by numerous major

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[129] Horton et al., *Northeast*, in CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT, 373 (2014), at http://nca2014.globalchange.gov/report/regions/northeast; *see also* EPA, Fact Sheet: What Climate Change Means for Massachusetts (Aug. 2016), at https://ia801602.us.archive.org/9/items/climate-change-ma/climate-change-ma.pdf.

[130] Massachusetts Department of Public Health*, Capacity to Address the Health Impacts of Climate Change in Massachusetts*, 6 (April 2014), at http://www.mass.gov/eohhs/docs/dph/environmental/exposure/climate-change-report-2014.pdf.

[131] *Id*; Centers for Disease Control and Prevention, 2014 Adult Asthma Data: Prevalence Tables and Maps, *at* https://www.cdc.gov/asthma/brfss/2014/tableC1.htm; Massachusetts Department of Public Health, Pediatric Asthma, *at* https://matracking.ehs.state.ma.us/Health-Data/Asthma/pediatric.html.

[132] Horton, *supra*, at 373.

[133] Massachusetts Climate Action Partnership, *Massachusetts Wildlife Climate Action Tool – Stressors: Storms and floods* (2015), at https://climateactiontool.org/content/storms-and-floods.

weather disasters, including Superstorm Sandy and Tropical Storm Irene.[134] Superstorm Sandy, a post-tropical storm in 2012, was the most extreme and destructive event to affect the northeastern United States in 40 years and the second costliest in the Nation's history. Storm impacts in Massachusetts included strong winds, record storm tide heights, flooding of some coastal areas and loss of power for 385,000 residents.[135] Massachusetts suffered an estimated $375 million in property losses alone.[136] In January 2018, the storm surge from a powerful winter storm caused major coastal flooding and resulted in a high tide in Boston of 15.16 feet, the highest tide since records began in 1921, even surpassing the infamous Blizzard of 1978.[137] And two months later, a March coastal storm resulted in a 14.67 feet Boston tide (the third-highest on record[138]), damaged 2,113 homes, including 147 that were destroyed, and caused more than $24 million in flooding damage across six Massachusetts coastal counties.[139]

Beyond the damage that more intense storms can cause homes, businesses, and private and public infrastructure generally, such events also threaten the aging combined sewer and stormwater systems serving many Massachusetts cities such as Boston and Lowell. Heavy precipitation and coastal flooding can overwhelm these systems and release untreated sewage to our rivers and coastal waters, threatening public health and water quality.[140]

Massachusetts is a coastal state especially vulnerable to sea level rise caused by climate change, which is already exacerbating coastal flooding and erosion from storm events and will eventually inundate low-lying communities, including the City of Boston. Roughly 5 million Massachusetts residents—75% of the state's population—live near the coast.[141] The total output of the Massachusetts coastal economy was $249.2 billion in 2014, representing over 54% of the state's annual gross domestic product, and coastal counties accounted for 53% of the state's

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[134] Runkle et al., *Massachusetts State Summary*, NOAA TECHNICAL REPORT NESDIS 149-MA, 4 (2017), at https://statesummaries.ncics.org/MA.

[135] *Id.*

[136] *Id.*

[137] Martin Finucane, *It's official: Boston breaks tide record*, BOSTON GLOBE, Jan. 5, 2017, *at* https://www.bostonglobe.com/metro/2018/01/05/official-boston-breaks-tide-record/UPbwDxgF0QXNOWvB9bcQ7L/story.html.

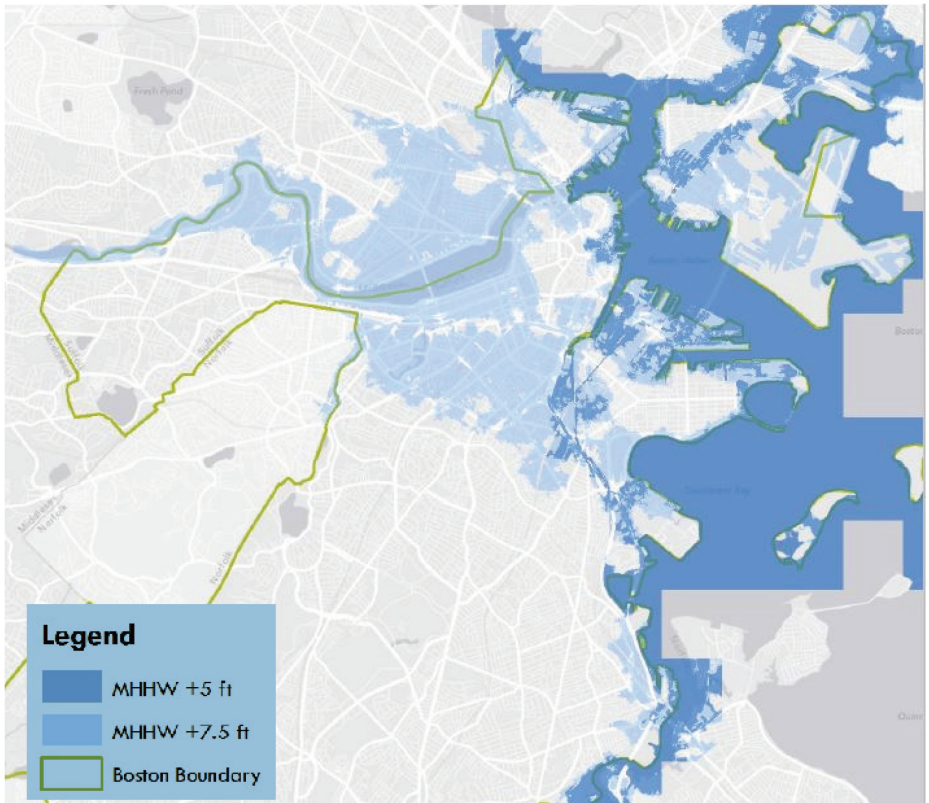
[138] Christina Prignano, *The Noon High Tide Was Bad, but the Midnight High Tide Could Be Worse,* BOSTON GLOBE, March 2, 2018, *at* https://www.bostonglobe.com/metro/2018/03/02/the-noon-high-tide-was-bad-but-midnight-high-tide-will-worse/m4O1PR8HRIoLsmx3mp2YvO/story.html.

[139] Christian M. Wade, *Baker Seeks Federal Disaster Funds for Storm Damages*, LAWRENCE EAGLE-TRIBUNE, May 1, 2018, *at* https://www.eagletribune.com/news/merrimack_valley/baker-seeks-federal-disaster-funds-for-storm-damages/article_d2f0c7b4-bd75-5a8b-8a0c-4dedbe44a7b4.html.

[140] City of Boston, *Climate Ready Boston, Final Report*, 290 (December 2016), *at* https://www.boston.gov/sites/default/files/20161207_climate_ready_boston_digital2.pdf.

[141] NOAA, National Coastal Population Report, 9 (2013), *at* https://aamboceanservice.blob.core.windows.net/oceanservice-prod/facts/coastal-population-report.pdf.

employment and wages.[142] According to the National Climate Assessment, in Boston alone, cumulative damage to buildings, building contents, and associated emergency costs could potentially be as high as $94 billion between 2000 and 2100, depending on the sea level rise scenario and which adaptive actions are taken.[143]



Mean high high water (MHHW) plus 5 and 7.5 feet in Boston.

Increased sea level, combined with increased erosion rates, is also predicted to threaten Massachusetts' barrier beach and dune systems. Development on the beaches themselves, as in the case of Plum Island, will continue to face challenges associated with erosion and storm damage. Barrier beaches will be more susceptible to erosion and overwash, and in some cases breaching. Such breaching will put at risk extensive areas of developed shoreline located behind these barrier spits and islands, such as the shorelines of Plymouth, Duxbury, and Kingston. Engineered structures, such as seawalls designed to stabilize shorelines, could be overtopped. The cost of maintaining and upgrading these engineering structures and replenishing dunes and beaches damaged by erosion will increase as sea levels rise, requiring investments of millions of dollars by local governments.[144] Large areas of critical coastal and estuarine habitat, including the North Shore's Great Marsh—the largest continuous stretch of salt marsh in New

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[142] NAT'L OCEAN ECONOMICS PROGRAM, STATE OF THE U.S. OCEAN AND COASTAL ECONOMIES: COASTAL STATES SUMMARIES – 2016 UPDATE 29 (2016), *at* http://midatlanticocean.org/wp-content/uploads/2016/03/CoastalStatesSummaryReports_2016.pdf

[143] Horton, *supra*, at 379.

[144] For one example, a recent, large-scale beach replenishment project in Winthrop, Massachusetts secured $26 million in state funds for completion. See Beth Daley, *Sand Wars Come to New England*, BOSTON GLOBE, (Dec. 15, 2013), *available at* https://www.bostonglobe.com/lifestyle/health-wellness/2013/12/15/sand-wars-come-new-england-coast/F2ClK6e20wtcZeCoUQC9AM/story.html.

England, extending from Cape Ann to New Hampshire—are at risk as they will be unable to adapt and migrate as sea level rises and local land subsides.[145]

Massachusetts already is seeing what climate change means for our natural resources. The signs of spring—including the arrival of migratory birds and the blooming of wildflowers and other plants—are arriving earlier. Warmer temperatures also are contributing to the rise in deer populations in Massachusetts, resulting in loss of underbrush habitat for forest species and the spread of tick-borne diseases such as Lyme disease. As the Gulf of Maine is warming much faster than other water bodies, key cold-water ocean fisheries, including cod and lobster, are in decline. The timing of the migration of anadromous fish species, such as Atlantic salmon and alewives, has advanced in the last few decades, and they are migrating earlier in the season.[146]

Minnesota

Minnesota's climate is changing, and it's already affecting residents' health and the state's environment and economy. Rising temperatures may interfere with winter recreation, extend the growing season, change the composition of trees in the North Woods, and increase water pollution problems in lakes and rivers. The state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

The Minnesota Pollution Control Agency (MPCA) is a member of Minnesota's Environmental Quality Board (EQB). EQB's 2015 "Minnesota and Climate Change: Our Tomorrow Starts Today" report, outlines many changes our state is already experiencing as a result of climate change.[147] Minnesota is getting warmer and increases in temperatures means ice cover on lakes is forming later and melting sooner, which impacts traditional winter sports and tourism; the ragweed pollen season is increasing; and Minnesota is seeing a rise in tick- and mosquito-borne illnesses; among other current and expected impacts.

Minnesota has gotten noticeably warmer, especially over the last few decades. The temperature in the state has increased 1°F to 2°F since the 1980s.[148] Since the beginning of

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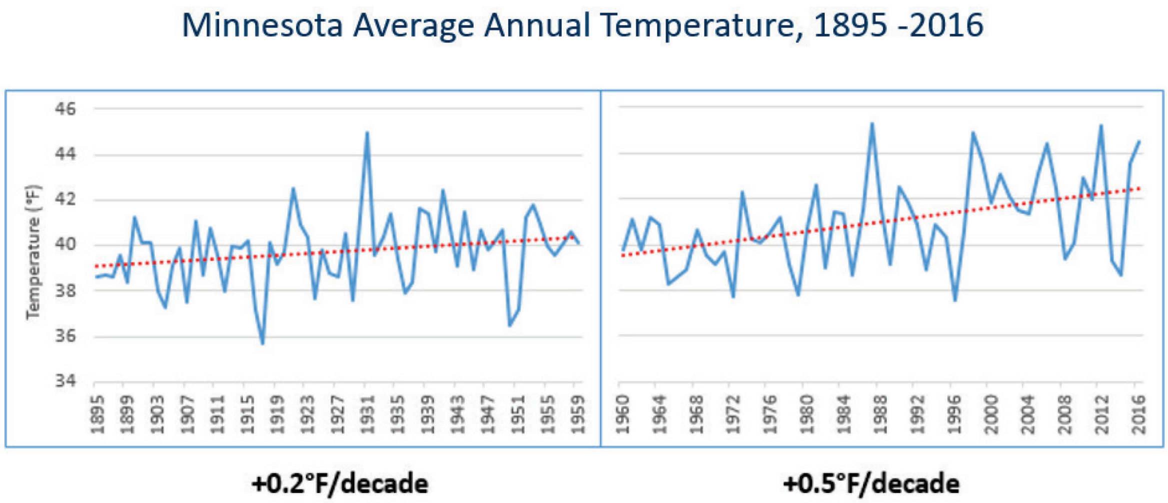
[145] City of Boston, *Climate Ready Boston, supra*, at 60.

[146] EPA, Fact Sheet: What Climate Change Means for Massachusetts, *supra*; Massachusetts Climate Action Partnership, *supra* note 99, *Ecology and Vulnerability: Alewife*, *at* http://climateactiontool.org/species/alewife.

[147] Environmental Quality Board, "Minnesota and Climate Change: Our Tomorrow Starts Today"(2015), *available at* https://www.eqb.state.mn.us/content/climate-change

[148] *Minnesota and Climate Change: Our Tomorrow Starts Today*, at 6, available at: (https://www.eqb.state.mn.us/content/climate-change) (hereinafter "Minnesota and Climate Change,") citing *Climate at a Glance: Time Series* (n.d.) (retrieved July 2014, from National Climactic Data Center, available at: http://www.ncdc.noaa.gov/cag/time-series)) and Zandlo, J. (2008, March 13), *Climate Change and the Minnesota State Climatology Office: Observing the Climate* (retrieved July 2, 2014, from Minnesota Climatology Working Group, *available at* http://climate.umn.edu/climateChange/climateChangeObservedNu.htm); *see also* Pryor, S. C. et al., 2014: *Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment*,

the data record (1895) through 1959, Minnesota's annual average temperature increased by nearly 0.2°F per decade, which is equivalent to over 2°F per century. This is shown in the graph at the left (below). This warming effect has accelerated over the last 50 plus years. Data from 1960-2016 show that the recent rate of warming for Minnesota has sped up substantially to over 0.5°F per decade, which is equivalent to 5.0°F per century. This is shown in the graph to the right (below).

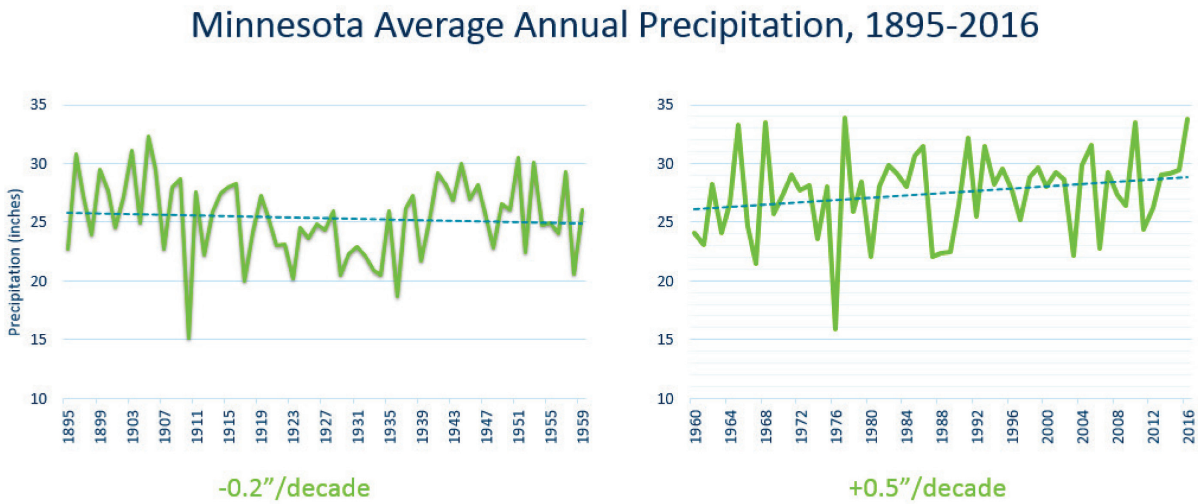


Source: NOAA, 2017

With a warming atmosphere, more evaporation occurs. The graph on the left (below) highlights the trend for the early part of the last century, 1895-1959, while the graph on the right (below) highlights the trend for the most recent half century, 1960-2016. For most of the first half of the 20th century, the trend in precipitation was slightly downward, at a loss of 0.2 inches per decade or the equivalent of -2 inches per century. This downward trend was influenced by the Dust Bowl years of the 1930s. However, the rate of precipitation across the state has increased by nearly 0.5 inches per decade or the equivalent of 5 inches per century over the last 50+ years.[149]

J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N.

[149] *See* Minnesota Dep't of Health, *Climate Change in Minnesota*, www.health.state.mn.us/divs/climatechange/climate101.html (last visited Oct. 24, 2018) (relying on NOAA data)



Source: NOAA, 2017

Floods are becoming more frequent. According to EPA, over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent, with greater inter-annual variability.[150] But rainfall during the four wettest days of the year has increased about 35 percent.[151] Yearly frequency of the largest storms – those with three inches or more of rainfall in a single day – have more than doubled in just over 50 years.[152] In the past decade, such dramatic rains have increased by more than 70 percent. Since 2004, Minnesota has experienced three 1,000-year floods and an increase in intense weather events including hailstorms, tornadoes and droughts. In 2007, we saw several counties in the state receive drought designation, while others were declared flood disasters – an occurrence that repeated itself in 2012 when 11 counties declared flood emergencies while 55 received drought designations.

Climate change impacts outside of Minnesota have affected our air quality and our health. Since 2015, thirteen of seventeen air quality alerts issued by the Minnesota Pollution Control Agency are directly attributable to wildfires or forest fires in Canada or the western United States.

Climate change has caused financial impacts to Minnesota as well. In 2013, Minnesota had some of the highest weather-related disaster claims in the nation. Since 1997, 32 severe weather natural disasters have cost Minnesota nearly $500 million in natural disaster recovery

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[150] U.S. EPA, *What Climate Change Means for Minnesota* (August 2016), *available at*: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwibxob4l4zXAhXs6YMKHcl0BnUQFggoMAA&url=https%3A%2F%2Fwww.epa.gov%2Fsites%2Fproduction%2Ffiles%2F2016-09%2Fdocuments%2Fclimate-change-mn.pdf&usg=AOvVaw13tl9K6gVwgwua3_nhSUzk

[151] *Id.*

[152] Minnesota and Climate Change, *supra*, at 6; *see also* Saunders, S. et al., *Doubled Trouble: More Midwestern Extreme Storms. Rocky Mountain Climate Organization; Natural Resources Defense Council* (2012).

assistance to affected jurisdictions alone.[153] The impacts of climate change are expected to worsen in Minnesota, affecting our economy, our ecosystems and the health of all Minnesotans.

New Mexico

The Southwest and New Mexico are experiencing the effects of climate change at a rate much faster than the majority of U.S. states. Warming trends in the southwestern U.S. have exceeded global averages by nearly 50 percent since the 1970s, and average temperatures in New Mexico have been increasing 50 percent faster than the global average over the past century.[154] Temperatures in the Upper Rio Grande River basin are increasing at a rate of roughly 0.7° F per decade, contributing to an average warming of 2.7° F since 1970.[155] Mountains have shown a higher rate of temperature rise when compared to lower elevations.[156] Both minimum and maximum monthly temperatures also show rising trends. The number of very hot days and nights -- defined as temperatures above the warmest 10 percent of days on record -- has increased since 1950. Heat waves lasting longer than four days have also significantly increased since 1960.[157] These occurrences do not only affect a specific part of the state; over 95 percent of New Mexico has experienced mean temperature increases.[158]

Key findings from the Third U.S. National Climate Assessment (Assessment) for the Southwest include:

- Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems.[159] (This is a critical issue for New Mexico because the state's social, economic and environmental

[153] Minnesota and Climate Change, *supra*, at 6; *see also* Office of the Legislative Auditor, State of Minnesota (2012), *Helping Communities Recover from Natural Disasters: Evaluation Report Summary*

[154] Nature Conservancy, *Implications of Recent Climate Change*, at iii; Robert Repetto, *New Mexico's Rising Economic Risks from Climate Change*, DĒMOS, at 1 (2012).

[155] Jason Funk et al., *Confronting Climate Change in New Mexico* at 6-7, 9 (Union of Concerned Scientists, April 2016); www.ucsusa.org/NewMexicoClimateChange (last visited Oct. 18, 2018).

[156] Dagmar Llewellyn & Seshu Vaddey, *West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment*, at 1, 37-38, 117 (U.S. Department of Interior, Bureau of Reclamation, Dec. 2013); https://www.usbr.gov/watersmart/baseline/docs/urgia/URGIAMainReport.pdf (last visited Oct. 19, 2018).

[157] Repetto, Robert, *New Mexico's Rising Economic Risks from Climate Change*, at 1, *available at* https://www.demos.org/sites/default/files/publications/UpdatedNMFullReport.pdf (last visited Oct. 24, 2018); *see also* Nature Conservancy, *Implications of Recent Climate Change*, *supra*, at 4.

[158] Nature Conservancy, *Implications of Recent Climate Change*, *supra*, at iii.

[159] U.S. Global Change Research Program, *2014 National Climate Assessment*, at 463 (2014), *available at* https://nca2014.globalchange.gov/report/regions/southwest%0D (last visited Jan. 8, 2018).

systems are already water-scarce and thus vulnerable to the supply disruptions which are likely to accompany future climate changes.[160]).

- Increased warming, drought, and insect outbreaks caused by or linked to climate change have increased the frequency of catastrophic wildfires impacting people and ecosystems in the Southwest. Fire models project more wildfire and increased risks to communities across extensive areas.[161]

- The Southwest's 182 federally recognized tribes and communities share particularly high vulnerabilities to climate changes such as high temperatures, drought, forest fires, and severe storms. Tribes may face loss of traditional foods, medicines, and water supplies due to declining snowpack, increasing temperatures, increasing drought, forest fires, and subsequent flooding. Historic land settlements and high rates of poverty – more than double that of the general United States population – constrain tribes' abilities to respond effectively to climate challenges.[162]

- The Southwest produces more than half of the nation's high-value specialty crops, which are irrigation-dependent and particularly vulnerable to extremes of moisture, cold, and heat. Reduced yields from increasing temperatures and increasing competition for scarce water supplies will displace jobs in some rural communities.[163]

- Increased frost-free season length, especially in already hot and moisture-stressed regions like the Southwest, is projected to lead to further heat stress on plants and increased water demands for crops. Higher temperatures and more frost-free days during winter can lead to early bud burst or bloom of some perennial plants, resulting in frost damage when cold conditions occur in late spring; in addition, with higher winter temperatures, some agricultural pests can persist year-round, and new pests and diseases may become established.[164]

Key findings from the Assessment for New Mexico include:

- Streamflow totals in the Rio Grande and other rivers in the Southwest were 5 percent to 37 percent lower between 2001 and 2010 than average flows during the 20th century.

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[160] Brian H. Hurd & Julie Coonrod, *Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities*, NM State University, Technical Report 45, at 1, 24 (2008); https://aces.nmsu.edu/pubs/research/economics/TR45.pdf (last visited Oct. 18, 2018).

[161] *Id.*

[162] The White House, Office of the Press Secretary, *FACT SHEET: What Climate Change Means for New Mexico and the Southwest*, at 3 (2014), *available at* https://obamawhitehouse.archives.gov/sites/default/files/docs/state-reports/NEWMEXICO_NCA_2014.pdf (last visited Oct. 18, 2018); *see also Confronting Climate Change in New Mexico, supra,* at 6-7, 9.

[163] U.S. Global Change Research Program, *2014 National Climate Assessment*, *supra*, at 463.

[164] *Id.*

Projections of further reduction of late-winter and spring snowpack and subsequent reductions in runoff and soil moisture pose increased risks to water supplies needed to maintain cities, agriculture, and ecosystems.[165]

- Drought and increased temperatures due to climate change have caused extensive tree death across the Southwest. Winter warming due to climate change has exacerbated bark beetle outbreaks by allowing more beetles, which normally die in cold weather, to survive and reproduce.[166] Wildfire and bark beetles killed trees across one fifth of New Mexico and Arizona forests from 1984 to 2008.[167] Climate changes caused extensive piñon pine mortality in New Mexico between 1989 and 2003.[168]

- Exposure to excessive heat can aggravate existing human health conditions, such as respiratory and heart disease. Increased temperatures can reduce air quality because atmospheric chemical reactions proceed faster in warmer conditions. As a result, heat waves are often accompanied by increased ground level ozone, which can cause respiratory distress. Increased temperatures and longer warm seasons will lead to shifts in the distribution of disease-transmitting mosquitoes.[169]

Additionally, a recent study led by Los Alamos National Laboratories found that greenhouse gas-driven warming may lead to the death of 72 percent of the Southwest's evergreen forests by 2050, and nearly 100 percent mortality of these forests by 2100.[170]

If action is not taken to reduce greenhouse gas emissions, climate models project substantial changes in New Mexico's climate over the next 50 to 100 years. Barring reduction efforts, projected climate changes by mid- to late 21st century include: air temperatures warming by 6-12 degrees Fahrenheit on average, but more so in winter, at night, and at high elevations; more episodes of extreme heat, fewer episodes of extreme cold; more intense storm events and flash floods; and winter precipitation falling more often as rain and less often as snow.[171] Severe and sustained drought will stress water sources, already over-utilized in many areas, forcing

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[165] *Id.*

[166] *Id.*

[167] *Id.* at 468.

[168] *Id.* at 484.

[169] *What Climate Change Means for New Mexico and the Southwest*, *supra*, at 2-3.

[170] Chris Mooney, *Scientists say climate change could cause a 'massive' tree die-off in the U.S. Southwest*, WASH. POST, Dec. 21, 2015, *available at* https://www.washingtonpost.com/news/energy-environment/wp/2015/12/21/scientists-say-climate-change-could-cause-a-massive-tree-die-off-in-the-southwest/ (last visited March 14, 2019); McDowell, N.G., et al., "Multi-scale predictions of massive conifer mortality due to chronic temperature rise," in *Nature Climate Change* 6, 295-300 (Dec. 2015), https://doi.org/10.1038/NCLIMATE2873.

[171] *Confronting Climate Change in New Mexico, supra,* at 3.

increasing water-allocation competition among farmers, energy producers, urban dwellers, and ecosystems.[172]

New York

New York has begun to experience adverse effects from climate change. In 2014, the New York Attorney General's Office released a report, *Current and Future Trends in Extreme Rainfall Across New York State*, which highlights dramatic increases in the frequency and intensity of extreme rain storms across New York.[173] As but one example, devastating rainfall from Hurricane Irene in 2011 dropped more than 11 inches of rain in just 24 hours, causing catastrophic flooding in the Hudson Valley, eastern Adirondacks, Catskills and Champlain Valley. Thirty-one counties were declared disaster areas. Over 1 million people were left without power, more than 33,000 had to seek disaster assistance, and 10 were killed. Damage estimates totaled $1.3 billion. While no individual storm can be tied to climate change, the trends in extreme rainfall already being felt across New York State are consistent with scientists' predictions of new weather patterns attributable to climate change.

Hurricane Irene Flooding

Image from ABC 7 Eyewitness News

[172] *What Climate Change Means for New Mexico and the Southwest*, *supra*, at 1-2.

[173] *Current & Future Trends in Extreme Rainfall Across New York State, A Report from the Environmental Protection Bureau of the New York State Attorney General* (Sept. 2014) (based on data from the 2014 National Climate Assessment and the National Oceanographic and Atmospheric Administration's Northeast Regional Climate Center), available at: https://ag.ny.gov/pdfs/Extreme_Precipitation_Report%209%202%2014.pdf

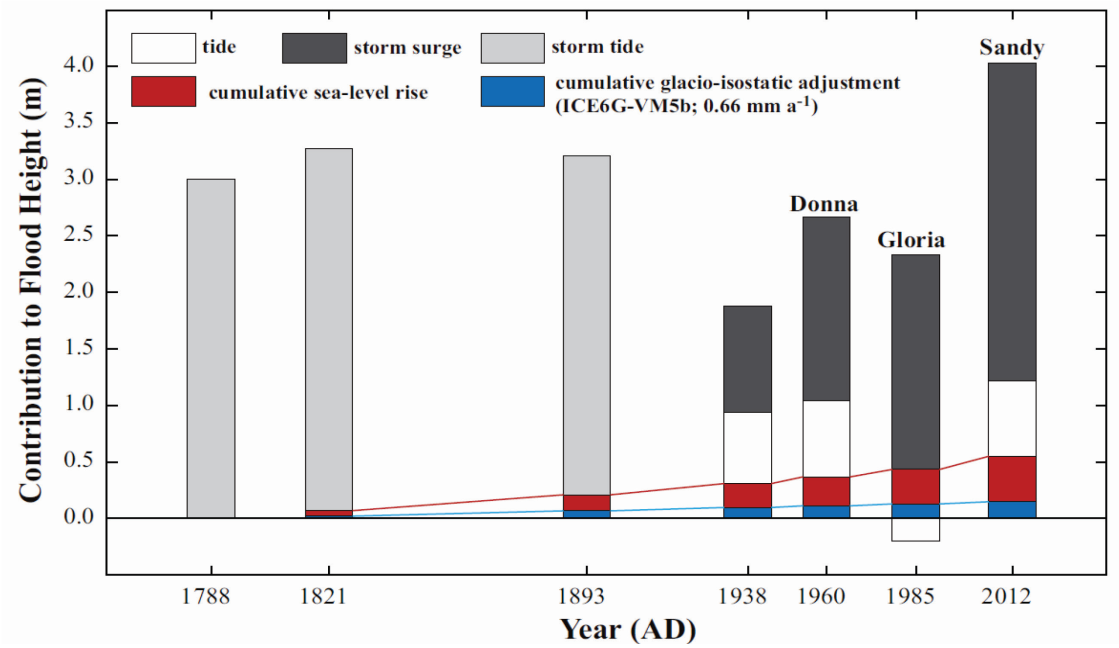
Similarly, in August 2014, a weather front stalled over Long Island, dumping more than 13½ inches of rain—nearly an entire summer's worth—in a matter of hours and breaking the state's rainfall record. That deluge flooded out over 1,000 homes and businesses, opened massive sinkholes on area roadways, and forced hundreds to evacuate to safer ground. Initial damage estimates exceeded $30 million.

Historic Long Island Flash Flooding

Image from NYTimes (Andrew Theodorakis/Getty Images)

Also, New York's rate of sea level rise is much higher than the national average and could account for up to 6 feet of additional rise by 2100 if greenhouse gas emissions are not abated. Storm surge on top of high tide on top of sea level rise is a recipe for disaster for coastal New York. The approximately 12 inches of sea level rise New York City has experienced since 1900 may have expanded Hurricane Sandy's flood area by about 25 square miles, flooding the homes of an additional 80,000 people in the New York City area alone.[174] That flooding devastated areas of New York City, including the Brooklyn-Queens Waterfront, the East and South Shores of Staten Island, South Queens, Southern Manhattan, and Southern Brooklyn, which in some areas lost power and other critical services for extended periods of time.

[174] New York City Panel on Climate Change 2015 Report, Chapter 2: Sea Level Rise and Coastal Storms. Ann. N.Y. Acad. Sci. ISSN 0077-8923, available at: http://onlinelibrary.wiley.com/doi/10.1111/nyas.12593/full



Estimated Contribution to Flood Heights in New York City for Notable Historical Hurricanes[175]

Hurricane Sandy exposed critical weaknesses in the resilience of New York's utility infrastructure, the danger that this weakness poses to New Yorkers, and the collateral damage to the economy:

- Almost 2 million utility customers suffered from electricity outages;
- Tens of thousands of utility customers were left without power for weeks;
- Hospitals were shut down and patients displaced;
- Many drinking water utilities lost power, which disrupted their ability to provide safe water; and sewage treatment plants could not operate, resulting in billions of gallons of untreated or partially treated sewage flowing into local waterways.

The costs of Hurricane Sandy to New York alone will likely top $40 billion, including $32.8 billion to repair and restore damaged housing, parks and infrastructure and to cover economic losses and other expenses. That figure includes $9.1 billion to help mitigate and prevent potential damages from future severe weather events.[176]

Of course, sea level rise will not stop in 2100, nor in 2200 especially if a high GHG emission scenario continues, resulting in locked-in or "committed" sea level rise over hundreds or thousands of years, drastically altering New York's coastline and disrupting our

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[175] Kemp et al., Contribution of relative sea-level rise to historical hurricane flooding in New York City, *Journal of Quaternary Science 28(6), at* 537-541 (2013).

[176] *See* State of New York, *Governor Cuomo Holds Meeting with New York's Congressional Delegation, Mayor Bloomberg and Regional County Executives to Review Damage Assessment for the State in the Wake of Hurricane Sandy*, available at: https://www.governor.ny.gov/news/governor-cuomo-holds-meeting-new-yorks-congressional-delegation-mayor-bloomberg-and-regional

communities.[177] The figure below[178] illustrates the inundation in portions of New York City resulting from the committed sea level rise expected from 4ºC (7.2ºF) of warming.[179], Note that in the ongoing rulemaking for the Safe Vehicles Rule, the National Highway Traffic Safety Administration has determined that taking no policy actions to reduce CO2 emissions will cause global surface temperature in 2100 to increase to 3.48ºC[180], close to the 4ºC warming represented in the figure.

Although New York has taken a number of actions to reduce pollutants such as nitrogen oxides and volatile organic compounds that contribute to ground level ozone (smog) formation, ozone pollution remains a persistent problem. Much of New York City and Long Island have not attained the 2008 ozone standards, much less the more protective 2015 standards. A significant amount of the pollutants that contribute to smog is generated in upwind states and carried by prevailing winds into New York and other northeastern states. As the climate warms, increased temperatures create more favorable conditions for the formation of smog. According to the Third National Assessment on Climate Change, for example, under a scenario in which greenhouse

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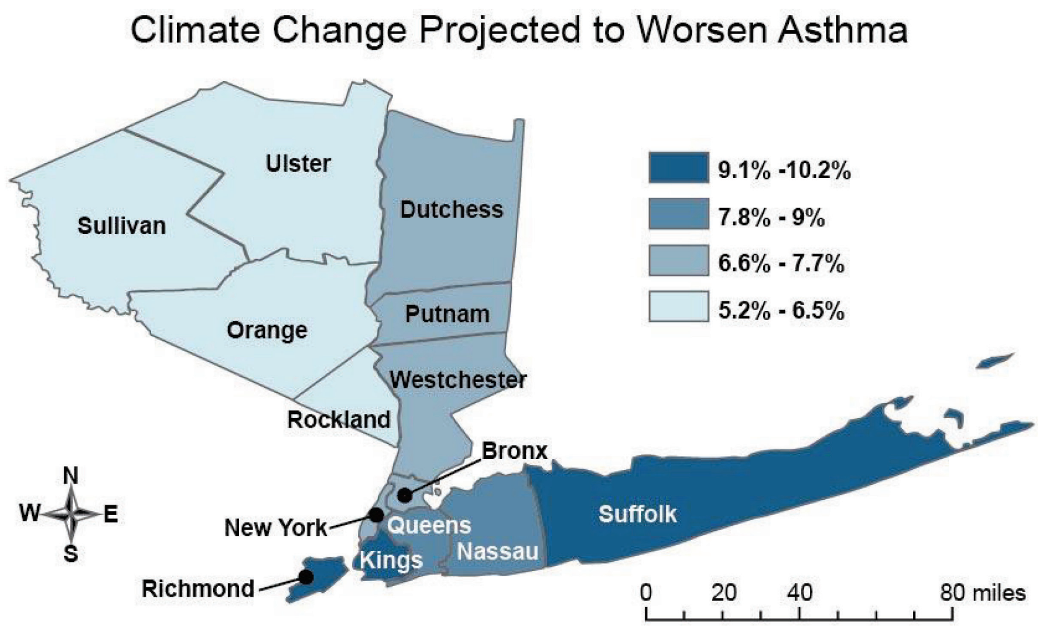
[177] U.S. Global Change Research Program, 2014 National Climate Assessment, at 345.

[178] Data file available at http://sealevel.climatecentral.org/maps/google-earth-video-global-cities-at-risk-from-sea-level-rise

[179] Carbon choices determine US cities committed to futures below sea level. Strauss,B.H., S. Kulp, and A. Levermann. PNAS November 3, 2015 112 (44) 13508-13513, *available at* https://doi.org/10.1073/pnas.1511186112

[180] Draft Environmental Impact Statement for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021–2026 Passenger Cars and Light Trucks. NHTSA. July 2018. Docket No. NHTSA-2017-0069. 500 pp.

gases continue to increase, this would lead to higher ozone concentrations in the New York metropolitan region, driving up the number of ozone-related emergency room visits for asthma in the area by 7.3 percent--more than 50 additional ozone-related emergency room visits per year in the 2020s, compared to the 1990s.[181] The figure below, included in that report, shows that projected worsening in asthma cases in the New York City area.



North Carolina

The effects of climate change have been felt and will continue to be felt from the mountains to the sea and across every sector of North Carolina's economy.

With approximately 3,375 miles of shoreline,[182] North Carolina is particularly vulnerable to the effects of sea-level rise. In its 2010 Sea Level Rise Assessment Report, the North Carolina Coastal Resource Commission's Science Panel on Coastal Hazards concluded that a 39-inch rise in sea levels was likely to occur on the North Carolina coast in the next century.[183] The Panel's

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[181] U.S. Global Change Research Program, *2014 Third National Assessment on Climate Change*, at 222 (citing Sheffield, P. E., J. L. Carr, P. L. Kinney, and K. Knowlton, Modeling of regional climate change effects on ground level ozone and childhood asthma. American Journal of Preventive Medicine, 41, 251-257 (2011), *available at* http://download.journals.elsevierhealth.com/pdfs/journals/0749-3797/PIIS0749379711003461.pdf)

[182] NOAA Office for Coastal Management, Shoreline Mileage of the United States, https://coast.noaa.gov/data/docs/states/shorelines.pdf.

[183] N.C. Coastal Resource Commission Science Panel, North Carolina Sea-Level Rise Assessment Report (March 2010), available at

2015 update predicted that sea levels would rise by 1.9 to 10.6 inches at different locations along North Carolina's coast by 2045.[184]

Because of eastern North Carolina's low-lying topography, North Carolina faces extensive loss of land to inundation from sea-level rise.[185] In 2014, the North Carolina Division of Emergency Management concluded that over the century, North Carolina could see the inundation of 800 square miles of North Carolina's coastal plain, representing 9% of the land area in North Carolina's 20 coastal counties.[186] Another study predicted that 13 North Carolina communities will face chronic inundation from sea level rise by 2035 and that a further 36 communities will experience chronic inundation by 2100.[187]

North Carolina sits within a frequent hurricane path, making its coastal region especially vulnerable to hurricanes and inland flooding. This year, Hurricane Florence claimed the lives of 44 people in North Carolina and caused an estimated $17 billion in damage.[188] The storm shattered the previous rainfall record set by Hurricane Floyd in 1999 of 24.06 inches. During the hurricane, Elizabethtown, North Carolina saw 35.93 inches of rainfall and Swansboro, North Carolina saw more than 33 inches of rainfall.[189] A rainfall meteorologist at North Carolina State University calculated that Hurricane Florence, compared to all storms in the United States over the last 70 years, produced the second highest amount of rain in a concentrated (14,000 square mile) land area.[190] On the meteorologist's list, four of the top seven storms occurred in the last

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https://files.nc.gov/ncdeq/Coastal%20Management/documents/PDF/Coastal%20Hazards%20Storm%20Information/NC_Sea_Level_Rise_Assessment_Report_2010_CRC_Science_Panel.pdf.

[184] N.C. Coastal Resource Commission Science Panel, North Carolina Sea-Level Rise Assessment Report: 2015 Update to 2010 Report and 2012 Addendum (March 31, 2015), available at https://files.nc.gov/ncdeq/Coastal%20Management/documents/PDF/Science%20Panel/2015%20NC%20SLR%20Assessment-FINAL%20REPORT%20Jan%2028%202016.pdf.

[185] North Carolina Department of Public Safety, North Carolina Emergency Management Geospatial and Technology Management, North Carolina Sea Level Rise Impact Study: Final Study Report (June 2014).

[186] *Id.*

[187] Union of Concerned Scientists, When Rising Seas Hit Home: Fact Sheet: North Carolina Faces Chronic Inundation (July 2017), *available at* https://www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-northcarolina-fact-sheet.pdf.

[188] Press Release, North Carolina Governor's Office, Six Months After Florence Made Landfall, North Carolina Continues Work to Rebuild (Mar. 12, 2019), https://governor.nc.gov/news/six-months-after-florence-made-landfall-north-carolina-continues-work-rebuild; Press Release, North Carolina Governor's Office, Updated Estimates Show $17 Billion in Damage (Oct. 31, 2018), https://governor.nc.gov/news/updated-estimates-show-florence-caused-17-billion-damage.

[189] WRAL-TV, Record Rainfall: Some Saw Almost 3 Feet from Florence (Sept. 17, 2018), *available at* https://www.wral.com/florence-causes-record-rainfall-/17850750/.

[190] Borenstein, S., Florence Is Nation's Second Wettest Storm, Behind Harvey, WFTV (Sep. 27, 2018), *available at* https://www.wftv.com/weather/eye-on-the-tropics/florence-is-nation-s-second-wettest-storm-behind-harvey/842701535.

three years.[191] In 2016, Hurricane Matthew had devastating impacts on many of the same areas of eastern North Carolina, killing at least 27 people and causing some $1.5 billion in damage, from which the state is still recovering.[192]

The amount of rainfall and flooding these hurricanes have brought used to be extremely rare in North Carolina, but it is not rare anymore. Based on pre-climate change weather patterns, Hurricane Florence's rainfall was described as an event that eastern North Carolina could expect to occur only once every 1000 years.[193] Hurricane Matthew, a 500-year flood event,[194] hit eastern North Carolina just two years before Florence. As Governor Cooper of North Carolina said, "We have to understand that when you have two so-called 500-year floods within 22 months of each other, [we're] not sure you're talking about [a] 500-year flood anymore. We've got something else on our hands."[195] A third 500-year flood event, caused by Hurricane Floyd, struck eastern North Carolina in 1999.[196] That makes three 500-year (or longer) flood events to hit eastern North Carolina in the past 19 years.

Climate change presents severe health risks for North Carolina's citizens, especially vulnerable populations such as the elderly and children. The North Carolina Department of Health and Human Services has evaluated health risks associated with climate change impacts such as increased drought, increased precipitation, heat waves, hurricanes, and sea-level rise.[197] The health risks associated with these impacts include:

- Waterborne disease outbreaks, increased foodborne illnesses, and compromised drinking water quality.
- Increases in mosquito populations after hurricanes and high rain events.
- Physical injuries caused by hurricanes, flooding, high winds, droughts, and heat waves.
- Respiratory illness caused by prolonged drought periods.

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[191] *Id.*

[192] Federal Emergency Management Agency, Six Months Following Hurricane Matthew, Volunteers Work for North Carolina Progress (April 6, 2017), *available at* https://www.fema.gov/news-release/2017/04/06/six-months-following-hurricane-matthew-government-partners-volunteers-work.

[193] Risk Management Solutions, Hurricane Florence: Rainfall up to a 1,000-Year Return Period (Sep. 14, 2018), *available at* https://www.rms.com/blog/2018/09/14/hurricane-florence-rainfall-up-to-a-1000-year-return-period/.

[194] Office of Water Prediction, National Weather Service, Hurricane Matthew, 6-10 October 2016 Annual Exceedance Probabilities (AEPs) for the Worst Case 24-Hour Rainfall (prepared Oct. 18, 2016), *available at* http://www.nws.noaa.gov/ohd/hdsc/aep_storm_analysis/AEP_HurricaneMatthew_October2016.pdf.

[195] Perchick, M., Florence Flooding: Gov. Cooper Continues Survey of Flood Damage, Announces Housing Assistance Program, WTVD-TV (Sept. 22, 2018), *available at* https://abc11.com/florence-flooding-gov-cooper-continues-survey-of-flood-damage/4314903/.

[196] Millner, M., University of North Carolina, Remembering Hurricane Floyd (Oct. 2009), *available at* https://docsouth.unc.edu/highlights/floyd.html.

[197] N.C. Department of Health and Human Services, Division of Public Health, North Carolina Climate and Health Profile (March 2015), *available at* http://epi.publichealth.nc.gov/oee/climate/ClimateAndHealthProfile.pdf.

- Lung disease and premature death from heart or lung disease from increased ground-level ozone formed by rising temperatures.[198]

Droughts caused by climate change can make a forest more prone to wildfires,[199] creating another major risk to North Carolinians' health. Between October and November of 2016, thirty fires scorched 80,000 acres in drought-stricken western North Carolina counties. State air quality officials detected 24 instances of code orange conditions during the fires, 11 instances of code red, two in code purple and two in code maroon. Fine particulate matter from wildfires is an existing threat to North Carolinians' health, causing increases in respiratory and cardiovascular emergencies in downwind communities.[200]

Climate change also harms North Carolina's agriculture and agribusiness sector, which is largely based in the eastern part of the state and contributed $84 billion to North Carolina's economy in 2016.[201] Major crops include corn, cotton, tobacco, sweet potatoes, pork, turkey, and chicken. Increasingly severe droughts cause crop failures, and higher temperatures reduce livestock productivity.[202] Saltwater intrusion from sea level rise can make soils too salty for native plants to grow, impacting crop yields.[203] North Carolina's forestry industry would suffer similar impacts from saltwater intrusion, and increasingly severe and frequent hurricanes would damage North Carolina's forestlands. One study in North Carolina predicted that forest damages rise by $500 million for every increase in category level of hurricane.[204]

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198 *Id.*

199 *Id.*

200 N.C. Department of Health and Human Services, Division of Public Health, North Carolina Climate and Health Adaptation Plan Update (2016), *available at* http://epi.publichealth.nc.gov/oee/climate/ClimateAndHealthAdaptationPlan.pdf.

201 Brian Long, Today's Topic: Economic impact of NC agriculture, agribusiness increases to $84 billion, In the Field, N.C. Dep't of Agriculture and Consumer Services (June 7, 2016), *available at* http://info.ncagr.gov/blog/2016/06/07/todays-topic-economic-impact-of-nc-agriculture-agribusiness-increases-to-84-billion/

202 EPA, What Climate Change Means for North Carolina (August 2016), *available at* https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-nc.pdf

203 N.C. Department of Environmental Quality, Division of Coastal Management, Sea Level Rise, https://deq.nc.gov/about/divisions/coastal-management/coastal-management-hot-topics/sea-level-rise (last visited Jan. 4, 2018)

204 University of Maryland, Center for Integrative Environmental Research, Economic Impacts of Climate Change on North Carolina (Sept. 2008), *available at* http://cier.umd.edu/climateadaptation/North%20Carolina%20Economic%20Impacts%20of%20Climate%20Change%20Full%20Report.pdf.

North Carolina's tourism industry, which generated $22.9 billion in visitor spending in 2016, is also at risk.[205] Tourism is threatened by loss of beach areas due to sea level rise and decrease in demand for coastal travel due to unpredictable weather patterns.[206]

North Carolina is already incurring significant transportation and infrastructure costs due to climate change impacts. Large numbers of North Carolina's coastal railways, ports, airports, and water and energy supply systems are at low elevations and are therefore vulnerable to the effects of sea level rise and more frequent hurricanes.[207] The North Carolina Department of Transportation is raising the roadbed of U.S. Highway 64 across the Albemarle-Pamlico Peninsula by four feet, which includes 18 inches to account for sea level rise.[208]

Finally, climate change harms North Carolina's tremendous ecological resources, such as its coastal estuaries. North Carolina's coastal estuaries perform essential functions, including filtering pollutants and supporting fisheries.[209] Disruption of these important resources from storm damage and salt water intrusion negatively impacts fisheries and depletes water quality.

Oregon

Oregon is already experiencing adverse impacts of climate change and these impacts are expected to become more pronounced in the future, significantly affecting Oregon's economy and environment:

Loss of Snowpack and Drought

The seasonal flow cycles of rivers and streams are changing due to warmer winters and decreased mountain snowpack accumulation, as more precipitation falls as rain, not snow.[210] The Third Oregon Climate Assessment Report[211] explained that events in 2015 demonstrated the kind of impacts this has already had, and will have in the future:

> In 2015, Oregon was the warmest it has ever been since record keeping began in 1895 (NOAA, 2017). Precipitation during the winter of that year was near normal, but winter temperatures that were 5–6°F above average caused the precipitation that did fall to fall

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[205] North Carolina Tourism Generates Record Employment and Visitor Spending in 2016, Economic Development Partnership of North Carolina (May 8, 2017), *available at* https://edpnc.com/north-carolina-tourism-generates-record-employment-visitor-spending-2016/

[206] University of Maryland, Economic Impacts of Climate Change on North Carolina, *supra*.

[207] EPA, What Climate Change Means for North Carolina*, supra.*

[208] U.S. Global Change Research Program, National Climate Assessment (2014), https://nca2014.globalchange.gov/report/regions/southeast.

[209] N.C. Department of Environmental Quality, Sea Level Rise, *supra*.

[210] P. Zion Klos et al., *Extent of the Rain-Snow Transition Zone in the Western U.S. Under Historic and Projected Climate*, 41 Geophysical Res. Letters 4560, 4560–68 (2014).

[211] *The Third Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, January 2017.

> as rain instead of snow, reducing mountain snowpack accumulation (Mote et al., 2016). This resulted in record low snowpack across the state, earning official drought declarations for 25 of Oregon's 36 counties. Drought impacts across Oregon were widespread and diverse:
>
> Farmers in eastern Oregon's Treasure Valley received a third of their normal irrigation water because the Owyhee reservoir received inadequate supply for the third year in a row (Stevenson, 2016) …
>
> People near the Upper Klamath Lake were warned not to touch the water as algal blooms that thrived in the low flows and warm waters produced extremely high toxin levels (Marris, 2015) …
>
> More than half of the spring spawning salmon in the Columbia River perished, likely due to a disease that thrived in the unusually warm waters (Fears, 2015) …
>
> The West Coast–wide drought developed alongside a naturally-driven large, persistent high-pressure ridge (Wise, 2016). However, anthropogenic warming exacerbated the drought, particularly in Oregon and Washington (Mote et al., 2016; Williams et al., 2015) …
>
> Oregon's temperatures, precipitation, and snowpack in 2015 are illustrative of conditions that, according to climate model projections, may be considered "normal" by mid-century.[212]

And there has been more bad news since 2015. In 2018, researcher John Abatzoglou reported that:

> Drought impacts are being felt most notably in Oregon, which endured a period of substandard snowpack followed by unusually dry and warm conditions since May. The impacts cover the gamut from fire to farms to fish …
>
> Fishing restrictions have been enacted in the Umpqua River in western Oregon due to critically warm stream temperatures for steelhead and salmon. The combination of very

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[212] *Id.* at 12-13, citing: P. W. Mote et al.,. *Perspectives on the causes of exceptionally low 2015 snowpack in the western United States.(*2016).; D. Fears, *As salmon vanish in the dry Pacific Northwest, so does Native heritage*, Washington Post (2015); J. Stevenson, *Documenting the Drought*, The Climate CIRCulator (2016); E..Marris*, In the Dry West, Waiting for Congress*, The Klamath Tribes Tribal News and Events (2015); A.P. Williams et al., *Contribution of anthropogenic warming to California drought during 2012-14,* Geophysical Research Letter, 2015.

low flows—including recent daily record low flows—due to subpar precipitation and warm temperatures have allowed water temperatures to warm faster than usual.[213]

Sea Level Rise

Ocean sea levels will rise between four inches and four-and-a-half feet on the Oregon coast by the year 2100, and coastal residents, cities and towns along Oregon's 300 miles of coastline and 1400 miles of tidal shoreline will be threatened by increased flooding and erosion as a result. Residential development, state highways, and municipal infrastructure are all at risk to such threats.[214]

Ocean Acidification and Hypoxia

As a result of climate change, ocean waters are now more acidified, hypoxic (low oxygen), and warmer, and such impacts are projected to increase, with a particular detrimental impact on some marine organisms like oysters and other shellfish, which will threaten marine ecosystems, fisheries and seafood businesses that play a vital role in Oregon's economy and culture.[215] As the Third Oregon Climate Assessment Report observed, "[T]he West Coast has already reached a threshold and negative impacts are already evident, such as dissolved shells in pteropod populations … and impaired oyster hatchery operations …"[216]

The Oregon Coordinating Council on Ocean Acidification and Hypoxia recently reported that "[n]ew research points to an ever-growing list of marine organisms that are now known to be vulnerable to the threats of ocean acidification and hypoxia (OAH). The list includes species such as Dungeness crabs, rockfishes and salmon that underpin livelihoods and connections to the sea for many Oregonians."[217]

In March of 2017, KVAL TV in Eugene, Oregon chronicled the experience of the Whiskey Creek Hatchery off Netarts Bay in Tillamook, Oregon. Manager Alan Barton said that "[w]e probably produce about a third of all oyster larvae on the West Coast." But in 2007 and 2008, hatchery output collapsed by 75%. Working with scientists from Oregon State University,

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[213] Abatzoglou, "Drought Returns to the Pacific Northwest," OCCRI Climate Circulator (August 2018).

[214] *See* W. Spencer Reeder et al., *Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines*, *in Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities* 67–109 (Meghan M. Dalton et al. eds., 2013); Ben Strauss et al., Climate Cent., *California, Oregon, Washington and the Surging Sea: A Vulnerability Assessment with Projections for Sea Level Rise and Coastal Flood Risk* 29 (2014).

[215] *See* Francis Chan et al., Cal. Ocean Sci. Tr., *The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions* (2015); Julia A. Ekstrom et al., *Vulnerability and Adaptation of U.S. Shellfisheries to Ocean Acidification*, 5 Nature Climate Change 207, 207–14 (2015).

[216] *Third Oregon Climate Assessment Report, supra,* at 36.

[217] Oregon Coordinating Council on Ocean Acidication and Hypoxia, 1st Biennial Report, at 8, September 15, 2018.

Whiskey Creek identified ocean acidification as the problem. They developed a way to treat the water at the hatchery, which has been successful. But Barton does not believe that treatment is a long-term solution:

> "The short term prospects are pretty good. But within the next couple of decades we're going to cross a line I don't think we're going to be able to come back from," he says. "A lot of people have the luxury of being skeptics about climate change and ocean acidification. But we don't have that choice. If we don't change the chemistry of the water going into our tanks, we'll be out of business. It's that simple for us."[218]

Forests, Pests and Fires

Oregon is largely defined by its iconic forests, which climate change threatens in a myriad ways, as the Third Oregon Climate Assessment Report detailed:

> Future warming and changes in precipitation may considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century. Changing climatic suitability and forest disturbances from wildfires, insects, diseases, and drought will drive changes to the forest landscape in the future. Conifer forests west of the Cascade Range may shift to mixed forests and subalpine forests would likely contract. Human-caused increases in greenhouse gases are partially responsible for recent increases in wildfire activity. Mountain pine beetle, western spruce budworm, and Swiss needle cast remain major disturbance agents in Oregon's forests and are expected to expand under climate change. More frequent drought conditions projected for the future will likely increase forest susceptibility to other disturbance agents such as wildfires and insect outbreaks.
>
> Future warming and changes in precipitation may considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century (Littell et al., 2013). Furthermore, the cumulative effects of changes due to wildfire, insect infestation, tree diseases, and the interactions between them, will likely dominate changes in forest landscapes over the coming decades (Littell et al., 2013). ..
>
> Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States, particularly in forested ecosystems (Dennison et al., 2014; Jolly et al., 2015; Westerling, 2016; Williams and Abatzoglou, 2016). The lengthening of the fire season is largely due to declining mountain snowpack and earlier spring snowmelt (Westerling, 2016). In the Pacific Northwest, the fire season length increased over each of the last four decades, from 23 days in the 1970s, to 43 days in the 1980s, 84 days in the 1990s, and

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[218] KVAl-TV, '*One morning we came in and everything was dead': Climate Change and Oregon oysters*, March 1, 2017.

> 116 days in the 2000s (Westerling, 2016). Recent wildfire activity in forested ecosystems is partially attributed to human-caused climate change: during the period 1984–2015, about half of the observed increase in fuel aridity and 4.2 million hectares (or more than 16,000 square miles) of burned area in the western United States were due to human-caused climate change (Abatzoglou and Williams, 2016).[219]

Health Effects

An increase in forest fire activity is one of the various ways in which climate change threatens human health. As the Third Oregon Climate Assessment noted, "Climate change threatens the health of Oregonians. More frequent heat waves are expected to increase heat-related illnesses and death. More frequent wildfires and poor air quality are expected to increase respiratory illnesses."[220] For example:

> Climate change is expected to worsen outdoor air quality. Warmer temperatures may increase ground level ozone pollution, more wildfires may increase smoke and particulate matter, and longer, more potent pollen seasons may increase aeroallergens (Fann et al., 2016). Such poor air quality is expected to exacerbate allergy and asthma conditions and increase respiratory and cardiovascular illnesses and death (Fann et al., 2016).[221]

Oregon has already experienced a dramatic increase in "unhealthy air days" due to forest fires. The Medford metro region experienced 20 air quality alert days due to fire from 1985 through 2001, 19 of those in one year. From 2002 through 2012, Medford had 22 such days. But since 2013, Medford has had 74 such days, including 20 in 2017 and 35 in 2018.[222] Portland, meanwhile, had a total of two such days from 1985 through 2014 – but 13 such days from 2015 through 2018.[223]

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[219] *The Third Oregon Climate Assessment Report* , citing J.T. Abatzoglou and A.P. Williams, *Impact of anthropogenic climate change on wildfire across western US forests.*, Proceedings of the National Academy of Sciences 113 (2016); P.E. Dennison et al, *Large wildfire trends in the western United States, 1984–2011*, Geophysical Research Letters 41 (2014); J.SD. Littell et al., *Forest ecosystems: Vegetation, disturbance, and economics,* Chapter 5. In: Dalton, Mot, and Snover(eds) *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Island Press, Washington, DC (2013); A. L. Westerling , *Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring*. Phil. Trans. R. Soc. B 371 (2016).

[220] *Third Oregon Climate Assessment Report, supra,* at 74.

[221] *Id.,* citing N. Fann et al.,Ch. 3: *Air Quality Impacts. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. US Global Change Research Program*, Washington, DC (2016).

[222] In addition to the impact on human health, fires in the Medford area have punished a beloved Oregon institution, the Oregon Shakespeare Festival in Ashland. In 2018 alone, the Festival had to cancel – or move indoors, to smaller venues – 20 performances, costing the Festival money and ruining many theater-goers' plans. *Wildfire Smoke Disrupts Oregon Shakespeare Festival*, New York Times, August 24, 2018.

[223] Oregon DEQ, *Forest Fire Smoke Impact on Air Quality Health Trends in Bend, Klamath Falls, Medford, and Portland (1985 to 2018),* DEQ18-NWR-0066-TR (October 2018). It is worth noting

During the 2017 Eagle Creek fire, the Oregon Health Authority (OHA) reported a 29% increase in emergency room visits for respiratory symptoms in the Portland metro region.[224]

In its 2014 Oregon Climate and Health Profile Report, OHA elaborated on the health effects of wildfire smoke:

> Particulate matter (PM) in smoke from wildfires is associated with cancer, cardiopulmonary disease and respiratory illness … As a result of projected increases in wildfire, Spracklen et al. (2009) anticipate an increase in aerosol organic carbon of up to 40% and an increase in elemental carbon in the western U.S. of up to 20% in 2046–2055 compared to 1996–2005 … PM associated with wildfires in California has been shown to be more toxic to the lungs than normal ambient PM … PM exposure from wildfire smoke is a risk beyond the immediate area of the fire, since high winds can carry the PM long distances … Increases in smoke are associated with hospital admissions for respiratory complaints, and long-term exposure worsens existing cardiopulmonary disease … bronchitis and pneumonia.[225]

Impact on American Indian Tribes

As the Legislative Summary of the Third Oregon Climate Assessment Report observed:

> Changes in terrestrial and aquatic ecosystems will affect resources and habitats that are important for the sovereignty, culture, economy, and community health of many American Indian tribes. Tribes that depend upon these ecosystems, both on and off reservation, are among the first to experience the impacts of climate change. Of particular concern are changes in the availability and timing of traditional foods such as salmon,

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that although air quality alerts are often limited to especially vulnerable populations – "unhealthy for sensitive groups" – Medford in 2017-18 has experienced 38 days in which the air was unhealthy for all populations, including five "very unhealthy" days and one "hazardous" day.

[224] Statewide Fire Activation Surveillance Report (090517-090617), Oregon Health Authority.

[225] Oregon Climate and Health Profile Report at 39 (Oregon Health Authority, Public Health Division, 2014), citing C.A. Pope et al,. *Cardiovascular mortality and long-term exposure to particulate air pollution: Epidemiological evidence of general pathophysiological pathways of disease,* Circulation. 2004;109:71–7.; C.A. Pope and D.Q. Dockery, Dockery, *Health effects of fine particulate air pollution: lines that connect*., Journal of the Air & Waste Management Association (1995). 2006;56:709–42; World Health Organization. *Review of Evidence on Health Aspects of Air Pollution–REVIHAAP Projec*t (2013.) J.L, Mauderly and J.C. Chow , *Health effects of organic aerosols. Inhalation toxicology.* 2008;20:257–88; T.C.Wegesser and K.E. Pinkerton KE, J.A. Last, *California wildfires of 2008: coarse and fine particulate matter toxicity,* Environmental Health Perspectives. 2009;117:893–7.; M. Ginsberg et al. *Monitoring Health Effects of Wildfires Using the BioSense System--San Diego County, California*, October 2007. Morbidity and Mortality Weekly Report. 2008;57(27):741–4; R.J. Delfino et al., *The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003*, Occupational and Environmental Medicine. 2009;66:189–97.

shellfish, and berries, and other plant and animal species important to tribes' traditional way of life.[226]

The threat that climate change poses to salmon populations is a particular source of concern for the tribes:

> A 2015 study of Columbia River Basin tribes, including the Confederated Tribes of Warm Springs (CTWS) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), found that the primary concerns regarding climate change impacts included the quantity and quality of water resources, snowpack, water temperatures for spawning conditions, and fishing rights (Sampson, 2015). Pacific salmon have great cultural, subsistence, and commercial value to tribes in the Pacific Northwest, and are central to tribal cultural identity, longhouse religious services, sense of place, livelihood, and the transfer of traditional values to the next generation (Dittmer, 2013). During the last 150 years, culturally important salmon populations have declined (Dittmer, 2013). Continuation of past trends of earlier spring peak, more extreme high flows and more frequent low flows in the low elevation basins of northeast Oregon, home to the CTWS and CTUIR, may force earlier migration of juvenile salmon, challenge returning adults in low flow conditions, and increase scour risk for emerging young salmon (Dittmer, 2013).[227]
> Page 58:

The threat that climate change poses to forests is likewise a major concern for tribes:

> Changes in forest ecosystems and disturbances will affect resources and habitats that are important for the cultural, medicinal, economic, and community health of tribes (Lynn et al., 2013). In Oregon, 62% of tribal reservation land is forested, and the US government has a trust responsibility toward such forests (Indian Forest Management Assessment Team, 2013). American Indian and Alaska Native tribes that depend on forest ecosystems, whether on or off reservations, are among the first to experience the impacts that climate change is having on forests, such as the expansion of invasive species, insects, diseases, and wildfires (Norton-Smith et al., 2016). Invasive species that displace native species can negatively affect tribal subsistence and ceremonial practices, although there is little knowledge about on how climate change will interact with invasive species (Norton-Smith et al., 2016). Increasing wildfire, insects, and diseases have jeopardized the economic and ecological sustainability of tribally managed forests and important tribal resources (Indian Forest Management Assessment Team, 2013; Norton-Smith et al., 2016). Collaborative adaptive forest management that integrates tribal traditional

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[226] *The Third Oregon Climate Assessment Report, supra,* (Legislative Summary).

[227] K. Dittmer, *Changing streamflow on Columbia basin tribal lands—climate change and salmon*, Climatic Change 120(3) (2013); D. Sampson, *Columbia River Basin Tribes Climate Change Capacity Assessment*, Institute for Tribal Government, Hatfield School of Government, Portland State University: Portland, OR (2015)

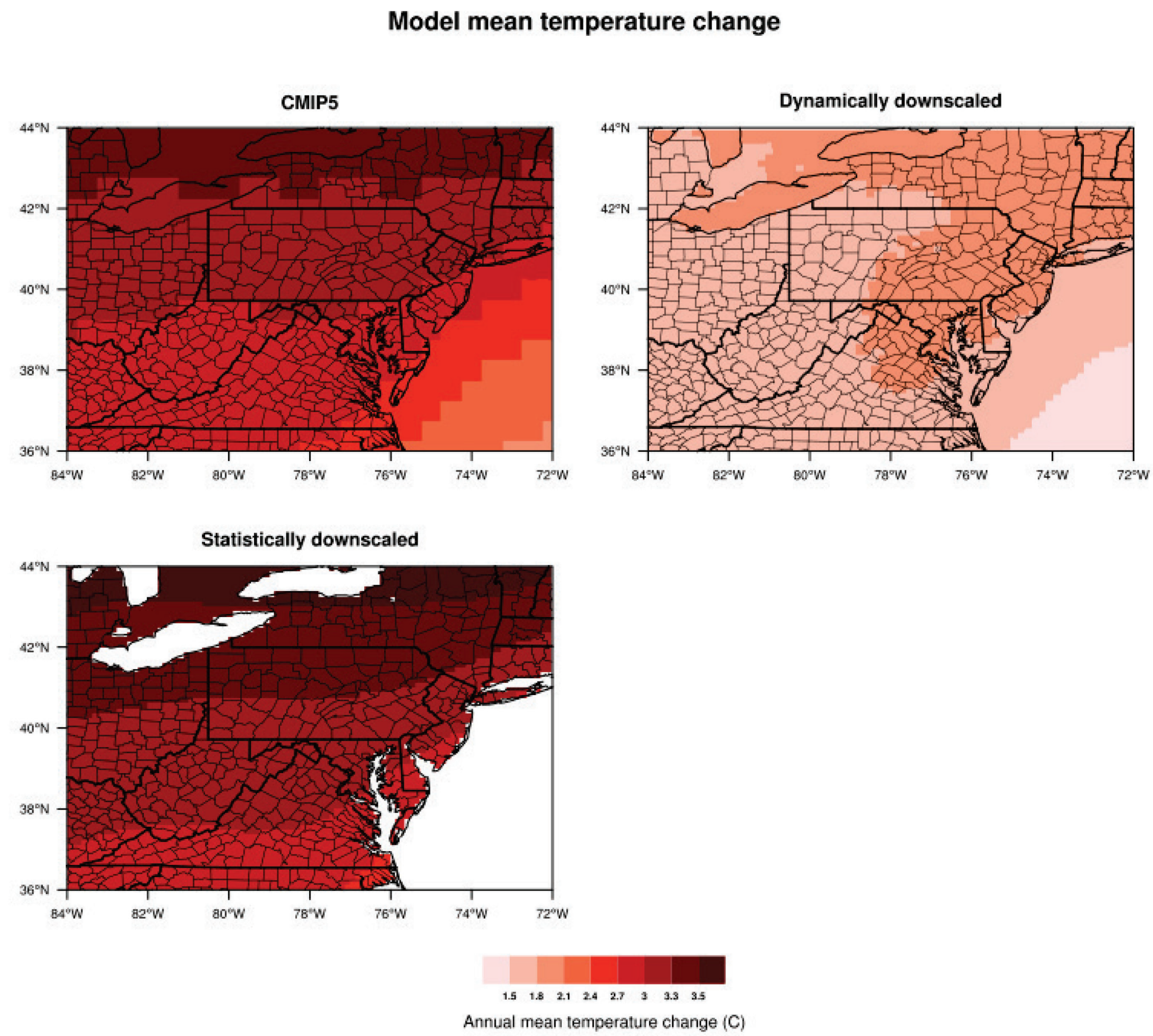
ecological knowledge can support socio-ecological resilience to climate change (Armatas et al., 2016).[228]

Pennsylvania

The Commonwealth of Pennsylvania faces two fundamental threats related to climate: (1) sea level rise and its impact on communities and cities in the Delaware River Basin, including the city of Philadelphia; and (2) more frequent extreme weather events, including large storms, periods of drought, heat waves, heavier snowfalls, and an increase in overall precipitation variability. Based on studies commissioned by the Pennsylvania Department of Environmental Protection, as part of its mandate under the Pennsylvania Climate Change Act, 71 P.S. §§ 1361.1 – 1361.8, Pennsylvania has undergone a long-term warming of more than 1°C over the past 110 years.[229] The models used in the 2015 Climate Impacts Assessment Update suggest this warming is a result of anthropogenic influence, and that this trend is accelerating. Projections in the 2015 Update show that by the middle of the 21st century, Pennsylvania will be about 3°C warmer than it was at the end of the 20th century.

[228] Citing C. Armatas et al., *Opportunities to utilize traditional phenological knowledge to support adaptive management of social-ecological systems vulnerable to changes in climate and fire regimes*, Ecology and Society 21 (2016) ; *Assessment of Indian Forests and Forest Management in the United States,* Indian Forest Management Assessment Team (2013) ; K. Lynn et al., *Northwest Tribes: Cultural Impacts and Adaptation Resources*: Chapter 8. In: M. M. Dalton et al., *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Island Press: Washington, DC (2013),; K. Norton-Smith et al., *Climate change and indigenous peoples: a synthesis of current impacts and experiences* (2016). .

[229] *See* "Pennsylvania Climate Impacts Assessment Update," May 2015, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-108470/2700-BK-DEP4494.pdf. *See also* "Pennsylvania Climate Impacts Assessment Update," October 2013, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-97037/PA%20DEP%20Climate%20Impact%20Assessment%20Update.pdf; "Pennsylvania Climate Assessment," June 2009, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-75375/7000-BK-DEP4252.pdf.



Modeling charts from the 2015 Update show that in both the CMIP5 and statistically downscaled CMIP5 datasets, mid-century temperatures in the Philadelphia region are projected to be similar to historical temperatures in the Richmond, VA area. Similarly, Pittsburgh's temperatures are projected to resemble the historically observed temperatures in the Baltimore-Washington area. The mean warming across the state simulated by these models is generally 3.0-3.5 °C (5.4-6.3°F). The CMIP5 model mean change is 3.0-3.3 °C (5.4-6.0 °F) across nearly the entire state. The statistically downscaled CMIP5 model mean change is 3.3-3.5 °C (5.9-6.3°F) in the northern half of the state and 3.0-3.3 °C (5.4-6.0°F) in the southern half. Finally, the dynamically downscaled dataset model mean change is only 1.5-1.8 °C (2.7-3.2°F) across the western half of the state and 1.8-2.1 °C (3.2-3.8 °F) across the eastern half. The reduced warming is likely at least partially because these models rely on a different emissions scenario, in which the buildup of greenhouse gases in the atmosphere occurs at a slower rate than in the than in the scenarios that the CMIP5 models use.

The 2015 Climate Impacts Assessment Update also finds that this warming trend will threaten Pennsylvania in other ways:

- Pennsylvania agriculture will have to adapt to by greater extremes in temperature and precipitation.[230] Pennsylvania dairy production is likely to be negatively affected by climate change due to losses in milk yields caused by heat stress, additional energy and capital expenditures to mitigate heat stress, and lower levels of forage quality.

- Pennsylvania's forests will be subject to multiple stressors.[231] The warming climate will cause tree species inhabiting decreasingly suitable habitat to become stressed. Mortality rates are likely to increase and regeneration success is expected to decline for these tree species, resulting in declining importance of those species in the state.

- Suitable habitat for plant and wildlife species is expected to shift to higher latitudes and elevations.[232] This will reduce the amount of suitable habitat in Pennsylvania for species that are at the southern extent of their range in Pennsylvania or that are found primarily at high latitudes; the amount of habitat in the state that is suitable for species that are at the northern extent of their range in Pennsylvania will increase. The Canada lynx, which is already rare in Pennsylvania, will likely be extirpated from the state.

- The public health of Pennsylvanians is threatened because climate change will worsen air quality relative to what it would otherwise be, causing increased respiratory and cardiac illness.[233] The linkage between climate change and air quality is most strongly established for ground-level ozone creation during summer, but there is some evidence that higher temperatures and higher precipitation will result in increased allergen (pollen and mold) levels as well.

- West Nile disease is endemic in Pennsylvania.[234] It is currently most prevalent in Southeastern and Central parts of the state, and less prevalent in the Laurel Highlands and the Allegheny Plateau. However, climate change is expected to increase the prevalence of West Nile disease in the higher-elevation areas, due to higher temperatures. In addition to its range, the duration of the transmission season for West Nile disease is sensitive to climate. Warmer temperatures result in a longer transmission season, and therefore greater infection risk.
- Climate change will have a severe, negative impact on winter recreation in Pennsylvania.[235] Downhill ski and snowboard resorts are not expected to remain economically viable past mid-century. Snow cover to support cross country skiing and

[230] 2015 Climate Impacts Assessment Update, *supra*, at 63.

[231] *Id*. at 114.

[232] *Id.*

[233] *Id*. at 321.

[234] *Id*. at 135.

[235] *Id*. at 141.

snowmobiling has been declining in Pennsylvania, and is expected to further decline by 20-60%, with greater percentage decreases in southeastern Pennsylvania, and smaller decreases in northern Pennsylvania.

- Climate change poses a threat to the fauna of the tidal freshwater portion of the Delaware estuary in Pennsylvania.[236] One reason is that increased water temperatures with climate change decrease the solubility of oxygen in water and will increase respiration rates, both of which will result in declines in dissolved oxygen concentration. Thus, climate change will worsen the currently substandard water quality in the tidal freshwater region of the Delaware Estuary.

- The freshwater tidal wetlands along Pennsylvania's southeastern coast are a rare, diverse, and ecologically important resource.[237] Climate change poses a threat to these wetlands because of salinity intrusion and sea-level rise. Sea-level rise, however, has the potential to drown wetlands if their accretion rates are less than rates of sea-level rise.

Rhode Island

Climate change is adversely impacting Rhode Island in many diverse ways, including warming air temperatures, warming ocean temperatures, rising sea level, increased acidity of ocean waters, increased rainfall amounts, and increased intensity of rainfall events.

Rhode Island has experienced a significant trend over the past 80 years toward a warmer and wetter climate. Trends are evident in annual temperatures, annual precipitation, and the frequency of intense rainfall events. Temperatures have been steadily climbing in the Ocean State since the early 1930s. The average annual temperature for the state is currently increasing at a rate of 1 degree Fahrenheit every 33 years. The frequency of days with high temperatures at or above 90 degrees has increased while the frequency of days with minimum temperatures at or below freezing has decreased.[238]

There has also been a pronounced increase in precipitation from 1930 to 2013. Increased precipitation has occurred as a result of large, slow moving storm systems, multiple events in the span of a few weeks (such as the 2010 spring floods), as well as an increase in the frequency of intense rain events. The average annual precipitation for Rhode Island is increasing at a rate of

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[236] *Id*. at 152.

[237] *Id*.

[238] *Overview of a Changing Climate in Rhode Island*, David Vallee (Hydrologist-in-Charge, National Weather Service Northeast River Forecast Center, NOAA) and Lenny Giuliano (Air Quality Specialist, Rhode Island Department of Environmental Management, State Climatologist, State of Rhode Island), August 2014 at 2-3, available at http://research3.fit.edu/sealevelriselibrary/documents/doc_mgr/444/Valee%20&%20Giuliano.%202014.%20CC%20in%20Rhode%20Island%20Overview.pdf.

more than 1 inch every 10 years. The frequency of days having one inch of rainfall has nearly doubled. Intense rainfall events (heaviest 1 percent of all daily events from 1901 to 2012 in New England) have increased 71 percent since 1958. The increased amounts of precipitation since 1970 has resulted in a much wetter state in terms of soil moisture and the ground's ability to absorb rainfall.[239]

In addition, the water in Narragansett Bay is getting warmer. Over the past 50 years, the surface temperature of the Bay has increased 1.4° to 1.6° C (2.5° to 2.9° F). Winter water temperatures in the Bay have increased even more, from 1.6° to 2.0° C (2.9° to 3.6° F). Ocean temperatures are increasing world-wide, but temperature increases in the northwestern Atlantic Ocean are expected to be 2-3 times larger than the global average.[240] Warmer water temperatures in Narragansett Bay are causing many changes in ecosystem dynamics, fish, invertebrates, and plankton. Cold-water iconic fishery species (cod, winter flounder, hake, lobster) are moving north out of RI waters and warm-water southern species are becoming more prevalent (scup, butterfish, squid). Rhode Island's marine waters are also becoming more acidic due to increasing CO_2. This may cause severe impacts to shellfish, especially in their larval life stages.[241]

Sea levels have risen over 9 inches in Rhode Island since 1930 as measured at the Newport tide gauge. The historic rate of sea level rise at the Newport tide gauge from 1930 to 2015 is presently 2.72 mm/year, or more than an inch per decade.[242] At present rates, sea levels will likely increase 1 inch between every 5 or 6 years in Rhode Island. NOAA is projecting as much as 6.6 feet of sea level rise by the end of this century in Rhode Island. In the shorter-term, NOAA predicts upwards of 1 foot by 2035 and 1.9 feet by 2050. [243] This has critical implications for Rhode Island, as thousands of acres of Rhode Island's coast will be affected.

Climate change is also altering the ecology and distribution of plants and animals in Rhode Island. In southern New England, spring is arriving sooner and plants are flowering earlier (one week earlier now when compared to the 1850s). For every degree of temperature rise in the spring and winter, plants flower 3.3 days earlier. For woody plants, leaf-out is occurring 18 days earlier now than in the 1850s. Changes in the timing of leaf-out, flowering, and fruiting in plants can be very disruptive to plant pollinators and seed dispersers.[244]

Changes in the timing of annual cycles has been observed in Rhode Island birds. Based on a 45-year near-continuous record of monitoring fall migration times for passerine birds in

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[239] *Id*. at 4.

[240] Rhode Island Executive Climate Change Coordinating Council (EC4) Science and Technical Advisory Board (STAB) Annual Report to the Full Council of the EC4 (May 2016), appendix to Rhode Island Executive Climate Change Coordinating Council Annual Report, June 2016, at 33-35, available at http://climatechange.ri.gov/documents/ar0616.pdf.

[241] *Id*.

[242] *Id*. at 28-30.

[243] *Id*.

[244] *Id*. at 38-40

Kingston, RI, Smith and Paton (2011) found a 3.0 days/decade delay in the departure time of 14 species of migratory birds.[245]

<u>Vermont</u>

Climate change is causing an increase in temperatures and precipitation in Vermont. Average annual temperature has increased by 1.3º F since 1960, and is projected to rise by an additional 2-3.6 º F by 2050.[246] Since 1960, average annual precipitation has increased by 5.9 inches.[247]

Heavy rainfall events are becoming more common.[248] Increasingly frequent heavy rains threaten to flood communities located in Vermont's many narrow river valleys. In 2011 Tropical Storm Irene dumped up to 11 inches of rain on Vermont, impacting 225 municipalities and causing $733 million in damage.[249] More than 1,500 residences sustained significant damage, temporarily or permanently displacing more than 1400 households.[250] More than 500 miles of state highway, 2000 municipal road segments, and 480 bridges were damaged.[251] Farms, water supply and wastewater treatment facilities were also damaged, and the channels of many streams were enlarged and/or relocated.[252]

In addition to threatening human lives and property, increasingly frequent heavy rains present challenges for state and local land use planning. Further, storm water runoff carries pollutants to the state's streams and lakes, and hinders the state's efforts to address phosphorous pollution and resulting algal blooms in Lake Champlain.

Climate change also threatens Vermont's environment and economy by affecting activities dependent on seasonal climate patterns, such as maple sugaring and winter sports.[253]

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[245] *Id.*

[246] *Vermont Climate Change Assessment*, http://vtclimate.org/vts-changing-climate/ (last visited Oct. 24, 2018).

[247] *Id.*

[248] *Id.*

[249] Pierre-Louis, Kendra, *Five Years After Hurricane Irene, Vermont Still Striving for Resilience,* Inside Climate News (Sept. 1, 2016), *available at* https://insideclimatenews.org/news/31082016/five-years-after-hurricane-irene-2011-effects-flooding-vermont-damage-resilience-climate-change.

[250] *Tropical Storm Irene by the Numbers* (Aug. 28, 2013), http://www.vermontbiz.com/news/august/tropical-storm-irene-numbers (last visited Oct. 24, 2018).

[251] *Id.*

[252] *Id.*

[253] U.S. EPA, *What Climate Change Means for Vermont* (August 2006), *available at* https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-vt.pdf.

Vermont is the nation's leading maple-syrup producing state[254]. Warmer temperatures are likely to shift the suitable habitat for sugar maples farther north into Canada.[255] Warmer winters may bring more rain and less snow to Vermont, harming the skiing, snowboarding, and snowmobiling industries and local economies that depend on them. *Id.* During the winter of 2016-17, Vermont recorded more than 3.9 million skier visits, second only to Colorado among the states.[256]

Climate change is also contributing to increased distribution and abundance of ticks and increased tickborne diseases, including Lyme disease and Anaplasmosis, in Vermont.[257] Vermont has the nation's highest per-capita incidence of Lyme Disease.[258]

Virginia

It's not a question of if or when; Virginia is currently experiencing the effects of climate change. Virginia's low-lying coastline is especially vulnerable to this threat. Virginia has experienced the highest rates of sea level rise along the East Coast: in Virginia Beach, the sea has risen by almost a foot since the 1960s[259] and more than 14 inches since 1930.[260] Ordinary rain events now cause flooding in the streets of Norfolk, including large connector streets going underwater.[261] Norfolk naval base, the largest navy base in the world, currently is "one of the most vulnerable to flooding" military installations in the U.S., as relative sea-level rise

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[254] Vermont Agency of Agriculture Food & Markets, *Vermont Leads Nation in 2018 Maple Season Production* (June 13, 2018), http://agriculture.vermont.gov/Vermont%20Leads%20Nation%20in%202018%20Maple%20Season%20Production (last visited Oct. 24, 2018).

[255] U.S. EPA, *What Climate Change Means for Vermont, supra.*

[256] *Vermont ski industry rebounds to nearly 4 million visits*, Vermontbiz (June 15, 2017), https://vermontbiz.com/news/june/vermont-ski-industry-rebounds-nearly-4-million-visits (last vistited Oct. 24, 2018).

[257] Vermont Department of Health, *Climate Change and Tickborne Diseases*, http://www.healthvermont.gov/health-environment/climate-health/tickborne-diseases (last visited Oct. 24, 2018).

[258] DeSmet, Nicole, *Tick-borne diseases: Getting worse, CDC study finds*, Burlington Free Press (May 9, 2018), *available at* https://www.burlingtonfreepress.com/story/news/local/vermont/2018/05/09/tick-spreading-lyme-diseases-getting-worse-cdc-study-finds/589714002/.

[259] City of Virginia Beach, *Comprehensive Sea Level Rise*, https://www.vbgov.com/government/departments/public-works/comp-sea-level-rise/Pages/default.aspx (last visited Oct. 24, 2018).

[260] Chesapeake Bay Foundation, *Sea Level Rise: Finding Nature-Based Solutions to Sea Level Rise*, http://www.cbf.org/issues/climate-change/sea-level-rise.html (last visited Oct. 24, 2018).

[261] Gregory, Matt, *Rain causes Norfolk streets and neighborhoods to flood,* WAVY-TV (Sept. 21, 2016), *available at* http://wavy.com/2016/09/21/rain-causes-norfolk-streets-and-neighborhoods-to-flood/

contributes to “more frequent nuisance flooding and increased vulnerability to coastal storms.”[262] According to Old Dominion University’s Center for Sea Level Rise, the city of Norfolk alone will need at least $1 billion in the coming decades to replace current infrastructure and keep water out of city homes and businesses.[263] According to a recent study by the Hampton Roads Planning District Commission, costs from three feet of sea-level rise in the Hampton Roads region are expected to range between $12 billion and $87 billion.[264] Climate change has lengthened Virginia’s allergy season and facilitated the spread of tick and mosquito borne illnesses—the ticks carrying Lyme disease are now reported in at least 72 counties, up from 12 counties in 1996.[265] These direct results of climate change generate negative impacts on Virginians, their quality of living, and their pocketbooks. Environmental impacts have direct and immediate negative economic results.

Washington

Washington is a coastal state, a mountain state, and a forest state. Reports prepared by the University of Washington Climate Impacts Group show that climate change will significantly adversely affect each of these signature features of Washington. In addition to these impacts, climate change will cause significant harm to public health.

Approximately 4 million of Washington’s 6.5 million people live in the area around Puget Sound. Climate change will cause the sea level to rise and permanently inundate low-lying areas in the Puget Sound region.[266] Under a business as usual greenhouse gas scenario, sea level is predicted to rise in Seattle relative to 2000 levels by 2 feet by 2050 and 5 feet by 2100.[267] Sea level rise will also increase the frequency of coastal flood events. For example, with 2 feet of sea level rise (predicted for Seattle), a 1-in-100 year flood event will become an annual event. Sea level rise will also cause coastal bluffs (the location of many family homes in Puget Sound) to

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[262] U.S. Dept. of Defense, Report on Effects of a Changing Climate to the Department of Defense” (Jan. 2019), https://www.documentcloud.org/documents/5689153-DoD-Final-Climate-Report.html.

[263] Center for Sea Level Rise, Old Dominion University, "Center For Sea Level Rise" (2017). *Hampton Roads Intergovernmental Pilot Project: Website*. 1, *available at* http://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1000&context=hripp_website.

[264] *Id*.

[265] National Resources Defense Council, *Climate Change and Health in Virginia* (April 2018) *available at* https://assets.nrdc.org/sites/default/files/climate-change-health-impacts-virginia-ib.pdf

[266] U.S. Census Bureau, *Annual Estimates of the Population of Combined Statistical Areas: April 2010 to July 2011*, U.S. Census Bureau, https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_B01003&prodType=table (last visited Oct. 24, 2018).

[267] State of Knowledge: Climate Change in Puget Sound (November 2015), Climate Impacts Group, University of Washington, (hereinafter “State of Knowledge, Puget Sound”) at 4-7; available at https://cig.uw.edu/resources/special-reports/ps-sok/

recede by as much as 75-100 feet by 2100 relative to 2000.[268] This would be a doubling, on average, of the current rate of recession. Sea level rise will also result in reduced harvest for commercial fishing and shellfish operations.[269]

Climate change is also causing ocean acidification**,** through the absorption in the ocean of excess carbon dioxide from the atmosphere. Ocean waters on the outer coast of Washington and the Puget Sound have become about 10-40 percent more acidic since 1800.[270] This increased acidity is already affecting some shellfish species.[271] Washington has the largest shellfish industry on the west coast, contributing $184 million to Washington's economy in 2010 and employing 2710 workers.[272] Under a business as usual greenhouse gas scenario, ocean waters are expected to become at least 100 percent more acidic by 2100 relative to 1986-2005.[273] The predicted level of ocean acidification is expected to cause a 34 percent decline in shellfish survival by 2100.[274]

Washington depends on yearly winter mountain snow pack for drinking water, as well as water for irrigation, hydropower, and salmon. Washington's winter mountain snowpack is decreasing because climate change is causing more precipitation to fall as rain rather than snow. Snowpack decreased in Washington's Cascade Mountains by about 25 percent between the mid-20th century and 2006.[275] By the 2040s, snowpack is predicted to decrease 38-46 percent relative to 1916-2006,[276] and by the 2080s, snow pack is expected to decline 56-70 percent.[277] This loss of snowpack will cause a 50 percent increase in the number of years in which water is not available for irrigation, as well as a 20 percent decrease in summer hydropower production.[278] In addition, the decrease in summer stream flows combined with higher stream temperatures will result in stream temperatures too high to support adult salmon.[279]

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[268] *Id*.

[269] *Id*.

[270] State of Knowledge Report, Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers, (December 2013), Climate Impacts Group, University of Washington (hereinafter "State of Knowledge Report"), at 2-6; available at https://cig.uw.edu/resources/special-reports/wa-sok/

[271] *Id* at 2-3.

[272] Washington: A Shellfish State, Washington Shellfish Initiative, at http://www.governor.wa.gov/sites/default/files/WSI%20factsheet.pdf

[273] State of Knowledge Report at ES-2.

[274] *Id* at 8-4.

[275] *Id* at 2-5

[276] *Id* at ES-2.

[277] *Id* at 6-10.

[278] *Id* at 6-5.

[279] *Id* at ES-4, 6-6, 6-11, 6-12.

Climate change is also impacting Washington's forests. Of Washington's total area (42.5 million acres), a little more than half (22 million acres) is forested.[280] Washington's forest products industry generates a gross income of about $48 billion per year, provides more than 100,000 jobs, and contributes approximately $4.9 billion in annual wages.[281] Climate change is threatening this industry in a number of ways. For example, Douglas fir accounts for almost half the timber harvested in Washington.[282] Under a moderate greenhouse gas scenario, Douglas fir habitat is expected to decline 32 percent by the 2060s relative to 1961-1990.[283] In addition, the area of Washington forest where tree growth is severely limited by water availability is projected to increase (relative to 1970-1999) by about 32 percent in the 2020s, with an additional 12 percent increase in the 2040s and another 12 percent increase in the 2080s.[284] Wildland fires pose another threat to Washington's forests. Under a business as usual greenhouse gas scenario, decreases in summer precipitation, increases in summer temperatures and earlier snow melt are predicted to result in up to a 300 percent increase in the area in eastern Washington burned annually by forest fires[285] and up to a 1000 percent increase in area burned annually on the west side of the state (typically, the wet side).[286]

By far the highest costs to the state, however, are expected to come from harm to public health. More frequent heat waves and more frequent and intense flooding may harm human health directly. Warming may also exacerbate health risks from poor air quality and allergens. Climate change can indirectly affect human health through its impacts on water supplies, wildfire risks, and the ways in which diseases are spread. Risks are often greatest for the elderly, children, those with existing chronic health conditions, individuals with greater exposure to outside conditions, and those with limited access to health resources.[287]

District of Columbia

The District of Columbia is a densely populated area located at the confluence of two tidal rivers and accordingly is particularly vulnerable to the impacts of climate change including dangerous heat waves, flooding caused by rising tides and heavy rains, and increasingly severe weather.

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[280] Washington Forest Protection Association, Sustainable Forestry, ,http://www.wfpa.org/sustainable-forestry/ (last visited Oct. 24, 2018).

[281] Washington Department of Commerce, Forest Products Sector, at http://www.commerce.wa.gov/growing-the-economy/key-sectors/forest-products/ (last visited Oct. 24, 2018).

[282] Washington Department of Natural Resources, 2015 Washington Timber Harvest Report, (Sept. 2016), *available at* https://www.dnr.wa.gov/publications/em_obe_wa_timber_harvest_2015_final2.pdf

[283] State of Knowledge Report, *supra*, at 7-1.

[284] *Id* at 7-3.

[285] *Id*.

[286] *Id* at 7-4.

[287] State of Knowledge, Puget Sound, *supra*, at ES-7.

Water levels along the Potomac and Anacostia Rivers have increased 11 inches in the past 90 years due to a combination of sea level rise and subsidence. As a result, nuisance flooding has increased by more than 300% according to the National Oceanic and Atmospheric Administration.[288] By 2080, the U.S. Corps of Engineers predicts up to 3.4 feet of additional sea level rise in the District.[289] At the same time, heavy rain events are projected to grow more frequent and intense according to local climate change projections completed by the District. As a result, today's 100-year rain event could become a one in 25-year event by mid-century.[290] The combined impact of rising tides and heavier rains pose significant threats to the District's infrastructure, community resources, cultural assets, government and military facilities, and residents. For example, during the second half of the century, Joint Base Anacostia-Bolling and Washington Navy Yard can expect more frequent and extensive tidal flooding, loss of currently utilized land, and substantial increases in the extent and severity of storm-driven flooding. With an intermediate rate of sea level rise, Naval Support Facility Anacostia could lose roughly 50 percent of its land area, and the Washington Navy Yard about 30 percent of its current land area, by end of century.[291]

The District is also vulnerable to rising temperatures and a corresponding increase in extreme heat events. Local climate change projections indicate that the number of heat emergency days, defined as days when the heat index exceeds 95 degrees Fahrenheit, could more than double from the current 29 days per year to 80 days per year by the 2050s under a high emission scenario.[292] As temperatures rise, and dangerously hot days grow more frequent, heat-related illnesses are also likely to increase. Hotter temperatures can also stress infrastructure like roads, rail lines, and our power grid, causing disruptions.

Boulder, CO

Like many cities and communities across the country and around the world, Boulder is adjusting to a "new normal," where the effects of climate change are becoming increasingly

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[288] National Oceanic and Atmospheric Administration (2014), *Sea Level Rise and Nuisance Flood Frequency Changes around the United States,* NOAA Technical Report NOS CO-OPS 073 available at http://www.noaanews.noaa.gov/stories2014/20140728_nuisanceflooding.html.

[289] District of Columbia Department of Energy & Environment (2015), *Climate Projections & Scenario Development,* p. 46, available at https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/150828_AREA_Research_Report_Small.pdf

[290] *Id.* at 36.

[291] **Union of Concerned Scientists, *On the Front Lines of Rising Seas: Joint Base Anacostia-Bolling and Washington Navy Yard* (2016), available at** https://www.ucsusa.org/global-warming/global-warming-impacts/sea-level-rise-flooding-joint-base-anacostia-bolling-and-washington-navy-yard#.WlPQVrynHRY

[292] Climate Projections & Scenario Development, *supra*, at 27.

apparent. Global climate change will affect Boulder's ability to deliver services including fire protection and other emergency services, flood control and public works projects, and health care and social services for vulnerable populations.

According to the National Climatic Data Center, the frequency of billion-dollar extreme weather events from severe storms, flooding, droughts and wildfires has increased dramatically in recent years, trending from an average of less than three events per year in the 1980s to an average of nearly ten events per year from 2010 to 2014.[293]

The 2011 National Academies of Science assessment indicates that a one-degree Celsius rise in temperature would increase fire incidence probabilities by over 600 percent.[294] Rising temperatures also increase the length of drought cycles, which intensify flood, fire risks and create additional risks for Boulder's water supply. These dry conditions have in turn exacerbated insect, exotic weed, and disease threats in the flora and fauna communities.

In addition, a 2015 report by the University of Colorado Boulder and Colorado State University prepared for the Colorado Energy office states that Colorado's climate has warmed in recent decades, and climate models unanimously project this warming trend will continue into the future.[295] Although the actual pace of warming is dependent on the rate of worldwide greenhouse gas emissions, climate change has impacted and will continue to impact Colorado's resources in a variety of ways, including more rapid snowmelt, longer and more severe droughts, and longer growing seasons.

Since 1989, Boulder County has experienced four major wildland fires, the most recent of which was the Fourmile Canyon fire in 2010. The Fourmile Canyon fire destroyed over 6,000 acres of forest and 168 homes. The City's principal water treatment facility is in the region affected by the fire and was placed at risk.[296]

In September 2013, the City experienced a flood that caused damages estimated as high as $150 million. In the region, four people died, 1,202 people were airlifted from their homes, and 345 homes were destroyed. Over a period of eight days, Boulder received an unprecedented 17.15 inches of rain. To put this into context, Boulder's annual average precipitation is just 19.14 inches. In September, Boulder normally averages just 1.61 inches of rain. This disaster was so widespread and devastating that the Boulder County Board of Commissioners declared a county-

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[293] National Climatic Data Center, *Extreme Weather,* https://nca2014.globalchange.gov/report/our-changing-climate/extreme-weather (last visited Oct. 24, 2018).

[294] Lukas, Jeff, et al., *Climate Change in Colorado* (Aug. 2014), *available at* https://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf

[295] *Colorado Climate Change Vulnerability Study* (Jan. 2015), *available at* http://wwa.colorado.edu/climate/co2015vulnerability/co_vulnerability_report_2015_final.pdf

[296] Graham, Russell, et al., *Fourmile Canyon Fire Findings* (Aug. 2012), *available at* https://www.fs.fed.us/rm/pubs/rmrs_gtr289.pdf

wide disaster, the Governor declared the flood a state disaster, and the President declared the flood a national disaster.[297]

Boulder's complex topography and natural climate variability make it difficult, and sometimes impossible, to predict when and how often extreme events may occur. Flash flooding, for example, does not follow the boundaries of established flood maps, a lesson learned through the adversity of the 2013 floods. Flash floods may inundate neighborhoods and roads with little advance notice, impacting locations that may not have experienced flooding in the past. At the same time, increasing global temperatures exacerbate many of these hazards.[298]

But shocks are not limited to natural hazards or the effects of climate change. A globally-connected economy and the ability for pests and diseases to circle the globe with unprecedented speed, for example, mean our community's will face a host of challenges that can strike at little notice and have severe, unknowable repercussions.

Perhaps the most significant long-term impact of climate change to Boulder is the potential for impacts to water supply. Increased temperatures will require larger amounts of water to sustain outdoor uses such as agriculture and urban tree canopies. About 89 percent of the water consumption in Colorado is associated with agriculture so even a modest increase in agricultural water needs will have a significant impact on overall water demands in the state.[299]

Like most water users in Colorado, Boulder's water supply infrastructure depends on the accumulation of snowpack in the Rocky Mountains during winter months followed by a predictable melting and runoff into storage reservoirs throughout the rest of the year. A significant shift from snow to rain or in the timing of runoff would result in a shortfall in water supply because reservoirs are not sized to hold water supply that historically was held in the snowpack.[300]

Although virtually any aspect of Boulder's economy could be affected by changes in the climate, specific industries that rely on natural resources—agriculture, tourism and recreation, and mining and extraction—are particularly vulnerable. Reduced snowpack is an obvious concern in the ski sector, but also important are earlier melt as well as seasonal shifts in temperature, which can exacerbate wildfire potential, negatively affect plants and wildlife, and increase public exposure to vector-borne diseases.[301]

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[297] Boulder County, 2013 Flood Recovery, https://www.bouldercounty.org/disasters/flood/2013-flood/ (last visited Oct. 24, 2018).

[298] *Climate Change in Colorado, supra*.

[299] *Id.*

[300] *Id.*

[301] *Colorado Climate Change Vulnerability Study* , *supra.*

Chicago

Climate change will exacerbate existing environmental impacts on Chicago residents and lead to new, harmful impacts. Detailed, peer-reviewed federal research has exhaustively examined climate change impacts. In 2014, the US Global Change Research Program published the Third National Climate Assessment (NCA-3), developed with input from 13 federal agencies. The NCA-3 noted that climate change poses a threat to human health in many ways, including "increased extreme weather events…decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks."[302] Each of those threats is likely to exacerbate existing public health concerns affecting Chicagoans. For example, the health of the people of Chicago under current conditions already includes a substantial burden of asthma, which is worsened by decreased air quality. Mental health is also already a major concern, especially for Chicago's substantial low income population. Waterborne, foodborne, and vectorborne disease are already costly in their tolls on the health of Chicago residents and the economy.[303]

Many Americans are already familiar with high-impact weather events impacting Chicago. Most tragically, Chicago has suffered from extreme weather in the form of the 1995 heat wave (which caused an estimated 741 deaths). Since 1980, Chicago's average temperature has increased approximately 2.6 degrees.[304] In the near future, Chicago will likely experience between 5 to 25 days a year with heat and humidity conditions similar to the 1995 heat wave that caused approximately 750 deaths in the city.[305] In addition, urban flooding during and after intense rain storms, leads to economic losses for families and businesses. The City of Chicago and other public agencies spend significant sums to support the readiness of public health professionals, emergency response agencies, and health care delivery systems so that they are resilient to extreme weather.[306]

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[302] U.S. Global Change Research Program, NCA-3, at 221 (2014), *available at* https://nca2014.globalchange.gov/system/files_force/downloads/low/NCA3_Full_Report_09_Human_Health_LowRes.pdf?download=1

[303] *See* Physicians for Social Responsibility – Chicago Chapter, Cook County Climate Change and Public Health Action Plan at 7-11, *available at* http://www.chicagopsr.org/PDFs/climatechangepublichealthplancookcounty.pdf (discussing prevalence and impact of waterborne, foodborne and vectorborne disease in Cook County, in which Chicago is the largest municipality).

[304] Chicago Climate Action Plan, Climate Change and Chicago, http://www.chicagoclimateaction.org/pages/climate_change_and_chicago/5.php (last visited Oct. 24, 2018).

[305] Hettinger, Claire, *Illinois cound see effects of climate change as soon as 2020* (Sept. 1, 2016), http://cu-citizenaccess.org/2016/09/01/illinois-could-see-effects-of-climate-change-as-soon-as-2020/ (last visited Oct. 24, 2018); Hayhoe, K., et al., "Climate change, heat waves, and mortality projections for Chicago," in *J. of Great Lakes Res.*, Vol. 36, Supp. 2, pp. 65-73 (2010), https://doi.org/10.1016/j.jglr.2009.12.009.

[306] *See e.g.*, City of Chicago, Application Narrative for Public Comment, National Disaster Resilience Competition (March 11, 2015) (discussing City and sister agency expenditures to prepare for

In 2017, the Fourth National Climate Assessment (NCA-4), "Climate Science Special Report" (CSSR), also published by the U.S. Global Change Research Program, provided updated information about the current state of the climate and the risk of extreme heat and flooding in the U.S. While data summaries or climate projections were not available solely for Chicago, information specific to the Midwest was provided and can be used to make reasonable estimates of climate impacts in the city itself. The CSSR was "designed to be an authoritative assessment of the science of climate change, with a focus on the United States, to serve as the foundation for efforts to assess climate-related risks and inform decision-making about responses."[307] The CSSR notes that "[t]he last few years have seen record-breaking, climate-related weather extremes, and the last three years, specifically, have been the warmest years on record for the globe. These trends are expected to continue over climate timescales."[308]

Looking to the future, the CSSR predicts how climate change will exacerbate public health risks for Chicagoans, especially urban heat waves and urban flooding. "Heatwaves have become more frequent in the United States since the 1960s, while extreme cold temperatures and cold waves are less frequent. Recent record-setting hot years are projected to become common in the near future for the United States, as annual average temperatures continue to rise. Annual average temperature over the contiguous United States has increased by 1.8°F (1.0°C) for the period 1901–2016; over the next few decades (2021–2050), annual average temperatures are expected to rise by about 2.5°F for the United States, relative to the recent past (average from 1976–2005), under all plausible future climate scenarios."[309] The CSSR also notes that annual precipitation has increased in Midwest, and with "high confidence" that "[h]eavy precipitation events in most parts of the United States have increased in both intensity and frequency since 1901."[310] Particularly concerning is that "[t]he frequency and intensity of heavy precipitation events are projected to continue to increase over the 21st century."[311]

The CSSR, marshalling scientific expertise from across the federal government, makes it clear that locations in the Midwest such as Chicago are expected to face increases in extreme weather events (as summarized above). Given the sound scientific basis for an expected increase in heat-related and flood-related health problems in the Chicago area, action at all levels of government is needed to prepare for those problems.

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and react to extreme weather events), *available at* https://www.cityofchicago.org/content/dam/city/progs/env/2015_03_11_Chicago_NDRC_Consolidated-PUBLICDRAFT.pdf.

[307] USGCRP, *2017: Climate Science Special Report: Fourth National Climate Assessment* at 1, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)], *available at* https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf.

[308] *Id.* at 12.

[309] *Id.* at 11.

[310] *Id.* at 20.

[311] *Id.* at 207.

While the City of Chicago is investing in climate change adaptation and resilience measures, it is essential that the federal government does all it can to reverse the causes of the abrupt warming of the Earth: the well-documented increase in concentrations of heat-trapping gases in the atmosphere. The costs of the Clean Power Plan are likely dwarfed by the massive savings in health care expenditures for heat-related illness, flood-related illness, and other health conditions, as well as the economic damages due to flooding in cities like Chicago. Any consideration of rescinding the Clean Power Plan and replacing it with a weaker rule such as EPA's ACE proposal must include the health and economic impacts of the anticipated increase in heat waves and flooding in Chicago.

The City of Los Angeles

As EPA's August 2016 bulletin entitled "What Climate Change Means for California" recognized, California's climate is changing, and Southern California in particular has already warmed about three degrees (F) in the last century.[312] Like California as a whole, in Los Angeles, climate change will result in more common heat waves, less rainfall, increased stress on water supplies, increased risk of wildfires, and increased threats to coastal development and infrastructure.

As for heat waves, a recent UCLA study concluded that under a business as usual scenario, the annual number of days when temperatures exceed 95 degrees (F) in Los Angeles will increase from 6 days (1981-2000) to 22 days (2041-2060), and ultimately to 54 days (2081-2100).[313] EPA's August 2016 bulletin recognizes that hot days "can be unhealthy—even dangerous." Indeed, high air temperatures, which are amplified in urban settings like Los Angeles, can cause heat stroke and dehydration and affect people's cardiovascular, respiratory, and nervous systems. Furthermore, as EPA's bulletin recognizes, warming can also increase the formation of ground-level ozone, a component of smog that can contribute to respiratory problems. Los Angeles already has the worst smog in the nation, and as the climate changes, progress toward clean air will become even more difficult and expensive. Extreme heat and poor air quality not only negatively impact Los Angeles residents and City employees, but also the City's ability to retain Los Angeles's status as a desirable business and tourist destination.

EPA's bulletin also recognized that the changing climate "is likely to increase the need for water but reduce the supply."[314] Studies cited in the Los Angeles Department of Water and Power (LADWP) 2015 Urban Water Management Plan reach the same conclusion. On the demand side, forecasted warming is projected to result in as much as a 7 percent increase in

[312] *See* EPA, *What Climate Change Means for California* (Aug. 2016), *available at* https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-ca.pdf.

[313] *See The Climate Change in the Los Angeles Region Project,* http://research.atmos.ucla.edu/csrl//LA_project_summary.html (last visited Oct. 24, 2018).

[314] EPA, *What Climate Change Means for California, supra.*

water demand.[315] Additionally, climate change would put stress on existing water supply infrastructure. The Los Angeles Aqueduct (LAA), which is one of the major imported water sources delivering a reliable water supply to the City, serves as just one example. The LAA originates approximately 340 miles away from Los Angeles, gathering snowmelt runoff in the Eastern Sierra Nevada. Projected changes in temperature (warmer winters) are anticipated to change precipitation patterns in the Eastern Sierra Nevada with less snow and more rain than historically encountered. This could strain the LAA's capacity to store runoff in surface reservoirs, as runoff would come earlier in the season than if the snowpack gradually melted in spring and summer, as has historically been the case. If climate change occurs as predicted, the City may have to expend substantial resources for operational and infrastructure changes to the LAA to ensure Los Angeles' continued reliance on this water source. [316]

EPA's bulletin also recognizes that "higher temperatures and drought are likely to increase the severity, frequency, and extent of wildfires," which already pose a substantial problem in Los Angeles. Indeed, 2017 was one of the worst wild fire seasons on record. As of December 12, 2017, it was reported that more than 405 square miles in Southern California had burned, 1160 structures had been destroyed, 90,000 people had been displaced, and more than 10,000 fire fighters from California ten other states had been employed to save lives and homes.[317] Researchers project that fires driven by Santa Ana winds, and the fires that occur earlier in the year in Southern California, will burn larger areas by midcentury in part due to rising temperatures.

Finally, the City of Los Angeles has substantial public and private coastal development. Sea level rise caused by climate change may threaten both private property and public infrastructure along the Los Angeles coast, including at the Port of Los Angeles, which ranks as the #1 container port in the United States and North America.

New York City

Changing climate hazards in the New York metropolitan region are increasing the risks for the people, economy, and infrastructure of New York City in numerous and dramatic ways, as documented in the New York City Panel on Climate Change's January 2015 report, *Building the Knowledge Base for Climate Resiliency*.[318] Annual temperatures are hotter, heavy downpours

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[315] LADWP 2015 Urban Water Management Plan, Chapter 12, at 5 (2015), *available at* https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-sourcesofsupply/a-w-sos-uwmp?_adf.ctrl-state=ty6h0ptsh_29&_afrLoop=280191713614151

[316] *Id.* at 6-9.

[317] *See* Fonseca, Ryan, *The Thomas fire and Southern California's other major wildfires by the numbers*, Los Angeles Daily News (Dec. 7, 2017; updated Dec. 12, 2017), *available at* https://www.dailynews.com/2017/12/07/by-the-numbers-the-southern-california-wildfire-battles-in-la-ventura-counties/.

[318] New York City Panel on Climate Change, *Building the Knowledge Base for Climate Resiliency: New York City Panel on Climate Change 2015 Report*, Annals of the New York Academy of Science, Vol. 1336 (Jan. 2015), at 9, *available at*

are increasingly frequent, and the sea is rising. These trends are projected to continue and even worsen in the coming decades due to higher concentrations of greenhouse gases in the atmosphere.

Sea level rise in New York City has averaged 1.2 inches per decade since 1900, nearly twice the observed global rate, with a total increase of more than a foot; approximately 60 percent of that rise is driven by climate-related factors.[319] As discussed above in the New York State section, this increase in sea level exacerbated the destruction of homes and businesses from flooding during Hurricane Sandy.[320]

Climate change also risks New Yorkers' health and safety. Extreme weather events can result in injury and loss of life resulting from exposure, interrupted utility service, or lack of access to emergency services.[321] In addition, warming temperatures exacerbate or introduce a wide range of health problems, including cardiovascular and respiratory diseases, pollution and allergen-related health problems, and vector-borne diseases.[322] The health consequences of climate change disproportionately affect our most vulnerable populations – the elderly, children, and low-income communities who already experience elevated instances of cardiovascular and respiratory diseases.[323]

Long-term changes in climate mean that when extreme weather events strike, they are likely to be increasingly severe and damaging. By the 2050s, New York City will likely experience sea levels that are up to thirty inches higher than today, the number of days with rainfall at or above two inches is projected to increase by as much as 67% by the 2020s, and by the 2080s, what would today be considered a 100-year flood (*i.e.*, a flood that has a 1% chance of occurring in any given year) could have as high as a 12% chance of occurring in any given year, and this flooding could be as much as 4.8 feet higher than today's 100-year flood because of sea level rise.[324] New York City is also likely to experience more frequent heavy downpours and many more days at or above 90 degrees Fahrenheit by that timeframe.[325]

Rising sea levels will expose the homes, businesses, streets, wastewater treatment plants, and power plants that line our 520 miles of coastline to increased hazards. More extreme weather

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http://onlinelibrary.wiley.com/doi/10.1111/nyas.2015.1336.issue-1/issuetoc (hereinafter "*New York City Panel on Climate Change 2015 Report*").

[319] *New York City Panel on Climate Change 2015 Report*, *supra,* Chapter 2.

[320] *Id.*

[321] *Id.* at 70.

[322] *Id.* at 78-82.

[323] *See* DOHMH, *Air Pollution and the Health of New Yorkers: The Impact of Fine Particles and Ozone* at 4, at https://www1.nyc.gov/assets/doh/downloads/pdf/eode/eode-air-quality-impact.pdf; *see also* Globalchange.gov, *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment Ch. 9, Populations of Concern* (April 2016), at https://health2016.globalchange.gov/populations-concern.

[324] *New York City Panel on Climate Change 2015 Report, supra,* at 31-33, 40-42.

[325] *Id.* at 27.

will also leave the City and its essential infrastructure susceptible to more frequent violent storms and severe flooding; at other times, the new extremes could subject the City to prolonged periods of drought.[326]

Heat waves, defined as three or more consecutive days of temperatures at or above 90 degrees, strain the City's power grid, cause deaths from heat stroke, and exacerbate chronic health conditions, particularly for vulnerable populations like the elderly.[327] Without mitigation of greenhouse gas emissions, the City can expect temperatures at or above 90°F for thirty-three days per year by the 2020s, for fifty-seven days by the 2050s, and for eighty-seven days by the 2080s.[328]

Philadelphia

Since 2010, Philadelphia has experienced a variety of extreme weather, including the snowiest winter, the two warmest summers, the wettest day, and the two wettest years on record, as well as two hurricanes and a derecho (a severe windstorm—usually associated with thunderstorms—that produces damage along a relatively straight path). Fifty-seven daily high temperature records have been set in Philadelphia since the year 2000, 28 of them since the year 2010. And the sea level around Philadelphia has been rising at a rate of roughly 0.11 inches per year since 1900, equivalent to an increase of nearly one foot in 100 years.[329]

Scientists expect these trends to continue in the future, at an accelerating pace and with increasing severity. The best available climate information suggests that weather in Philadelphia will become warmer and wetter during all seasons in the years and decades ahead, and that the rate of sea level rise will increase, especially toward the end of this century.[330]

Changes in climate matter to Philadelphia. Storms, heat waves, and floods already pose risks to residents and infrastructure, and the city is responsible for responding to these events by plowing the streets, managing stormwater, keeping Philadelphians safe during storms, and

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[326] *See generally id.* at 23-27. For a comprehensive discussion of the likely effects of climate change on New York City's watershed and water delivery systems, *see* New York City Department of Environmental Protection Climate Change Program, *Assessment and Action Plan* (May 2008), *at* http://www.nyc.gov/html/dep/ pdf/climate/climate_complete.pdf. Details of climate change impacts on the City's wastewater treatment system are presented in DEP's *NYC Wastewater Resiliency Plan: Climate Risk Assessment and Adaptation Study* (Oct. 2013), *at* http://www.nyc.gov/html/dep/html/about_dep/ wastewater_resiliency_plan.shtml.

[327] *New York City Panel on Climate Change 2015 Report, supra,* at 26.

[328] *York City Panel on Climate Change 2015 Report* at 31.

[329] Mayor's Office of Sustainability & ICF International, Growing Stronger: Toward A Climate-Ready Philadelphia, at 5 (2015), *available at*, https://beta.phila.gov/media/20160504162056/Growing-Stronger-Toward-a-Climate-Ready-Philadelphia.pdf

[330] *Id.*; *see also* ICF Incorporated, L.L.C., Useful Climate Information for Philadelphia, at 3 (2014), *available at* https://beta.phila.gov/media/20160505145605/Useful-Climate-Science-for-Philadelphia.pdf.

leading cleanup efforts when the storms clear. Philadelphia needs to build resilience to accommodate today's extremes while accounting for expected changes in the frequency of these events in the future.[331]

Expected effects of climate change in Philadelphia fall into three broad categories:

- *New Normals*

The city's buildings and infrastructure were designed to withstand past climate conditions, not those that scientists expect will occur in the future. Over time, prolonged exposure to higher temperatures and changing precipitation patterns may lead to safety hazards, service outages, and higher maintenance costs.

- *Changing Extremes*

Extreme events such as heat waves, intense rain or snowstorms, and tropical storms and hurricanes are expected to become more frequent and/or more severe as the climate changes.

- *Rising Seas*

Although Philadelphia is 90 miles inland from the mouth of the Delaware Bay, higher sea levels will raise water levels in the Delaware and Schuylkill Rivers. Higher baseline river levels would not only permanently inundate parts of Philadelphia but also increase the depth and extent of flooding in and around the city from storm surges.[332]

The impacts of climate change in Philadelphia will be costly. Just one severe hurricane could cause more than $2 billion in damages citywide.[333] On top of these additional disaster costs, climate change will increase the everyday cost of doing business.[334]

Extreme heat is also likely to increase risks to the health of vulnerable populations in the city. Heat events and hot days are projected to increase substantially in Philadelphia by the end of this century. Populations that are potentially vulnerable to extreme heat include the elderly, the very young, people with low socioeconomic status, and people without access to air-conditioned spaces. Nearly 27 percent of Philadelphia's population lives under the poverty level, more than 12 percent of the population is aged 65 years or older, and seven percent is under five years old.[335]

Heat can have both direct physiological impacts on health (such as heat stroke) and indirect impacts: for example, hot weather encourages the formation of ground-level ozone, which reduces air quality and poses risks to individuals with respiratory conditions such as

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[331] *See* Growing Stronger: Toward A Climate-Ready Philadelphia, *supra,* at 5

[332] *Id.*

[333] *Id.* at 9

[334] *Id.*

[335] *Id.* at 13

asthma. In 2010, nearly a quarter of children in Philadelphia County had asthma, among the highest rates in the nation.[336]

Extreme heat is responsible for more deaths in Pennsylvania than all other natural disasters combined, killing an average of 50 people per year between 1997 and 2004. A 10-day heat wave that hit Philadelphia in July 1993 resulted in 118 deaths.[337]

Extreme heat can also affect city services and infrastructure. For example, interviews with city departments indicated that hotter days may require construction activities (including street paving and repairs) to shift to night hours, and pavement may require longer curing times. Extreme heat that persists for multiple days and nighttime temperatures that remain elevated magnify these impacts.[338]

Rising sea levels are expected to increase the frequency and severity of flooding in Philadelphia. Coastal storms combined with higher sea levels will cause more extensive flooding than the same storms would cause today, although tides, saturation of the ground, ground temperature, and other factors can vary the degree of flooding experienced from two storms with the same amount of rainfall.[339]

Flooding presents many risks to Philadelphia, including public health and safety hazards, interruptions in key services, and damage to buildings and infrastructure. Floods can disrupt transportation, hampering emergency services and evacuation efforts. Because fuel pumps and sump pumps require electricity to operate, a power failure during a flood could limit the availability of fuel for generators and vehicles, and allow water levels to rise in buildings and other facilities.[340]

South Miami, FL

The City of South Miami is situated atop the Miami Ridge, a limestone outcropping that is cut through by a series of transverse glades that drain the Everglades basin into Biscayne Bay. The southernmost edge of the City of South Miami borders one such glade, the Snapper Creek Canal. South Miami is bisected by a second transverse glade, the Ludlam Glades Canal, which empties into the Snapper Creek Canal. In 2009, FEMA designated neighborhoods in these transverse glades as flood zone AE, requiring flood insurance.

By the late 1960s, saltwater had intruded far up the coastal drainages of Miami-Dade County. A series of saltwater exclusion dams were constructed on the canals and creeks to limit upstream flow, including on the Snapper Creek Canal downstream of South Miami. These dams freshened the drainages, but saltwater continued to advance underground because local sea level

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[336] *Id.*

[337] *Id.*

[338] *Id.*

[339] *Id.* at 14

[340] *Id.*

rise increased the hydrostatic pressure of intruding saltwater. As of 2011, underground saltwater had reached the southeastern corner of the City of South Miami. The South Florida Water Management District increased the height of the freshwater head on the inland side of the saltwater dams to counter the underground intrusion of saltwater. The maximum height of the freshwater buildup, however, has been limited by the low-elevation of the western suburbs, which, by law, cannot be deliberately flooded.

Local sea level rise in South Florida, including the City of South Miami, has greatly exceeded global sea level rise. Since 2010, Miami has seen an extra 5" of sea level rise. With the increase in local sea level rise in Miami, saltwater has begun overtopping the Snapper Creek Canal exclusion dam during recent "king tides" in October and November.[341]

Local sea level rise has increased the distance that storm surge can penetrate inland. Two days before landfall of Hurricane Irma on September 9, 2017, the National Hurricane Center issued its first ever storm surge warning for South Miami. For the first time ever, Miami-Dade County responded to the flood warning with a mandatory evacuation order for most of the City of South Miami.[342] Even though the storm center diverted, low areas of the City experienced floodwaters, and adjacent areas closer to the bay experienced significant damage from storm surge and flooding.

An unseen side-effect of the underwater battle being waged between freshwater and saltwater has been the rise of the local water table. In 2015, GEI Consultants, Inc. identified septic systems as the infrastructure in the City of South Miami at most immediate risk from the rising water table: *"The Snapper Creek Study Area had 11 properties (or 73% of the 15 records available) that were estimated to have the bottom of drainfield reached by rising groundwater within the next 25 years."* When groundwater reaches the level of a house's septic drainfield, wastewater from the house (including the toilets) will backflow into the bathtub instead of the septic tank. The remedy is replacing septic systems with a municipal sewer system.[343]

The City of South Miami, on September 15, 2015, approved a resolution authorizing SRS Engineering Inc. to provide complete engineering documents consistent with a Citywide Sanitary Sewer Master Plan to replace the vulnerable septic systems with municipal sewer infrastructure. The master plan was completed on September 14, 2016 with a total estimated cost to the City and its residents of $47,639,833.26.[344]

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[341] Dessu SB, Price RM, Troxler TG, Kominoski JS (2018). Effects of sea-level rise and freshwater management on long-term water levels and water quality in the Florida Coastal Everglades. Journal of Environmental Management, 21, 164-176, *available at* https://doi.org/10.1016/j.jenvman.2018.01.025

[342] *Miami-Dade Expands Evacuation Order*. Miami Herald (Sept. 7, 2017).

[343] Cooper JA, Loomis GW, Amador JA (2016). Hell and high water: Diminished septic system performance in coastal regions due to climate change. PLoS One. 2016; 11(9): e0162104. 2016 Sep 1. doi: 10.1371/journal.pone.0162104; Ariza M (Jun 25 2017) Miami, sea level rise is coming for your poop. New Tropic. https://thenewtropic.com/climate-change-septic-tanks-miami/

[344] SRS Engineering Inc. Citywide Sanitary Sewer Master Plan, September 14, 2016.

In addition to the direct effects of sea level rise, which will compromise the City's existing sanitary waste infrastructure, the City will likely experience indirect harm based on economic factors relating to rising flood insurance costs and loss of 30-year mortgage issuance in low-lying areas. FEMA flood insurance rates have already begun to rise for the many properties in the City's AE flood zones. Based on FEMA and NOAA projections for sea level rise, indirect harm to property values will begin to manifest in the City over the next 30 years, and, as a result, the City's tax base and our ability to deliver services will become increasingly compromised.[345]

Broward County, FL

Southeast Florida is particularly vulnerable to the predicted effects of climate change due to its extensive coastline, flat landscape, porous geology, and burgeoning coastal development. In South Florida, Miami-Dade, Broward, and Palm Beach counties collectively have populations approaching 6 million residents. Millions of these residents live on or near the shoreline.[346] Their safety depends on thousands of miles of canals for drainage and flood control.

Extreme high tides have become increasingly frequent and dramatic due to rising sea levels, over-topping seawalls, pushing up through storm water systems and contributing to flooding in communities far from the waterfront and coastal canals. King tides during the last two years have been more severe and expansive than predicted, compounded by diverse meteorological conditions, and, in 2015, occurred monthly for a full six months. These conditions revealed the complexity of the challenge, as Broward County cannot simply plan for any single scenario, but most consider the array of conditions on top of sea level rise that compound coastal flood conditions (e.g., high tides, slowing gulf stream, offshore storms, and super moons), independent of local rainfall. In Broward County, the condition is complicated by the expansive network of finger canals and waterways that generate more than 300 miles of shoreline and provide numerous entry points for water, creating vulnerabilities more expansive than the County's 23 miles of beach would suggest.[347]

Regionally, it has been estimated that $3 billion in property value is at risk with one foot of sea level rise. A storm surge could magnify this figure significantly. Rising sea levels threaten evacuation routes and critical energy, water, and wastewater infrastructure. Fort Lauderdale recently estimated that upgrades to the city's storm water system to combat rising sea levels would reach costs of $1 billion. In eastern Broward County, $5 billion of property is at risk with 2 feet of sea level rise, 64 percent of which is commercial.[348]

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[345] Flavelle C (19 Apr 2017) The Nightmare Scenario for Florida's Homeowners. Bloomberg News. https://www.bloomberg.com/news/features/2017-04-19/the-nightmare-scenario-for-florida-s-coastal-homeowners

[346] Coastal county definition, NOAA Office for Coastal Management, coast.noaa.gov, November 2017

[347] Broward County, Geographic Information Systems, staff analysis

[348] Analysis of the vulnerability of Southeast Florida to Sea Level Rise. August 2012. Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment Work Group, August 2012

Despite its severity, coastal flooding represents just a sliver of the challenge. The broader Broward landscape is also at risk due to the influence of sea level rise on our complex drainage and flood management system, as well as the groundwater table. Already, groundwater monitoring wells reveal a one-foot increase in groundwater elevations in coastal areas of the County, a condition that degrades the function of drainage wells and water management systems designed in accordance of hydrologic conditions that no longer exist. Hydrologic modeling performed in partnership with the U.S. Geological Survey (USGS) reveals a predicted one-to-one relationship between sea level rise and change in groundwater table in coastal areas of the county with 2.5 feet of sea level rise. The influence on the groundwater table is expected to reach more than 6 miles inland with a 50% response to each foot of sea level rise. This loss of groundwater storage is already compounding flooding, and will contribute to flood stages and flood risk for a growing portion of the community.[349]

For western communities, flood protection relies upon the ability of canals to drain stormwater runoff via discharge to the coast, discharge which is made feasible by gravity. Control gates separate tidal and freshwater reaches of these canals, but as rain falls and water stages increase, the gates are opened for flood relief, allowing inland stormwater to flow down gradient and discharge to tide. As sea level has risen, the downstream gradient has diminished, and discharges are slowed. During extreme high tide, some gates must remain closed, as coastal water levels rise above canal stages preventing release of stormwater and aggravating flood risk. Pumps to replace these gravity water control structures are estimated to cost $50 million each.[350] Existing pump systems are also inadequate. Provisional modeling performed by the USGS indicates that, by 2060, increases in groundwater level in response to rising seas will require an existing pump to run 24 hours a day to maintain flood control elevations.[351]

Rising seas impact water supplies as well, driving saltwater contamination into wellfields. USGS modeling in collaboration with the County reveals the predicted loss of 35 million gallons per day (MGD) in water supply capacity by 2060 (40 percent of Broward's coastal wellfield capacity), due fully to the additional influence of sea level rise. Sea level rise has doubled the rate of local saltwater intrusion into coastal wellfield (as compared to the influences of regional water management) and water supply operations. While the impacts will be realized county-wide, the affected wellfields pertain to Broward County and the Cities of Deerfield Beach, Pompano Beach, Hollywood, Dania Beach, and Hallandale Beach. The County is currently collaborating in a multi-jurisdictional alternative water supply project to help mitigate for these losses with construction of a 35 MGD surface water reservoir. The Phase 1 project cost is $161 Million.

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[349] Groundwater monitoring well data is available via https://nwis.waterdata.usgs.gov/nwis/gwlevels. Hydrologic modeling performed by the USGS and site-specific engineering calculations reveal recent and predicted loss of storage and compounded flood risk. Model results are not yet published.

[350] This is a minimum cost estimate based on FEMA reimbursement for retrofit of an equivalent structure in Miami-Dade County.

[351] Results not yet published.

In response to these overarching risks, Broward County, partner counties in the Southeast Florida Regional Climate Change Compact (Compact), and more than half of Broward municipalities have adopted a regional sea level rise projection for planning purposes, with an estimated 11 to 23 inches of additional sea level rise predicted by 2060.[352] This projection was developed via the activities of the 4-County Compact, formed in early 2010 as a voluntary collaboration among Palm Beach, Broward, Miami-Dade and Monroe Counties to jointly address shared climate mitigation and adaptation challenges. The County partnered with the U.S. Army Corps of Engineers under the Planning Assistance for States Program to undertake a hydrodynamic study to evaluate the combined influence of sea level rise, high tides, and high frequency storm events on flood conditions. The results of this study substantiate proposed establishment of a regional seawall and top-of-bank standard for tidally-influenced waterways, to improve community resilience to sea level rise and coastal flooding. A third-party risk-based economic analysis associated with this study revealed a 20.5-fold increase in economic exposure with just 1 foot of sea level rise for a storm surge event with a 1% annual probability.

To address these exposures, the County has modernized regulatory standards for surface water management systems to include wet season groundwater elevations under future sea level conditions, and is undertaking remap of the 100-year flood condition with an additional two feet of sea level rise to support new standards for finished floor elevations. The implications for planning and infrastructure design will be significant, but necessary given the risk and financial exposure of inaction.[353]

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[352] Unified Sea Level Rise Projection for Southeast Florida, Southeast Florida Regional Climate Change Compact. 2015

[353] National Hazard Mitigation Saves: an Independent Study to Assess the Future savings from Mitigation Activities. Vol. 1 – Findings, Conclusions and Recommendations. Vol. 2-Study Documentation. Appendices. MMC (Multihazard Mitigation Council). National Institute of Building Sciences, Washington, D.C. 2005