FLOODS IN THE CENTRAL U.S.

FED UP WITH FLASH FLOODS

De Soto, Mo., is a small town in Jefferson County on the state's eastern border, a 45-mile drive south from St. Louis. It boasts a quaint Main Street, a post office, and a creek that runs through its downtown. And, like so many towns across the Midwest, De Soto has a flooding problem. In the 4 years from 2015 to 2019, De Soto experienced five flood events, two of which were deemed presidential disasters.[46]

When Paula Arbuthnot moved to De Soto from a neighboring town in 2015, she hoped she was leaving the dangers of flash flooding behind. She had narrowly escaped being swept off the road in her car by a flash flood in nearby Hillsboro, Mo. She moved her family to De Soto, and by December, Joachim Creek, a tributary of the Mississippi River, had spilled over its banks and flooded the town. In fact, intense rainfall in the early hours of 26 December 2015 affected towns from southwestern Missouri all the way into central Illinois. Three interstates closed and six lives were lost.

TECHNOLOGY:
PREDICTING FLASH FLOODS

Flash flooding is characterized by a rapid rise in water levels in streams and creeks. The short time period between rainfall and onset of flooding, the localized occurrence, and the range of conditions that can result in flash floods make this type of flooding particularly difficult to predict.[70]

At NOAA's National Severe Storms Laboratory (NSSL) in Norman, Okla., research hydrologist Jonathan J. Gourley works to improve flash flood forecasting. The Multi-Radar/Multi-Sensor System (MRMS), which grew out of a technique Gourley helped develop where data from multiple weather radars are combined into one large "mosaic," can estimate rainfall rates and storm movement nationwide every 2 minutes.[71] Prior to MRMS, rainfall estimates were made on an hourly basis.[71] Using MRMS data, the new flash flood prediction system, named Flood Locations and Simulated Hydrographs (FLASH), doubles the accuracy of previous predictions, improves the spatial resolution to allow site-specific instead of county-wide predictions, and runs model simulations that cycle across the United States every 10 minutes.[70,72] In the summer of 2018, NWS forecasters began issuing flash flood warnings based on FLASH predictions.[73]

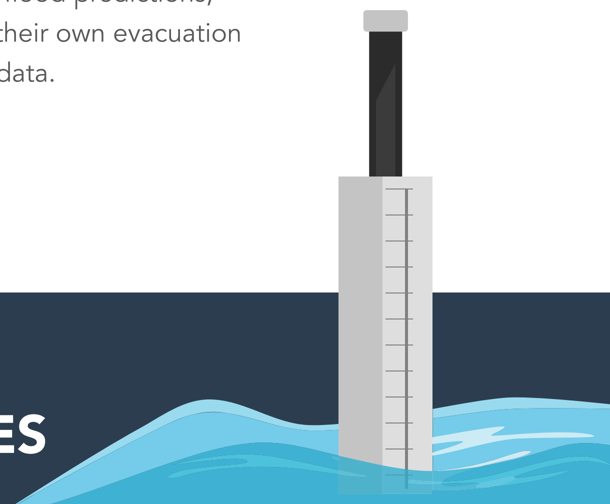
Susan Liley was also fed up with flooding. While her own home does not flood, she wanted to help others. She offered to help clean out flooded houses and distributed eggs from her chickens to families whose homes had flooded. She washed the clothes of a friend's granddaughter after they were submerged in floodwaters, and it felt like the last straw.

Arbuthnot, a civil engineer, and Liley, a retired secretary at the local high school and grandmother of four, connected online and decided to act. They cofounded the Citizens' Committee for Flood Relief (CCFR), an advocacy group focused on finding solutions to the worsening flooding in De Soto. They created a Facebook page and held monthly meetings at a local church. According to Liley, the group regularly attracts 20–30 people from the community and beyond. When heavy rains are expected in the area, they ask for volunteers to fill sandbags. Residents who experience flooding and those who don't are all concerned about the dangerous conditions in De Soto.

MAPPING AND MONITORING TO INFORM SOLUTIONS

Through their involvement with Higher Ground, an initiative of the nonprofit Anthropocene Alliance and the largest flood "survivor" network in the United States, Arbuthnot and Liley soon connected with AGU's Thriving Earth Exchange, which connects communities with scientists to solve local challenges. Thriving Earth Exchange introduced CCFR to hydrologists Robert Jacobson and Susannah Erwin at the U.S. Geological Survey (USGS), and hydrologist Dan Hanes and civil engineer Amanda Cox at Saint Louis University, all of whom volunteered their time to help the De Soto community.

The scientists suggested at the outset that CCFR lobby to have a streamflow gauging station installed on Joachim Creek, which USGS subsequently installed in 2018. The stream gauge measures the depth of water moving through Joachim Creek every 5 minutes,[47] giving the residents of De Soto near-instantaneous information about their stream levels, improved flood predictions, and the ability to make their own evacuation decisions based on the data.



TECHNOLOGY:
HOW WE USE STREAM GAUGES

Stream gauges are devices used to measure the depth of water flowing in a stream at one point over time, which can then be converted by a mathematical relationship called a "rating curve" into a volume of water. Within the United States, USGS supports a network of 10,330 gauges.[74] This network allows us to understand how much water is on the landscape during wet and dry periods and how the amount changes over time. Current and historical observations are available from USGS: https://waterdata.usgs.gov/nwis/sw. International records of streamflow can be accessed from the Global Runoff Data Centre, operated by the World Meteorological Organization: https://www.bafg.de/GRDC/.

The continental United States contains approximately 2.7 million segments of streams and rivers, stretching for more than 3.5 million miles[75]—enough to flow from the Earth to the Moon and back more than 7 times. Of these, only about 4,000 segments have a stream gauge with a measurement record long enough to generate a flood forecast.[76] NOAA's National Water Model, which debuted in 2015, is helping to close this gap.[76] Using NSF-supported supercomputers at the University of Illinois at Urbana-Champaign, the National Water Model incorporates data from the existing network of USGS gauges to calculate streamflow on all U.S. streams and rivers.[76]

Working with Higher Ground, CCFR was also able to secure a Silver Jackets study called a flood management plan. USACE supports communities in addressing flood risk through the Silver Jackets program.[48] The program brings together experts from federal agencies, including USACE, NWS, and USGS, as well as state, local, and tribal agencies, to coordinate efforts to address flooding risk.[48] The flood management plan assesses an area's vulnerability to flooding and offers options to minimize flood damage, with the goal of breaking a community out of the flood–rebuild cycle.[46]

Thriving Earth Exchange scientists helped review the first and second drafts of the Upper Joachim Creek Floodplain Management Plan, making comments and, most important, translating between USACE and resident priorities. With the support of technical advice and independent verification from Thriving Earth Exchange scientists, Arbuthnot and Liley successfully campaigned for the inclusion of a more detailed analysis in the next draft, using a 2-D hydraulic modeling technique.

FOR A FLOOD-WEARY CITY LIKE DE SOTO, ACCESS TO THESE RESULTS WILL PROVIDE RESIDENTS WITH CLARITY AND THE RELIEF OF KNOWING THEIR TRUE FLOODING RISKS AS THEY WEIGH THEIR OPTIONS.

They have also given Arbuthnot and Liley the information required to lobby local leaders to improve local ordinances. Both the city of DeSoto and Jefferson County governments have implemented new flood development ordinances that go beyond the usual recommendations by FEMA.

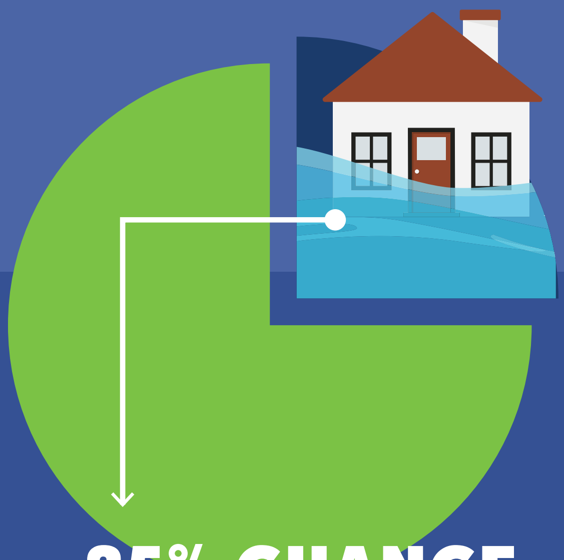
Their goal is to ensure that in the future, flooding will not be the same issue as it has been in the past.

PREDICTING AND MODELING FUTURE FLOODS

De Soto's challenges are a familiar story for cities and towns across the Midwest. This spring, Missouri River communities in South Dakota, Nebraska, Iowa, Missouri, and Kansas all saw major flooding. The floods were caused by more rain than usual falling on deeply frozen ground covered in snow.[10,49] The runoff, unable to be absorbed into the ground, overwhelmed streams and rivers. In March 2019, the upper Missouri River saw 4 times the usual amount of runoff, surpassing the previous record by 51%.[50] The river overflowed its banks and levees; for some communities, this was the sixth major flood event in the past 40 years.[51]

Research confirms what communities already know: The incidence of flooding in the central United States is on the rise.

A study funded by NSF examined data from stream gauges to determine flood rates. They found increasing flood rates between 1962 and 2011 at 34% of the sites included in the study, which were localized in the midwestern states of North Dakota, Iowa, Missouri, Illinois, Indiana, and Ohio.[52]



CLIMATE SCIENCE:

THE 100-YEAR FLOOD DOESN'T COME EVERY HUNDRED YEARS

An important area calculated on any flood hazard map is the 100-year floodplain. Similar to a coin toss, where for every toss you have a 50% chance of landing on heads, areas within the 100-year floodplain have, every year, a 1% chance of flooding. For homeowners who live in a 100-year floodplain, this translates into an approximately 25% chance their home will flood during a 30-year mortgage.[12]

Another reason why the 100-year flood doesn't come every 100 years is that the 100-year floodplain is, in part, determined using historical streamflow data. This calculation assumes that future streamflow will be like past streamflow.[77] In reality, changes to the landscape, built infrastructure, and climate cause changes to streamflow patterns that cannot be predicted using historical data.[77,78]

Climate science shows that the frequency and intensity of heavy precipitation events will increase as the atmosphere warms and holds more moisture.[9] Given the physical connection between precipitation and flooding, and observed correlations between the increasing number of high-intensity rainfall events and floods in the central United States, it seems likely that increases in heavy rainfall will lead to increases in flooding in some areas.[9,52] The overwhelming consensus among water resources engineers and scientists is that new methods and more long-term data are needed to calculate future flood risk accurately.[77,78]

Jacobson and many other scientists have spent their careers working to understand flooding along the Missouri River. They will be the first to tell you that the 2019 flooding will take years to fully understand.

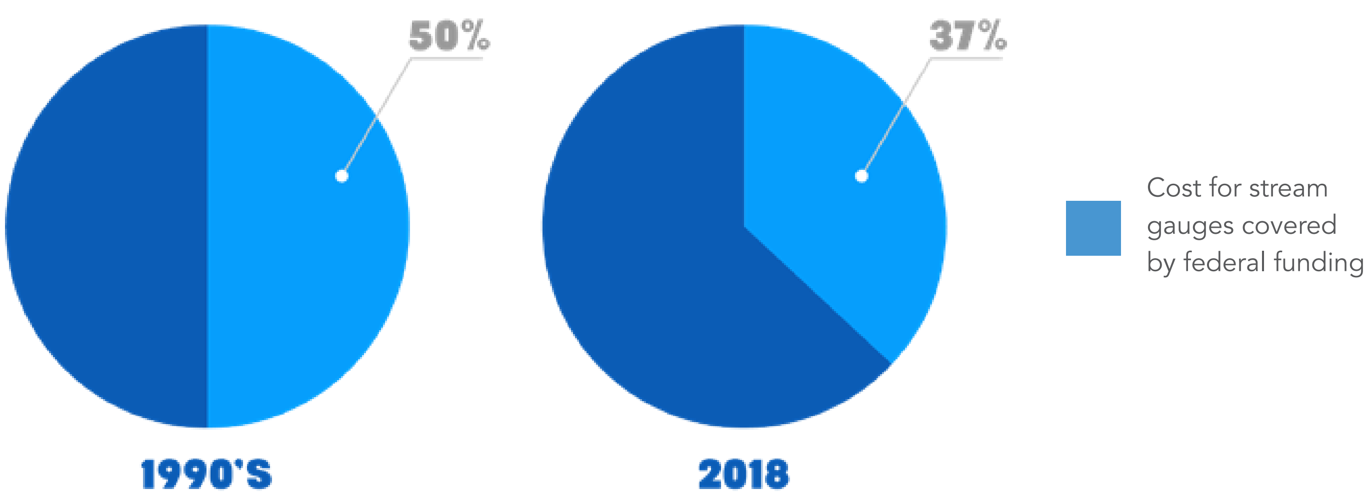
New data and new models are necessary to capture changing precipitation and land characteristics.

Flooding is caused by a combination of factors, which are intensifying due to climate change, including precipitation type, amount, and rate. In addition, rapid development constantly changes the likelihood that precipitation can be absorbed by the ground it falls on.

The Joachim Creek gauge in De Soto is maintained and partially funded by USGS, in cooperation with the city of De Soto and Jefferson County, Missouri. Flood warning systems enabled by streamflow gauging stations provide both tangible and intangible benefits. They allow residents to evacuate and protect their property; they give businesses and utility providers time to prepare, minimizing costs and disruption to customers; and they decrease the stress on an entire community that inevitably results from a rapid emergency evacuation.[53] Importantly, federal funding for stream gauges covers a shrinking portion of the costs (37% in 2018 versus 50% in the 1990s).[54] This creates a possibility that vulnerable communities will not have enough funds to support a stream gauge and understand their flooding risk. While determining an exact monetary value for flood warning systems is challenging, streamflow data collected by gauges—for all their possible uses, including flood management—have a benefit-to-cost ratio of about 4:1.[55]

STREAMFLOW GAUGES CAN HELP PROVIDE SOME IMMEDIATE RELIEF FROM FLOODING BY ALLOWING ADVANCE WARNING.

Knowing a flood is coming is one critical piece of information to communities like De Soto.



Long-term planning requires knowing where flooding is likely to occur, not just today but years into the future.

Developing a flood hazard map is one step toward this understanding and requires both streamflow data collected from gauges and an elevation map.

The USGS 3D Elevation Program (3DEP) has provided 3-D elevation data since 2014 with the support of multiple federal agencies.[56,57] These maps rely on light detection and ranging (lidar) laser technology. Lidar uses an aircraft to pulse laser light that bounces off the Earth's surface and returns to a sensor on the aircraft.58 Using these measurements, scientists can measure the Earth's surface at a horizontal resolution of approximately 2 feet or less, with a vertical error of about 4 inches.[57,58]

Currently, 3DEP data are available for 53% of the country.[56] These maps provide an estimated $502 million annually in benefits for the support of flood management decisions.[59] A survey of federal, state, local, and tribal governments and private companies identified 602 mission-critical functions that 3DEP maps support, falling into such diverse categories as infrastructure and construction management, agriculture and precision farming, and aviation navigation and safety.[59] Through supporting these functions, 3DEP provides a total potential annual benefit of $13 billion, or a possible 5:1 aggregate return on investment across all its uses.[59]

URBAN FLOODING SPILLS OVER

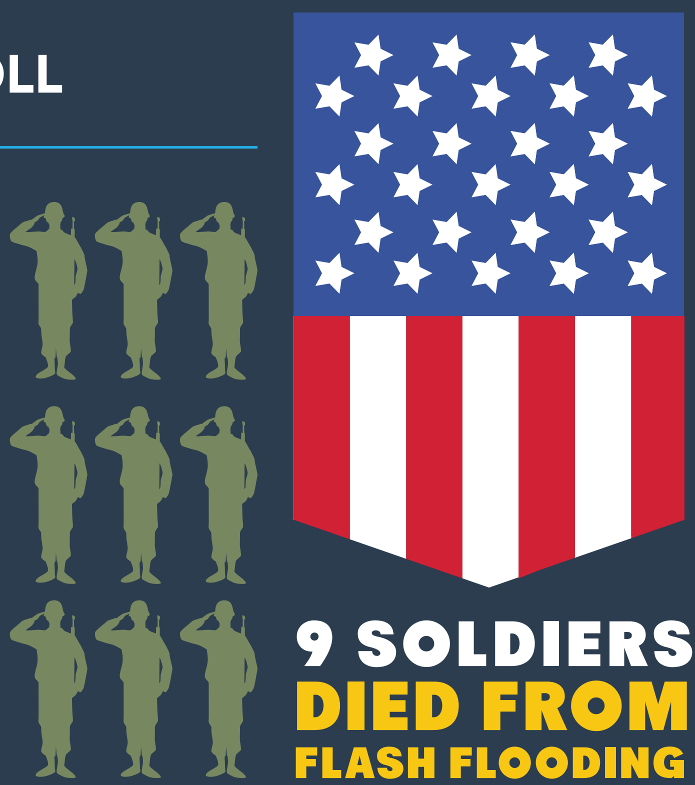
While residents of De Soto can point to Joachim Creek as the primary source of their flooding risk, in other communities across the country a different story is unfolding. For example, in the suburbs of Chicago, parking lots and basements flood without a stream in sight. When the Center for Neighborhood Technology (CNT), a nonprofit that strives to promote urban sustainability, investigated the issue, they found that the floods are being caused by storm water that has nowhere to go because of aging, undersized drainage systems overwhelmed by increased runoff from land development.

Harriet Festing, an advocate for communities dealing with the effects of climate change, led the effort for CNT. Digging into insurance claim data for Cook County, Illinois, which comprises Chicago and some of its suburbs, Festing found that flood insurance claims were no more likely within the mapped 100-year floodplain than outside of it.[60] This finding meant that the prevailing thinking—manage the floodplain and you will manage the floods—did not address the reality of urban flooding in Chicago. Subsequent reports have exposed urban flooding as a national problem.[61,62] With 86% of the U.S. population living in metropolitan and metropolitan-adjacent areas,[61] the implications are enormous.

HEALTH AND SECURITY:
FLOODING TAKES A TOLL

Flash flooding is the second leading cause of death from extreme weather in the United States, behind extreme heat.[33] At the U.S. military post Fort Hood in Texas, nine soldiers died from flash flooding during a training exercise in June 2016.[79] Since then, Fort Hood has installed six USGS stream gauges to help predict flash flooding events.[79,80]

In addition, in a survey of 100 residents of Cook County, Illinois, who experienced flooding in the past 5 years, 84% indicated that flooding caused stress, and 13% of respondents said that flooding contributed to the poor health of someone in their household.[60]



In her current role managing Higher Ground, Festing has also played a role in introducing communities facing urban flooding to scientists through her connections with AGU's Thriving Earth Exchange. This was how Joe Schulenberg, an assistant clinical professor at the University of Illinois at Chicago, met Delia Barajas, director of Ixchel, a grassroots organization advocating for racial equity in education and environmental justice for communities of color in the town of Cicero, a Chicago suburb. Together they sought to provide viable mitigation options for residents of Cicero and the nearby city of Berwyn affected by persistent drainage system backups resulting in basement flooding and sewer backups. These floods are even more life altering in these two towns, where a high cost of living and income inequality often lead to multiple families sharing single-family homes.

Schulenberg and a team of his students expected to provide engineering analysis and design alternatives to address the flooding in Cicero and Berwyn but soon realized the project would not be so simple. Schulenberg and his students found that nearly 70% of a given lot in the two municipalities is occupied by pavement or structures.[63] This lack of open space, combined with a lack of municipal and homeowner funds, made many of the solutions that students suggested, such as constructing a rain garden or a bioswale (a shallow, sloped ditch covered in grass or other plants), to retain flooding from the street, unrealistic to achieve.

Information is another resource limiting Barajas and Schulenberg in their efforts to mitigate the urban flooding in Cicero in particular. Unlike Berwyn, which has a Stormwater Management Plan developed with the help of the Chicago Metropolitan Agency for Planning, Cicero has no readily available plan. Furthermore, while the maps for Berwyn's sewer system are digitized in geographic information system (GIS) software, Cicero's maps remain as scanned drawings from the 1930s. Without updated planning and mapping information, engineers like Schulenberg need to start from nearly scratch when approaching Cicero's flooding problems.

The most challenging aspect for Schulenberg and his students was approaching the issue of urban flooding through an environmental justice lens. "You can do all the studies you want, but if you don't look at it through the lens of racial justice, you're missing the key part," says Barajas. The lack or denial of resources that many lower-income and minority communities face—in terms of access to funding, open space, and information—compounds the effects Cicero and Berwyn residents experience from urban flooding and make them more vulnerable to other environmental threats. For instance, Cicero is downwind of both a major railyard and a wastewater treatment facility, which contribute to air quality issues through soot and noxious odors, respectively.[64,65] Independent water testing has also revealed some instances of lead in Cicero's drinking water, caused by aging water distribution pipes.[66] Ixchel members are spread thin as they work to address flooding and air and water quality in their communities simultaneously. But as more engineers like Schulenberg and his students are willing to engage in analyses and information gathering that recognize how these impacts relate to each other and larger systemic barriers, they are likely to have more help in the future.

NEW SOLUTIONS TO AN OLD PROBLEM

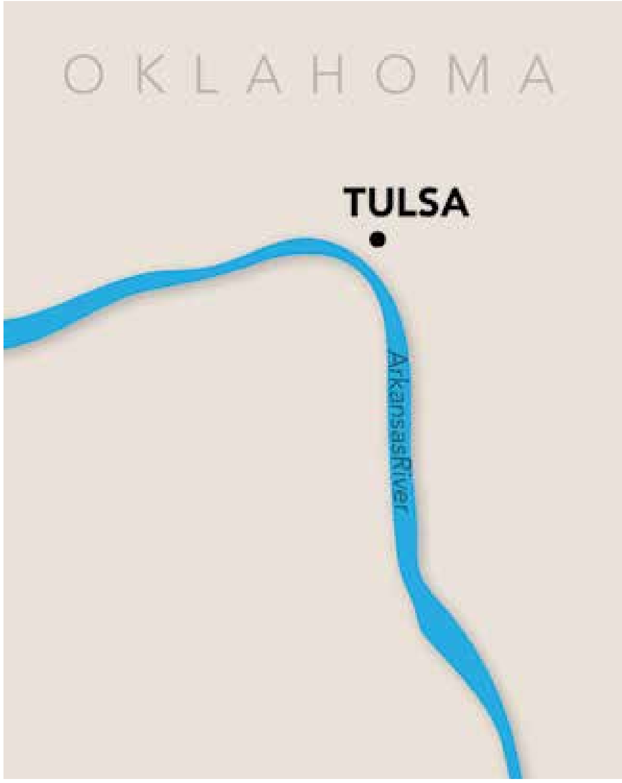
A growing number of communities are seeking new solutions to flooding. Many are opting for so-called "green" infrastructure, which works by allowing storm water to seep into the ground or by slowing the release of water downstream. Examples include rain gardens, permeable pavement, and bioswales. These efforts are based on new understanding of flood mitigation and management and contrast with traditional "gray" infrastructure, such as storm drains in a city road or levees between a town and a river, which both work by diverting water as quickly as possible downstream.

Toledo, Ohio, a city near the western point of Lake Erie, began considering green infrastructure after major flooding in 2006.[67] With funding from the Environmental Protection Agency's (EPA) Great Lakes Restoration Initiative and NOAA, Toledo undertook a study that found that green infrastructure that decreased peak streamflow in nearby Silver Creek by 10% could reduce total economic losses by 46% from a 100-year storm.[67,68] Motivated by this study, Toledo and EPA worked together to install a bioswale.[67]

In Tulsa, Okla., multiple levees and a dam on the Arkansas River built by USACE in the 1940s and 1950s did little to prevent flooding and only provided the community a false sense of security. Seeking new solutions to an old problem, the city established a Department of Stormwater Management in 1984.[69] The city used funds from FEMA to buy out and convert flooded properties to green areas, which are now used for both flood risk reduction and recreation.[69] The city also added stream buffers that provide additional environmental benefits and detention basins for added water storage during storms.[69]

The spring 2019 floods along the Missouri River prompted USACE to ask Congress to authorize an updated study of the region, but it remains an open question how policy makers and others in the United States will respond to this disaster. Flood risk management along any river is a complex problem that requires holistic watershed management to avoid passing the floodwaters and associated risk downstream, and high-level modeling informed by long-term, continually updated data sets. Because of the combined efforts of scientists who have dedicated their careers to studying rivers and streams, along with the determination of concerned citizens and organizers across the country who have made their voices heard and demanded better solutions for their communities, progress is being made in tackling the challenges posed by our changing world.

BOTH TOLEDO AND TULSA SHOW HOW CITIES ARE SUCCESSFULLY USING GREEN INFRASTRUCTURE WHEN GRAY INFRASTRUCTURE ALONE DOESN'T SOLVE THE PROBLEM.



SUMMARY

Floods in the central U.S. takes many forms. From river flooding in rural areas of the country and port cities, to urban flooding in highly populated metropolitan and suburban areas, no state in the country is spared from the costs of floods in the central U.S.

Basic data provided by USGS on streamflow and topography are critical to informing communities about where and how often flooding is expected to occur.

Scientists are continually developing new techniques to predict flooding. Examples include the NSF-funded National Water Model, which allows forecasts for any stream in the nation, and NOAA-developed FLASH, a model and early warning system for flash floods.

We live in a changing world, something already recognized by communities and scientists working on flooding issues. We need more research on new solutions, such as nature-based flood mitigation options, to successfully adapt.