Testimony of Dr. Robert Kopp

Department of Earth & Planetary Sciences
Institute of Earth, Ocean, and Atmospheric Sciences
Rutgers University-New Brunswick

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On

The Impacts of Climate Change on New Jersey's Coasts

My name is Robert Kopp. I am a professor of Earth and Planetary Sciences and director of the Institute of Earth, Ocean, and Atmospheric Sciences at Rutgers University-New Brunswick. I am also a faculty affiliate of the Rutgers Climate Institute and the Rutgers Energy Institute there. I would like to thank Chair Pinkin and the members of the committee for inviting my testimony at this hearing. The views I am expressing are my own; I am not speaking as a representative of Rutgers University-New Brunswick or of any of the collaborations in which I have been involved.

I have been a member of the faculty at Rutgers for seven years. Prior to joining the Rutgers faculty, I received a Ph.D. in geobiology at the California Institute of Technology, served as a postdoctoral fellow in geosciences and public policy at Princeton University, and served as a science policy fellow at the U.S. Department of Energy's Office of Climate Change Policy and Technology. I have published over 70 peer-reviewed scientific publications over the last fifteen years; in the last nine years, almost all of these have related to climate change and sea-level rise.

As a professor at Rutgers, my research focuses on understanding uncertainty in past and future climate change, with particular focuses on sea-level change and the interactions between climate change and the economy. I am one of the lead authors of the book *Economic Risks of Climate Change: An American Prospectus*,[1] which came out in 2015, and of volume 1 of the US government's Fourth National Climate Assessment[2], which came out last year. I chaired the New

[1] TREVOR HOUSER ET AL., ECONOMIC RISKS OF CLIMATE CHANGE: AN AMERICAN PROSPECTUS (2015), http://www.climateprospectus.org/.
[2] USGCRP, CLIMATE SCIENCE SPECIAL REPORT: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME I (Donald J. Wuebbles et al. eds., 2017).

Jersey Climate Adaptation Alliance's Science and Technology Advisory Panel 2016 report on sea-level rise.[3]

As Director, a role I began in last summer, I oversee an Institute with over a hundred affiliated faculty. The Institute's mission focuses on advancing research, education and engagement about the past, present and future of our planet, and on development the knowledge and perspective needed for stewardship of a healthy, sustainable, and resilient planetary environment.[4] One of our key initiatives, the Coastal Climate Risk and Resilience Initiative,[5] is currently funded by the US National Science Foundation to educate graduate students across the natural sciences, social sciences, engineering, and urban planning to work with stakeholders to research and address the challenges of assessing and managing the risks climate change poses to the world's coastlines.

Assemblymember Pinkin invited me to testify today about the impacts of climate change on our state's coastlines. I'm going to focus on the challenges posed by sea-level rise, but before I get into those, I want to highlight some key conclusions supported by volume 1 of the US government's Fourth National Climate Assessment.[6]

1. **Climate change is happening today.** Global annually averaged surface air temperature has increased by about 1.8°F (1.0°C) over the last 115 years (1901–2016). The present time is now the warmest in the history of modern civilization.

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[3] R.E. KOPP ET AL., ASSESSING NEW JERSEY'S EXPOSURE TO SEA-LEVEL RISE AND COASTAL STORMS: REPORT OF THE NEW JERSEY CLIMATE ADAPTATION ALLIANCE SCIENCE AND TECHNICAL ADVISORY PANEL (2016).
[4] For more information about the Rutgers Institute of Earth, Ocean, and Atmospheric Sciences, see http://eoas.rutgers.edu/.
[5] For more information about Rutgers' Coastal Climate Risk and Resilience initiative, see http://c2r2.rutgers.edu/.
[6] USGCRP, *supra* note 2.

2. **Humans are responsible for it.** Based on many lines of evidence, including physical theory that dates back to the mid-nineteenth century, human activities – especially emissions of greenhouse gases – are the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

3. **Climate change is posing real risks to humans and the environment.** Thousands of studies conducted by researchers around the world have documented changes in surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor.

   For example, global average sea level has risen by about 7–8 inches since 1900, with almost half of that rise occurring since 1993. Human-caused climate change has made a substantial contribution to this rise since 1900, contributing to a rate of rise that is greater than during any preceding century in at least 2,800 years. Global sea-level rise has already affected the United States; the incidence of daily tidal flooding is accelerating in more than 25 Atlantic and Gulf Coast cities, and in Atlantic City, tidal flooding now occurs about ten times more frequently than it did in the 1950s.

4. **We can avoid many of the worst impacts of climate change through global action to reduce emissions, but to meet international goals, we need large efforts to reduce**

emissions starting now. At current rates of global greenhouse gas emissions, the odds of meeting the Paris Agreement goal of limiting global warming to less than 2°C (3.6°F) in will fall below 2:1 in approximately two decades. Stabilizing global average temperature, at any level, requires bringing net carbon dioxide emissions to zero.

5. **Even with such strong action, there are still going to be substantial impacts we cannot avoid and will need to manage.** Further warming will enhance all the effects we are seeing now: more heat waves, more intense floods and droughts, and higher sea levels, among them. To minimize risks, reductions in greenhouse gas emissions must therefore be combined with efforts to adapt to the changes that cannot be avoided.

6. **The more warming is allowed to transpire, the greater the odds the climate system will produce unpleasant surprises.** These surprises include both those scientists can see the outlines of – for example, the potential for commitment to a rise of global sea level of many feet due to the instability of the polar ice sheets – and others that are not yet known to science.

With respect to sea-level rise in New Jersey:

1. **Of all the climate change impacts economists know how to quantify, sea-level rise and the associated increase in coastal flooding pose the greatest economic risk to this state.**[7] Our book, *Economic Risks of Climate Change: An American Prospectus*, looked

[7] HOUSER ET AL., *supra* note 1.

at six types of impacts that cutting-edge economics is beginning to be able to quantify: temperature-related mortality, temperature-related impacts on labor productivity, effects on yields of major commodity crops, changes in energy demand, increases in violent crime, and property loss and business-interruption costs associated with coastal flooding. In New Jersey, without adaptive measures, damages are dominated by coastal flooding. Average coastal storm damage could increase by between $600 million and $4 billion per year – or even more in extreme sea-level rise scenarios – by the end of the century.

2. **Sea-level rise will lead to permanent inundation of some areas; it will also lead to more frequent tidal flooding and more intense storm flooding, as well as contamination of groundwater supplies.** Increases in tidal flooding – such as the 10-fold increase in the frequency of nuisance flooding in Atlantic City since the 1950s, a period that has seen about 9" of local sea-level rise – is the most visible, leading edge of these effects.[8]

3. **The effects of sea-level rise on the frequency of coastal flooding can be dramatic.** For example, in a middle-of-the-road sea-level rise scenario, leading to 1.4 feet of sea-level rise along the Jersey Shore between 2000 and 2050 and 3.4' between 2000 and 2100, the current '1-in-10 year' flood (3' above the high tide line) will become a '1-in-2 year' flood by 2050 and an annual flood by 2062. By 2100, it will become the daily high-tide level.[9]

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[8] William V. Sweet & Joseph Park, *From the extreme to the mean: Acceleration and tipping points of coastal inundation from sea level rise*, 2 EARTH'S FUTURE 2014EF000272 (2014).

[9] KOPP ET AL., *supra* note 3.

4. **Sea-level rise in the first half of this century is only slightly affected by changes in global greenhouse emissions.** Along the Jersey Shore, almost regardless of changes in greenhouse gas emissions, sea level is likely to rise by between 1.0 and 1.8 feet between 2000 and 2050.[10]

At 2 feet of sea-level rise, without adaptation, the homes of 36,000 people in this state would be subject to permanent flooding, and $15 billion of property would be permanently loss. With 5' of flooding – as would arise from the combined effect of 2' of sea-level rise and a 1-in-10 year flood – about 200 thousand people and $110 billion of property would be exposed.[11]

5. **How much sea level rises after 2050 is increasingly sensitive to the magnitude of global emissions reductions.**

Under a low-emissions pathway consistent with the Paris Agreement's long-term goals, New Jersey sea-level rise is likely to be between 1.6 and 3.5 feet. For high-emissions pathways, the magnitude of long-term sea-level rise is sensitive to rapidly developing knowledge about the Antarctic ice sheet and its potential instability. Depending on different ways of assessing the Antarctic response, likely sea-level rise under a fossil-fuel intensive, high emissions trajectory could be 2.4-4.5 feet or 4.4-8.3 feet over the 21st

[10] Robert E. Kopp et al., *Evolving understanding of Antarctic ice-sheet physics and ambiguity in probabilistic sea-level projections*, 5 EARTH'S FUTURE 1217–1233 (2017); Robert E. Kopp et al., *Probabilistic 21st and 22nd century sea-level projections at a global network of tide gauge sites*, 2 EARTH'S FUTURE 383–406 (2014); KOPP ET AL., *supra* note 3.
[11] B. STRAUSS ET AL., NEW JERSEY AND THE SURGING SEA: A VULNERABILITY ASSESSMENT WITH PROJECTIONS FOR SEA LEVEL RISE AND COASTAL FLOOD RISK 43 pp. (2014).

century. [12]

Under 4 feet of sea-level rise, without adaptation, the homes of 140,000 people would be subject to permanent flooding, and $76 billion of property to permanent loss. With a 1-in-10 year flood on top of 4 feet of sea-level rise, about 290 thousand people and $150 billion of property would be exposed. Under 8 feet of sea-level rise, the homes of 330 thousand people and $170 billion of property would be permanently lost.[13]

These are real risks that will pose an existential threat to some parts of this state. Even in the face of uncertainty about how much sea level will rise, there are steps New Jersey can take to reduce these risks. My Rutgers colleague Jeanne Herb will go into detail on specific policy proposals, but broadly:

1. **New Jersey can contribute to multi-state, national and global efforts to reduce greenhouse gas emissions.** If global efforts are substantial, they will significantly reduce the risk of extreme sea-level rise outcomes in excess of 6' of rise by 2100.

2. However, it is important to bear in mind that these benefits will not be felt significantly until the second half of this century and that, even with large-scale global efforts, sea-level rise in excess of 2' by 2050 and 4' by 2100 cannot be ruled out. **Thus, it is crucial that adaptation planning be integrated into state and municipal decisions related to zoning and infrastructure investment**, as well as into considerations of the long-term

[12] KOPP ET AL., *supra* note 3; Kopp et al., *supra* note 8; Kopp et al., *supra* note 8.
[13] STRAUSS ET AL., *supra* note 11.

fiscal health of the states' municipalities.

3. **The appropriate levels of sea-level rise to consider in a particular decision context depend upon both the timescale of the decision's consequences and the magnitude of those consequences**. In addition, it is important to recognize that future sea-level rise will further amplify existing risks of coastal flooding; failing to address existing vulnerabilities adequately guarantees that sea-level rise will be inadequately addressed. Sea-level rise needs to be considered on top of the flood risks that already exist at current sea levels.

4. **For decisions with time frames extending to 2030,** employing sea-level rise projections above year 2000 levels of about 1 foot provides an appropriate planning margin for decisions where consequences of flooding are small; 1-1.5' is more appropriate for decisions where consequences are large.

5. **For decisions with time frames extending to 2050,** 2' provides an appropriate margin when consequences of flooding are small; 2-3' provides an appropriate margin for more consequential decisions.

6. **Beyond 2050, sea-level rise projections are sensitive to both global emissions choices and cutting-edge scientific discoveries. Flexible adaptation pathways provide one way of dealing with what the scientific community calls 'deep uncertainty.'** One example of applying the 'flexible adaptation pathway' concept involves acting upon

projections for 2050 and laying out firm contingency pathways that will be followed over the coming decades as the range of future sea-level rise narrows. Such an approach is consistent with that recommended in the report of the New Jersey Climate Adaptation Alliance's Science and Technology Advisory Panel[14] and that specified in newly adopted California state guidance.[15]

For a high-emissions future, sea-level rise along the Jersey shore of 10' between 2000 and 2100 cannot currently be ruled out, so it is appropriate for these contingency plans to account for actions that will be taken to reduce risk in a range of scenarios leading to sea-level rise for 2100 between 2' and 10'.

7. Climate change in general and sea-level rise in particular poses challenges that will be with us for centuries to come. **Dealing with these challenges requires investments not just in the physical infrastructure of this state but in human capital, and New Jersey is positioned to be a leader in this area.**

Rutgers' nationally known expertise in key areas, including oceanography, coastal science, atmospheric science, geoscience, ecology, urban planning and landscape architecture, the extensive presence of the university in this state through its field stations and extension activities, and the engagement of municipalities and other stakeholders through organizations like the New Jersey Climate Adaptation Alliance all make New

[14] KOPP ET AL., *supra* note 3.

[15] CALIFORNIA OCEAN PROTECTION COUNCIL & CALIFORNIA NATURAL RESOURCES AGENCY, STATE OF CALIFORNIA SEA-LEVEL RISE GUIDANCE: 2018 UPDATE (2018), http://www.opc.ca.gov/climate-change/updating-californias-sea-level-rise-guidance/.

Jersey uniquely positioned to tie academic expertise on climate change and sea-level rise to on-the-ground decision support needs. Rutgers' Coastal Climate Risk and Resilience Initiative is one recently launched effort to capitalize on these strengths. With policy and financial support at the state level, we can go further, making this state a global pioneering leader in effective government-academic-private partnerships to manage the risks of sea-level rise.

Thank you again for the opportunity to testify.