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Issue Brief

Climate Change and Flooding in Central Appalachia

Communities in rural Appalachia face multiple water challenges that climate change is already impacting. These include extreme flooding events, lack of household water access, poor water quality, and lack of wastewater services.[1] Appalachia has some of the highest rates in the United States of households with Safe Drinking Water Act violations and without complete plumbing.[2] Here we present the observed and projected impacts of climate changes in Central Appalachia (shown in yellow in Figure 1) with a focus on increased extreme precipitation events and how flooding affects rural water and sanitation systems.

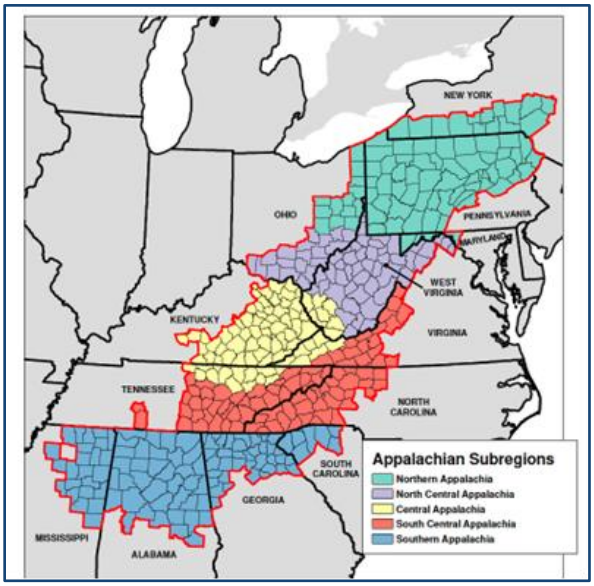

Figure 1: Appalachian Subregions
Source: Appalachian Regional Commission.[3]

KEY TAKEAWAYS

- Water access and infrastructure in Central Appalachia are already affected by climate change.
- Central Appalachia's varied geography, demographic composition, and legacy of extractive industries combined with climate change put the region at high risk for catastrophic flooding impacts.
- Extreme precipitation events such as floods can damage water infrastructure and compromise water quality.
- Climate change is projected to increase the frequency and severity of extreme precipitation in Central Appalachia, likely leading to more catastrophic floods in the region.

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Kentucky Floods of 2022

In July 2022, eastern Kentucky experienced several days of extreme rainfall that caused life-threatening, historic flooding.[4] Areas in eastern Kentucky recorded 8 inches of rain in a 24-hour period from July 27–28 and nearly 12 inches of rain from July 25–29.[4] The latter was a greater than 1,000-year event.[4] [1] The flooding necessitated hundreds of helicopter and boat rescues, and it swept away homes and portions of some communities (Figure 2), resulting in dozens of deaths and costly infrastructure damage, including widespread damage to rural water systems that affected the availability of safe drinking water and wastewater services.[5] While acknowledging that many water systems were struggling prior to the flood, officials indicated that the biggest challenge for recovery would be rebuilding water and wastewater systems.[5] At least three wastewater plants were rendered completely inoperable, and several others had limited operations due to the flooding, mudslides, rockslides, and power outages.[6] An estimated 18,000 service connections were without water, and another 45,600 connections received boil water notices.[6]

Figure 2: Flooding Devastation in July 2022, Southeastern Kentucky.[7]

The Kentucky floods of 2022 brought not only suffering and despair, but also hope and resilience in a place unequally and habitually exposed to risk.[8] Communities in Eastern Kentucky responded with caring and neighborly help, community self-organization, and collaboration, which demonstrated diverse and alternative responses to crisis.[8] Climate preparedness and response plans in Central Appalachia can enhance social infrastructure and local knowledge by offering strategies to address inequitable risks and social vulnerabilities, strengthening support systems, and contributing to better preparation for natural and technological disasters related to climate change.

[1] A 1,000-year event refers to an event (e.g., precipitation, flood) of that magnitude (or greater) has a 1 in 1,000 chance of occurring in any given year. In terms of probability, the 1,000-year event has a 0.1% chance of occurring in any given year (see https://www.usgs.gov/faqs/what-1000-year-flood).

In later sections we will discuss how extreme precipitation events such as the 2022 floods in Kentucky are projected to increase in both frequency and intensity. But first, it is important to understand what about Central Appalachia makes the region uniquely high risk to the impacts.

Central Appalachia's Unique Flood Risk

Several factors—including Central Appalachia's mountainous terrain, scattered housing on steep hillsides and in remote valleys, a history of natural resources extraction that intensifies flooding impacts, and high rates of low-income populations—contribute to the region's flood risk (Figure 3).[9] The region is home to minimal flat lands with many small communities built alongside small creeks and tributaries in narrow valleys known to the locals as "hollers" (hollows) that are especially vulnerable to flooding from extreme rainfall events, which are becoming more common under a warming climate.[10]

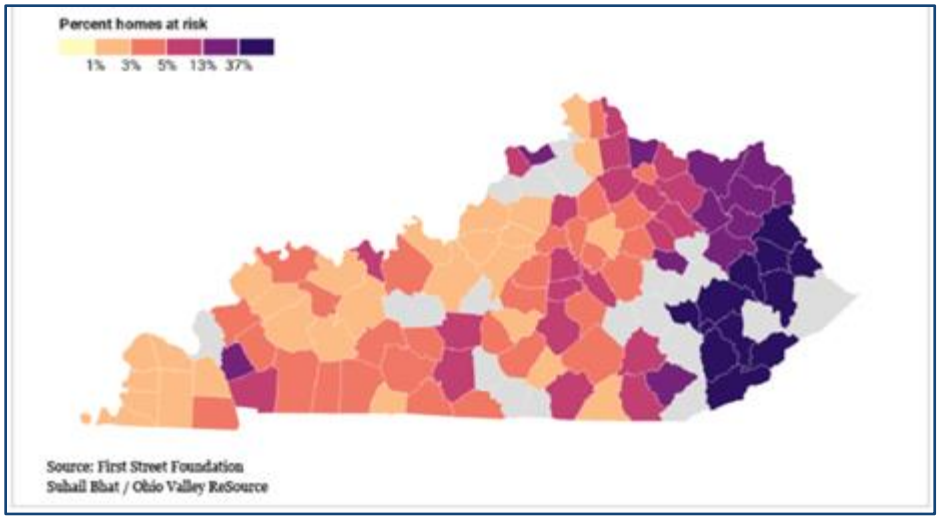

Figure 3: Percentage of Homes at Risk for Floods in Kentucky
Source: First Street Foundation[14] in Young and Bhat 2021.[15]

Historically, Central Appalachia has experienced some of the largest rainfall accumulations in the world at time intervals of less than 6 hours.[11] These occur because of small drainages and orographic (i.e., mountain) thunderstorm systems, which form when air is forced up by a mountain or hillside. These systems are known for producing heavy rainfall and catastrophic flooding.[11] Along the eastern margin and in the interior of Central Appalachia, catastrophic flooding is linked to "terrain-locked" thunderstorm systems that occur throughout the summer season.[11] These thunderstorms can stay over one mountain range for long periods of time as the complex terrain continues to generate warm, moist air, feeding storms and allowing them to remain at full strength for many hours.[12]

The legacy of extractive industries in Central Appalachia has removed some of the natural protections that could help alleviate flood risk.[9] The long history of coal mining

has resulted in the removal of trees, topsoil, and rocks, contributing to erosion[9] and a legacy of decaying infrastructure, all of which can exacerbate runoff and flooding.[13]

Central Appalachia is home to numerous communities that are highly susceptible to climate change impacts.[16,17] When compared with other rural residents in the United States, rural Appalachian residents have lower levels of income, employment, education, and access to the internet, and higher levels of disability (see Figure 4).[16] Communities of color make up a small percentage of the population in the region—5.8% in Central Appalachia and 7.8% in North Central Appalachia[16]—but have experienced disproportional poverty and inequitable access to clean water and functional infrastructure due to decades of discriminatory policies and practices.[18] Research has shown that people living in poverty are disproportionately likely to experience climate change impacts because multiple risks and economic stressors compound and make it harder for them to prepare or respond.[19] Eastern Kentucky contains higher levels of poverty than the rest of the state, with an average poverty rate of 18.9% in the state compared to 31.2% and 35.2% in Harlan County and Martin County, respectively.[20]

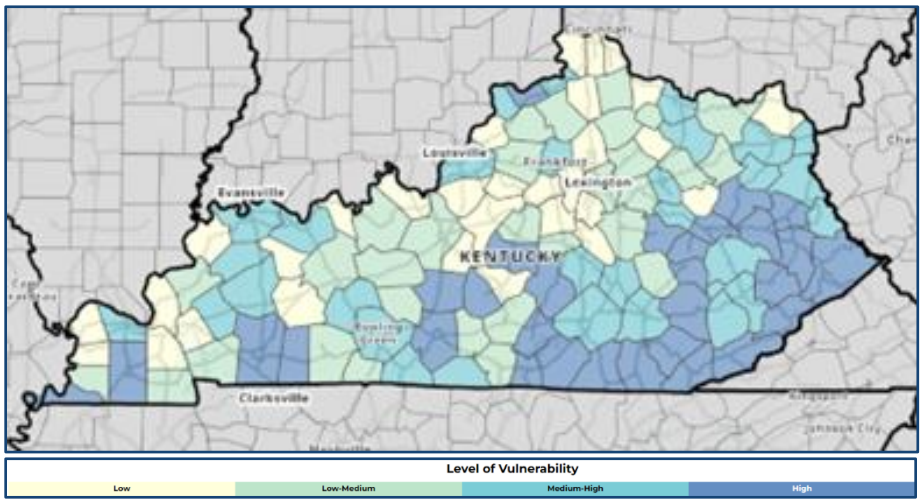

Figure 4: Social Vulnerability Map of Kentucky
Note: Factors include socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation.
Source: CDC/ATSDR.[21]

Observed and Projected Climate Change Effects on Extreme Precipitation in Central Appalachia

As the global climate changes, precipitation is projected to become more variable due to anthropogenic (i.e., human caused) warming. In the Southeast region of the United States, there have been increases in heavy rain events (Figure 5), and climate models predict an increase in extreme precipitation.[23,24,25] The number of days with heavy precipitation has increased in most locations across the Southeast, especially since the 1980s.[23]

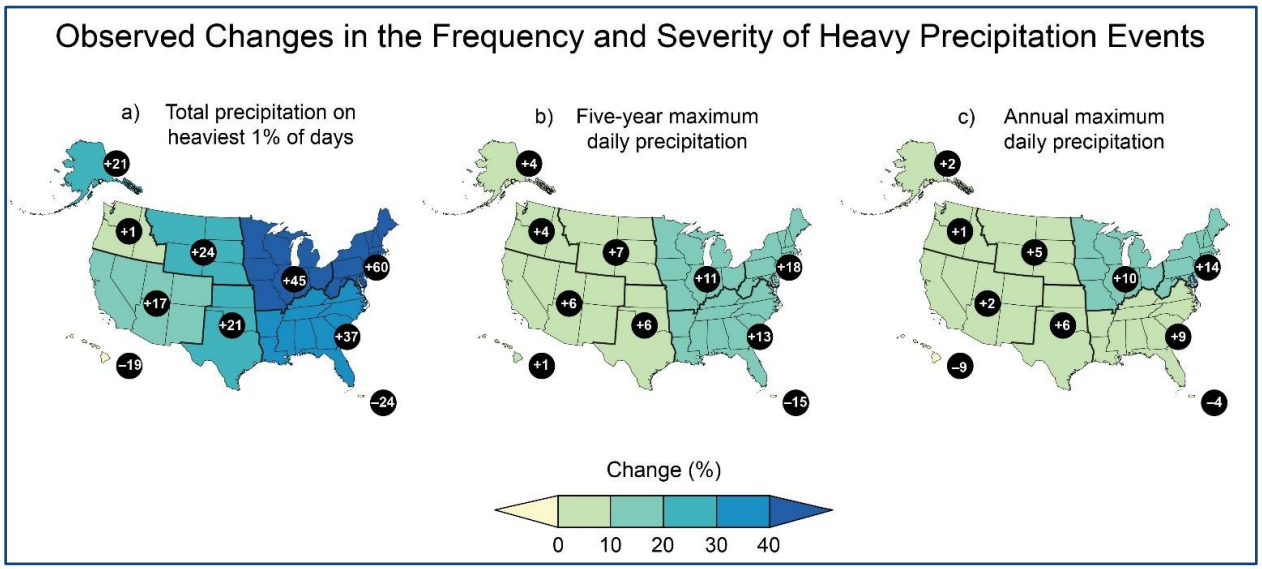

Figure 5: Heavy precipitation events are becoming more frequent and intense across the country and the Southeast specifically.
Source: Fifth US National Climate Assessment [24]

In Kentucky, total annual precipitation, and especially summer precipitation, showed an upward trend from 2015–2020.[26] Additionally, total annual precipitation since 2011 has averaged 7.4 inches above the long-term average from 1895–2020.[26] Given that increases in frequency and intensity of extreme precipitation are projected to continue, this will potentially increase the frequency and intensity of floods across the state.[26]

Since 2014, there has been an increasing number of costly and devastating extreme precipitation events across the Southeast.[23] Lawrence (population ~16,000) and Magoffin (population ~11,500) counties in eastern Kentucky, for example, recorded 12 climate disasters each from 2011–2021, receiving $2.8 million and $4.8 million in Federal Emergency Management Agency assistance during the 10-year period, respectively.[27] At the same time, counties in eastern Kentucky have the highest risk in the state for power outages, which can interrupt access to water and sanitation during disasters.[27]

Extreme Precipitation and Flooding Impacts on Water and Wastewater

In the Southeast, an increase in frequency of extreme precipitation events paired with a lengthening of dry spells between precipitations events can make water resources unpredictable.[25] The projected increase in extreme precipitation events will lead to intensified soil erosion and sedimentation, which exacerbates the risks of soil destabilization and landslides, especially in the steep mountain grades of the Central Appalachian landscape.[28] These events can damage already deteriorating water and wastewater infrastructure not designed to withstand these climatic changes as the

infrastructure was built to withstand historical conditions rather than current or future conditions.[29]

Flooding can also mobilize chemicals and pollutants that contaminate household and community water systems.[30] Extreme precipitation compromises drinking water by increasing sediment and nutrient loads in water sources.[31] Numerous studies have shown a strong association between extreme precipitation events and waterborne disease outbreaks in the United States.[32]

Water and wastewater systems can be especially vulnerable to climate change and floods. Wastewater systems, for example, are typically at the lowest point in the community and near bodies of water where they discharge.[33] Many drinking water treatment plants are located near the rivers and lakes where they draw water.[33] In cases of extreme precipitation, they are typically flooded first and may also lose power, disrupting service for community members. Extreme precipitation events can also overwhelm aging combined stormwater-sewer systems, which can lead to the introduction of contaminants and raw sewage into receiving waters.[34]

Partnering to Understand and Leverage Communities' Resources for Resilience

A partnership between the Pacific Institute, Rural Community Assistance Partnership, and Livelihoods Knowledge Exchange Network is assessing the risks and climate resilience of rural water systems in overburdened and under-resourced communities across the contiguous United States with a focus on the Central Appalachia and Southwest regions. This assessment aims to co-identify and co-design strategies and solutions for climate-resilient water systems with residents and leaders in rural communities. We also aim to contribute to community capacity-building for climate and water resilience in rural areas across the United States and catalyze the production of actionable knowledge on adaptation and emergency disaster preparedness. This partnership will leverage our organizations' expertise in co-developing collaborative, policy-relevant, multistakeholder research and knowledge exchange by providing technical assistance, training, and decision-support resources and tools to rural communities.

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