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Building Flood Resilience in West Virginia through Community-Engaged Research

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Riverine flooding events are expected to become increasingly severe in the coming decades due to climate change, resulting in an urgent need to build flood resilience in underserved areas of the country. West Virginia has some of the highest risk of flooding in the United States, which is often compounded by aging infrastructure and high levels of socioeconomic vulnerability. In June 2016, one storm caused flooding that killed twenty-three people, destroyed or damaged thousands of homes and businesses, and caused \$1 billion in damages across the state. Some of the most affected towns have yet to fully recover. This mixed-methods community-engaged research project was the first systematic investigation of lessons learned from the 2016 floods in Greenbrier County, West Virginia, a place devastated by this disaster. Using a county-wide survey, focus groups, and participatory GIS (PGIS), this project resulted in the creation of community-informed geospatial products to communicate flood risk, as well as a set of community-identified recommendations for increasing resilience to future flood disasters. Findings offer critical insights for more effective flood response and recovery in West Virginia and other rural areas of the United States with high riverine flood risk. **Key Words:** community-engaged research, flood risk, natural hazards, participatory GIS, resilience.

As made clear by flooding events in recent years from western North Carolina to eastern Kentucky to northern Vermont, rural inland communities in the United States are at a high risk of severe flooding. Such communities tend to have high levels of socioeconomic vulnerability and low capacity to respond to flood disasters (Poling and Shealy 2024). Nationally, West Virginia is ranked at or near the top in nearly every flood risk category including potential impacts of flooding on utilities, public safety infrastructure, commercial properties, and schools (First Street Foundation 2020), with at least one flooding-related federal disaster declared in each of the state's fifty-five counties since 1996 (West Virginia Division of Homeland Security and Emergency Management 2018; Land Use and Sustainable Development Law Clinic, WVU 2022). Between 1993 and 2017, floods resulted in an estimated \$1.8 billion in property damage and 103 deaths across the state (Patterson 2020). These already regular disasters are expected to become more severe because of climate change (Environmental Protection Agency 2016), with significant expected annual losses from riverine flooding across the majority of West Virginia counties (Federal Emergency Management Agency [FEMA] 2025). Like rural communities across the United States, these risks are compounded by aging infrastructure (American Society of Civil Engineers 2020), high levels of socioeconomic vulnerability

(Agency for Toxic Substances and Disease Registry 2020), and low rates of flood insurance coverage (FEMA 2018b).

On 23 June 2016, one storm delivered ten inches of rain across West Virginia, or 25 percent of the state's mean annual rainfall (Shinn and Caretta 2020; Caretta et al. 2021; Figure 1). Small creeks rose rapidly, killing twenty-three people, tearing homes from foundations, damaging businesses, and causing \$1 billion in damages across the state (Di Liberto 2016; Poling and Shealy 2024). Over 90 percent of those seeking FEMA assistance after the flood did not have flood insurance, and relied on a combination of personal finances, nonprofit assistance, and other government resources to rebuild (Poling and Shealy 2024). Some of the most affected towns continue to struggle with long-term recovery (Shinn and Caretta 2020; Lilly 2021; Poling and Shealy 2024; Shinn 2024). This article details findings from a community-engaged mixed-methods research project that investigated lessons learned from the 2016 flood in Greenbrier County, West Virginia. The project was the first systematic documentation of lessons learned from the 2016 event and findings offer critical insights for more effective flood response and recovery in West Virginia and other rural areas of the United States with high riverine flood risk.

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Figure 1 Rainelle, West Virginia, the day after the 2016 flood. Image courtesy of Elevated Media.

Conceptual Framework

Community Vulnerability and Resilience to Flooding

The relationship between social vulnerability and natural disasters is well established (Burton 1993; Buckland and Rahman 1999; Cutter, Boruff, and Shirley 2003), including in relation to flooding (Few 2003). Vulnerability is understood as the susceptibility of an individual or group to harm, which in part determines their ability to effectively respond to natural disasters (Cutter, Mitchell, and Scott 2000; Adger 2006; Turner 2016). Flood risk results from a combination of flood magnitude, exposure of population and assets to the hazard, and vulnerability of the exposed population (Fedeski and Gwilliam 2007; Hallegatte 2014). Several social factors can moderate or exacerbate a community's capacity to anticipate, respond to, and recover from natural hazards (Cutter, Boruff, and Shirley 2003; Cutter and Finch 2008; Kaźmierczak and Cavan 2011). Such factors include income levels (Morrow 1999; Cutter, Boruff, and Shirley 2003; Flanagan et al. 2011); age distribution (Morrow 1999; Cutter, Boruff, and Shirley 2003; Cutter and Finch 2008; Flanagan et al. 2011); racial and ethnic composition (Morrow 1999; Cutter, Boruff, and Shirley 2003; Flanagan et al. 2011); and other factors related to home values, employment, population growth rates, education levels, and home and vehicle ownership (Morrow 1999; Cutter, Boruff, and Shirley 2003; Thieken et al. 2008; Flanagan et al. 2011).

Communities can experience vulnerability to floods and other natural hazards while also exhibiting resilience (Cutter 2016). Community resilience is defined as “the ability of communities to withstand and mitigate the stress of a disaster” and is a key component of long-term disaster recovery (Chandra et al. 2011). Predisaster planning and coordination is an important part of enhancing community resilience, even—and perhaps especially—in

the context of high levels of social vulnerability (Phillips and Jenkins 2010; Stajura et al. 2012).

Participatory GIS for Predisaster Planning

Effective predisaster planning requires accurate knowledge about flood risk. Research on climate knowledge has found that nearly all cases of successfully utilized data production and implementation employed some form of iteration between producers and users of the product (Dilling and Lemos 2011). Still, hazard mitigation planning often stresses expert-driven procedures that do not engage the most vulnerable groups and communities (Hendricks, Meyer, and Wilson 2022). One approach that is proven effective in engaging local communities is participatory geographic information systems (PGIS), which explicitly engages feedback from the user during product development. PGIS emerged as a response to criticisms of traditional geographic information systems (GIS), which tended to neglect social and cultural dimensions, with a focus on connecting scientific knowledge generation and policy formulation to enhance societal outcomes (Brandt et al. 2020).

The primary objective of PGIS is to include stakeholders in the GIS process to address issues that directly affect them, thereby harnessing local spatial knowledge and enriching outcomes. Prior research has demonstrated the value of PGIS for community-level disaster resilience in the context of climate change and geohazards (Haworth et al. 2018; Liu et al. 2018; Nkoana, Verbruggen, and Hugé 2018; Pecl et al. 2019; Juhász et al. 2020; Williams, Pauli, and Boruff 2020; Nofal and Van De Lindt 2022), as well as flood mitigation specifically (Verplanke et al. 2016; Cruz-Bello and Alfie-Cohen 2022). PGIS fosters ownership among end users while increasing usability and filling knowledge gaps (Kemp 2008; Verplanke et al. 2016; Zolkafli, Brown, and Liu 2017; Yusuf et al. 2018; Ndzabandzaba 2020). As a result, PGIS can be a critical component of supporting communities with knowledge to improve resilience to natural hazards such as floods.

Case Study and Methods

Greenbrier County, West Virginia

This project focused on Greenbrier County, West Virginia, population 32,149 (U.S. Census Bureau 2023b), one of the counties most severely affected by the 2016 flood (Figure 2). Of the twenty-three casualties resulting from this event, fifteen were in Greenbrier County. Research activities centered on the towns of Rainelle and White Sulphur Springs. Both communities are situated in flood-prone

surveys were also made available at the City Hall in both towns. No one took advantage of this opportunity, however. As such, although the project made a concentrated effort to reach as many residents as possible, there was a potential bias against some of the most vulnerable groups.

Second, the research team held three in-person community focus groups in public spaces in Rainelle and White Sulphur Springs in November 2022 (twenty-six total participants) and four virtual focus groups via Zoom in January 2023 (sixteen total participants). Focus groups are designed to bring together participants around a common topic of interest and are a robust method for collecting a relatively large amount of qualitative data in a short time (Watson and Till 2010). Participant recruitment focused on those with insights on the 2016 flood and was done through existing relationships of the research team, with a snowball approach to expand the initial sample. Participants in community focus groups included affected residents, emergency responders, floodplain managers, health care professionals, mayors and city council members, business owners, and nonprofit organization representatives. Participants in virtual focus groups included representatives of FEMA, country-level emergency management, AmeriCorps, West Virginia Voluntary Organizations Active in Disasters (WV VOAD), and several faith-based organizations. Focus groups were held during day and evening times to maximize participation and each participant was offered a gift card to offset participation costs.

Focus groups were facilitated to generate discussion on (1) lessons learned from response to and recovery from the 2016 flood, (2) priorities for future flood response and recovery efforts, and (3) the PGIS activities described later. The same questions were asked of participants in each of the seven focus groups, and analysis focused on identifying common themes that emerged across the groups, minimizing the risk that a small number of individuals could skew the overall findings (see Supplemental Material Appendix B for a complete list of focus group questions).

Third, at each of the seven focus groups, PGIS methods were used to gather input on visual tools created by the research team. The primary objectives of the visuals were to communicate flood risks facing these communities based on climate change models. Flood risk analyses incorporated data on several indicators: flood hazards, physical exposure, human exposure, social vulnerability, physical vulnerability, physical loss, human impacts, and mitigation (see Supplemental Material Appendix C for complete details and data sources for each indicator). The results were used to produce two-dimensional (2D) maps and three-dimensional (3D) visualizations that were presented to focus group participants for feedback and refinement (Figure 3).

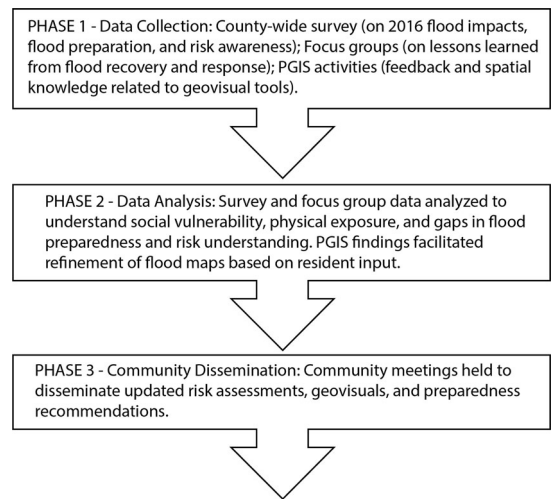


Figure 3 Overview of workflow of primary project activities. Note: PGIS = participatory geographic information systems.

Findings

Survey Findings

There were 1,168 valid survey responses, with an age range of 18 to 82 and an average age of 27.5. Annual household income ranged from less than \$20,000 to more than \$100,000. A total of 56 percent identified as female and 43 percent as male, and 80 percent identified as White. The average number of adults in households was 2.73, with 0.84 children. Approximately 75 percent reported full-time employment and nearly 70 percent had post-high school education, from trade school to advanced degrees.

Results indicate that the 2016 flood had widespread impacts on Greenbrier County. Nearly all respondents (98 percent) reported community impacts from the 2016 flood, with 76 percent reporting that their primary residence was either damaged (55 percent) or destroyed (44 percent). Of these, 87 percent reported being able to stay in their home despite damage, whereas some left their home for a short period of time (9 percent) and a few left permanently (3 percent). Of those whose homes were affected, over one-third did not believe they were vulnerable to flooding prior to the 2016 event (Figure 4).

Survey data revealed that recovery from the 2016 flood remains incomplete. When asked about the recovery level of their community, only 19 percent of respondents felt there had been a complete recovery, whereas 74 percent reported partial recovery. A full 92 percent of affected respondents received some kind of assistance for flood recovery, but only 52 percent of respondents reported a full recovery for their household (Figure 5). Respondents received

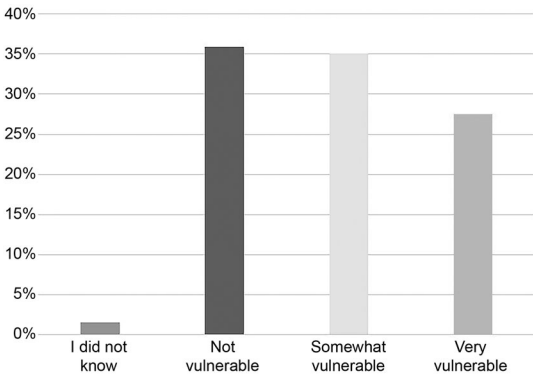


Figure 4 Perception of household vulnerability prior to 2016 flood.

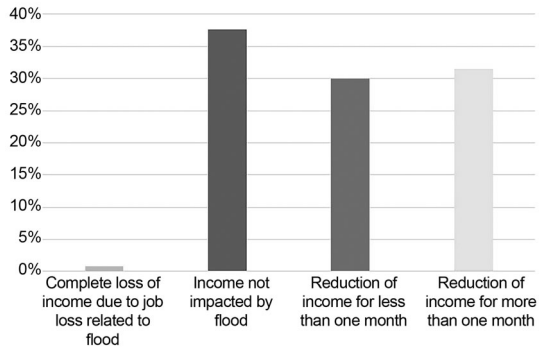


Figure 6 Impacts on income of 2016 flood.

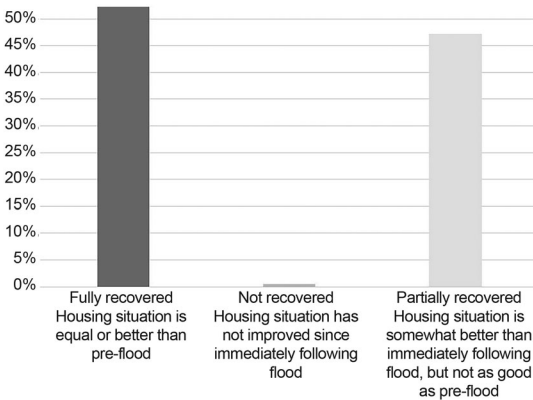


Figure 5 Household recovery from 2016 flood.

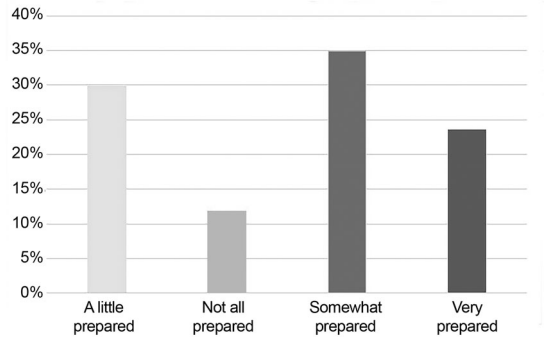


Figure 7 Household preparation for future floods.

help from a combination of sources, including FEMA, the National Guard, the Red Cross, faith-based organizations, and several nonprofit organizations. When asked how satisfied they were with the recovery process, 27 percent were very satisfied, 34 percent were somewhat satisfied, 34 percent were neither satisfied nor dissatisfied, and 4 percent were somewhat or very dissatisfied.

The survey indicated that the flood had widespread impacts on employment, including the necessity to take time off to repair damaged homes. When asked how the flood affected employment, 43 percent reported working more hours and 42 percent reported working fewer hours. As a result of these disruptions, over half of respondents whose jobs were affected by the flood experienced at least some reduction in income (Figure 6).

Respondents also reported emotional and mental health impacts related to the flood. When asked if the 2016 flood caused emotional or mental health impacts (diagnosed by a medical professional or not), 73 percent reported impacts, including new or increased levels of anxiety, depression, and fear of

large storms. Over half (54 percent) of people received support for these impacts, including from family and friends (27 percent) or mental health professionals (23 percent). An additional 23 percent reported wanting but not receiving mental health care.

Finally, responses indicate a wide range of perceptions on preparation for future floods, with less than a quarter feeling that either their household or their community are “very prepared” for future flooding (Figures 7 and 8). When asked if they have flood insurance for their homes, 47 percent reported having none, 21 percent reported having mandated flood insurance, 26 percent reported voluntarily purchasing flood insurance, and 6 percent were unsure if they had it at all.

Three broad conclusions stand out from this survey. (1) The high response rate, with approximately 4 percent of the total county population participating, indicates a great deal of interest in the ongoing impact of the 2016 flood. (2) Many residents and communities were not fully prepared for the flood, as indicated by disruptions to living situations, physical and emotional health, and employment. (3) Levels of recovery vary significantly and are incomplete. Tellingly, 92% of respondents reported receiving some kind of assistance but only 52% reported full recovery over six years after the flood.

Focus Group Findings

Two broad themes arose from the focus groups: (1) the need for predisaster preparation (e.g., coordination with FEMA and other organizations, establishing clear communication channels and leadership roles, and volunteer coordination), and (2) the need for additional predisaster capacity building (e.g., hiring and training floodplain managers, providing accurate flood insurance information, and creating improved flood risk assessment tools). As one participant said, “All disasters start local and end local,” highlighting the importance of community capacity building. Additionally, virtual focus group participants also discussed issues of equitable access to assistance, including for disabled residents, those with low literacy rates, and the inability of low-income households to access flood insurance. Focus group findings are summarized in Table 1, alongside representative participant quotes. Of note, although Rainelle and White Sulphur Springs had different socioeconomic contexts before the flood and are at different stages of postflood recovery, insights on lessons learned from the flood were similar across all seven focus groups and have been summarized accordingly.

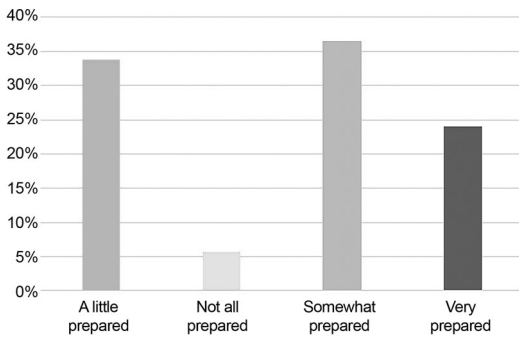


Figure 8 Community preparation for future floods.

Table 1 Focus group findings

Lesson learned from 2016 flood	Representative quote from focus group participant
Engage in predisaster community preparation	The thing that I would say is that number one, preparedness actually pays off.
Learn to navigate FEMA and other organizations before disaster	I would say the biggest thing that I could pass on to anyone else ... is to learn in advance as much as you can about dealing with FEMA and the other organizations.
Engage in predisaster community capacity and asset mapping	Understanding where in your community that capacity is ... folks with resources, that's the kind of thing I think that really helps build resilience.
Establish clear communication channels and leadership roles	We were building relationships pretty much from scratch, which is definitely not the way to do it ... partnerships didn't exist, networks didn't exist, playbooks didn't exist.
Conduct pre-disaster volunteer coordination and training	You're going to have people coming out of the woodwork and without a clear coordination plan ... you're going to have growing pains.
Hire and train floodplain managers	Today's the first time I've heard the word floodplain manager.
Provide flood insurance information to residents and realtors	So that should be a lesson learned- always push flood insurance ... that solves a whole world of issues.

Note: FEMA = Federal Emergency Management Agency.

Geovisualization Risk Indicators and Participatory GIS Findings

The following groups of indicators were used to analyze flood risk and create 2D and 3D visualizations of the results to present to the communities for their feedback.

Flood Hazard. In White Sulphur Springs, the effective 1 percent-annual-chance flood zone area, also known as the Special Flood Hazard Area (SFHA), is 266 acres or 21.9 percent of the community area, whereas in Rainelle it is 223 acres or 31.1 percent of the community area. These percentages are higher than the median ratio for all incorporated areas in the state (10.2 percent). Rainelle is potentially more exposed to higher flood depths, whereas in White Sulphur Springs, the primary concern lies in the considerable threat posed by flood velocity. Comparing the 2016 flood high-water marks in Rainelle with the estimated inundation depths by FEMA indicates the event was between a 1 percent-annual-chance (100-year) and 0.2 percent-annual-chance (500-year) flood event. In White Sulphur Springs, the 2016 flood exhibited similarities to a 500-year event.

Physical Exposure. Both Rainelle and White Sulphur Springs have a high level of physical exposure of primary structures in the high-risk floodplains (Table 2). The ratio of buildings in the floodplain to the total structures within the community is significantly higher for both areas compared to the state ratio. The median building value in the floodplain of White Sulphur Springs is higher than the statewide value, whereas it is lower in Rainelle. Most buildings in high-risk floodplains are residential; however, in Rainelle, the ratio of nonresidential structures is higher than the statewide ratio indicating higher risk of business interruption by flooding. In both communities, more than 75 percent of the flood-prone structures were constructed before the initial FEMA Flood Insurance Rate Map (FIRM)

Table 2 Building and parcel-level exposure in White Sulphur Springs (WSS) and Rainelle

Physical exposure indicators	WSS	Rainelle	Statistics in all West Virginia incorporated areas
Total primary building count in floodplain	425	338	59 (median)
Building ratio b/w floodplain and community total	26%	34%	9%
Building count in floodway (high velocity and depth)	105	47	12 (average)
Percent of SFHA buildings in floodway	25%	14%	8%
Total primary building value in floodplain	\$41.02 million	\$16.89 million	\$6.42 million (median)
Median building value in floodplain	\$49,000	\$38,000	\$42,000
Percent count residential building in floodplain	88%	74%	81%
Percent count nonresidential buildings in floodplain	12%	26%	19%
% pre-FIRM structures (includes "unknown")	88% before 1978	77% before 1987	77%
New maps: Buildings "mapped in" SFHA	75	325	19 (average)
New maps: Buildings "mapped in" floodway	14	38	97
Number of essential facilities in the moderate risk 0.2%-annual-chance floodplain	2	2	(Average)
Number of community assets (nonhistorical) in the high-risk 1%-annual-chance floodplain	8	7	3
Transportation: Road inundation of 1 ft. or higher (% of total road network mileage)	23%	36%	N/A
Transportation: Inundated bridges	3	2	N/A

Note: SFHA = Special Flood Hazard Area; FIRM = Flood Insurance Rate Map.

date when local floodplain development standards were established; consequently, these older buildings are likely more susceptible to damage and should be targeted for mitigation.

Essential facilities, such as police and fire stations, emergency operations centers, schools, hospitals, and nursing homes, play a vital role in delivering critical services to communities. One such facility—the White Sulphur Springs Police Department—is in the high-risk (100-year) floodplain. In Rainelle, two essential facilities are located in the high- and moderate-risk flood zones: the Rainelle Volunteer Fire Department and the colocated Town Hall and Rainelle Police Department. The location of these structures within the floodplain risks significant operational challenges during flooding events as well as the loss of critical governmental records and services. In White Sulphur Springs, eight community assets were identified within the high-risk floodplain, including four churches, the city hall, the municipal court, a U.S. Postal Service office, and a national fish hatchery. In Rainelle, there are six community assets in the high-risk flood zone including four churches, the Rainelle Public Library, and the Municipal Water Department. Findings also reveal that a considerable portion of the road network including U.S.

60 in both towns is at risk of inundation at flood depth of 1 foot or higher (Figure 9). Three bridges in White Sulphur Springs and two in Rainelle are also subject to flood inundation. These bridges can obstruct flow and increase the risk of impact by causing backwater flooding.

Human Exposure. A significant proportion of the population resides in the floodplains with a 1 percent annual chance of flooding in both communities. In White Sulphur Springs, 1,026 individuals are estimated to live in the high-risk area representing 39 percent of the city’s total population. In Rainelle, the estimated population residing in the floodplain is 582 accounting for 43 percent of the total population (U.S. Census Bureau 2023a). This percentage is significantly higher than the statewide percentage of 10 percent for all incorporated areas.

Social and Institutional Vulnerability. This study identified several social vulnerability indicators for the two communities, as summarized in Table 3. Rainelle is more vulnerable in all categories compared to the state ratios. Both communities have a higher average of renter-occupied properties, making structures and residents more susceptible to flood loss.

Physical Vulnerability. Primary structures located in flood zones that have subgrade basements

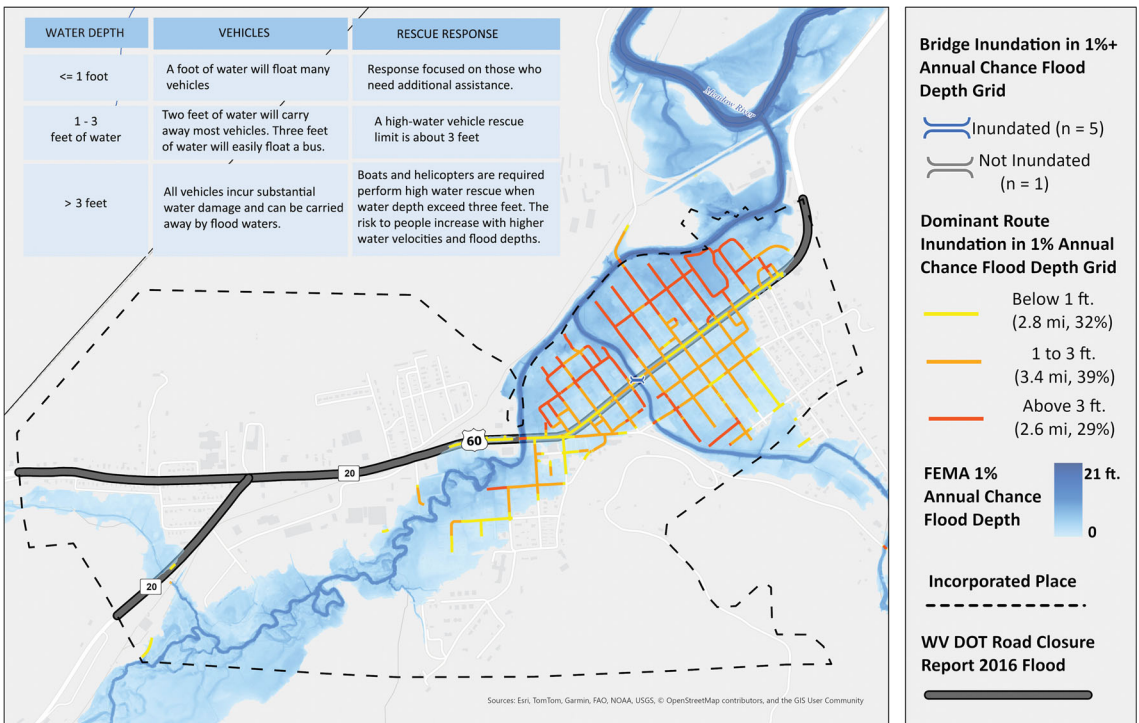


Figure 9 Roads at risk of being inundated in Rainelle.

Table 3 Analysis of social vulnerability in White Sulphur Springs and Rainelle based on the Census Bureau’s 2019 American Community Survey (ACS) 5-year estimates

Social vulnerability indicators	White Sulphur Springs	Rainelle	State ratio	National ratio
Poverty rate	14.4%	37.0%	17.3%	12.9%
Unemployment rate	21.4%	33.6%	23.8%	14.7%
Vulnerable ages ratio	41.7%	39.8%	30.8%	28.3%
Disability ratio	17.8%	26.9%	18.7%	13.0%
Population growth ratio	-9.1%	-20.9%	-3.2%	7.4%
Renter-occupied ratio	42.8%	43.0%	26.8%	36.0%
Housing values less than \$50,000	3.9%	37.5%	16.9%	6.6%
Housing median value	\$125,700	\$59,400	\$119,600	\$229,800

are more vulnerable to flooding. In comparison to the statewide ratio for all incorporated areas, both communities have a lower percentage of these structures (Table 4). One-story buildings are more vulnerable to flooding compared to multistory structures because if the flood water exceeds the first floor, the percentage of building damage will be higher and trapped occupants cannot escape to a higher level. The ratio of one-story residential buildings is higher than the statewide percentage. Rainelle has a much higher ratio of red tag structures (dilapidated, vacant, or buildings with appraised values equal to or less than \$10,000) in the floodplain, which means they could be more vulnerable in terms of building quality and the cost-effectiveness of mitigation measures.

Physical Loss. Field surveys of the 2016 flood for White Sulphur Springs and building-level loss models show that a significant number of structures will be substantially damaged at greater than 50

percent for flood events that exceed the 100-year base flood elevations (Table 5). Both building loss estimates and high-water marks indicate that the building damage percentages are considerable for both communities but are estimated to be higher in Rainelle due to the high inundation levels, longer flood duration, and wider flooding extent. Finally, the large amount of debris generated from major storms like the 2016 flood correlates to the high damage percentage of structures.

Both communities have higher amounts of paid losses compared to the state mean because of an increase in the number of claims from the 2016 flood disaster. Although the total number and value of structures in the high-risk floodplains of Rainelle is lower than White Sulphur Springs, the estimated debris, number, and amount of previous paid losses, and the number of repetitive loss structures is higher and indicative of repeated flooding events.

Table 4 Physical vulnerability analysis in White Sulphur Springs and Rainelle

Physical vulnerability indicators	White Sulphur Springs	Rainelle	Statistics in all West Virginia incorporated areas
Primary buildings with basements in floodplain	93	27	15 (median)
Percentage count buildings with basements in floodplain	22%	8%	37%
One-story residential buildings in floodplain	336	292	42 (median)
Percentage count one-story residential buildings in floodplain	79%	86%	69%
Low-valued (red tag) structures	20	56	6 (median)
Percentage low-valued (red tag) structures	5%	17%	4% (median)

Table 5 Physical loss estimates in White Sulphur Springs and Rainelle

Physical loss indicators	White Sulphur Springs	Rainelle	Statistics in all West Virginia incorporated areas
Substantial damage (> 50%) estimates	0	1	7 (average)
Percent substantial damage estimates	0%	0%	6% (average)
Substantial damage by 2016 flood	87	N/A	N/A
Moderate damage (10–50%) estimates	78	106	47 (average)
Percentage moderate damage estimates	18%	31%	34% (average)
Moderate damage by 2016 flood	98	N/A	N/A
Building debris removal estimates	450 ton	809 ton	165 ton (median)
Number of previous paid losses	89	152	63 (average)
Dollar amount of previous insurance claims	\$2,975,000	\$3,720,000	\$845,000 (average)
Number of repetitive loss structures	2	23	3 (median)

Table 6 Modeled human loss indicators in White Sulfur Springs and Rainelle

Human loss indicator	White sulphur springs	Rainelle	Average in all WV incorporated areas
Estimated Displaced Population	462	487	173
Percent of Population Displaced	17%	36%	13%
Estimated Population in Need of Short-Term Shelter	104	123	37

Human Displacement

In both communities, the ratio of estimated population displaced due to flood inundation of one foot or higher caused by a 1%-annual-chance (100-year) flood event is much higher than the state average for all incorporated areas. Moreover, the estimated number of individuals in need of short-term (up to two weeks) shelter in case of a 1%-annual-chance flood is also greater than the state average (Table 6).

Flood Mitigation. Mitigation measures implemented since the 2016 flood by the community were field verified and evaluated in accordance with the local floodplain management regulations (Table 7). Field verifications of both communities show that for most construction projects, the new structures were built to the base flood elevation of a 1 percent-annual-chance event (Figure 10). Field surveys show, however, that substantially damaged residential structures were often repaired but not elevated above the base flood elevation.

The percentage of elevated structures in the high-risk floodplain built to the design flood elevation

(DFE) set by the local floodplain management ordinance, or a two-foot safety factor above the 100-year base flood elevation, is lower in Rainelle (35 percent) than White Sulphur Springs (59 percent) as the town of Rainelle is more exposed to higher flood depths.

To measure a community’s recovery and resiliency against future floods, the net cumulative tax assessments of floodplain building values pre- and post-disaster were calculated. The net cumulative tax assessment reveals that the total floodplain building value in White Sulphur Springs has fully recovered and exceeded predisaster levels, whereas Rainelle has only partially recovered. Of the cumulative building values in the floodplain between 2015 and 2022, the predisaster values were \$13.3 million and \$23.0 million for Rainelle and White Sulphur Springs, respectively, and 2017 postflood decreased significantly to \$5.0 million for Rainelle and \$13.4 million for White Sulphur Springs. After mitigation efforts, in 2022 the cumulative building values in the floodplain for Rainelle and White Sulphur Springs increased to \$12.3 million and \$29.2 million, respectively (Figure 11).

Table 7 Highlights from the studied mitigation indicators in White Sulphur Springs and Rainelle

Mitigation indicator	White Sulphur Springs	Rainelle
Elevated structures to design flood elevation (DFE)	217	87
Percentage residential structures in 100-year floodplain elevated to DFE	59%	35%
Rehabilitated/repared structures	394	278
Unmitigated low-value structures	14	47
Area of open space preservation (OSP)	5 acres	3 acres
Ratio of OSP to Special Flood Hazard Area	2.6%	4.5%

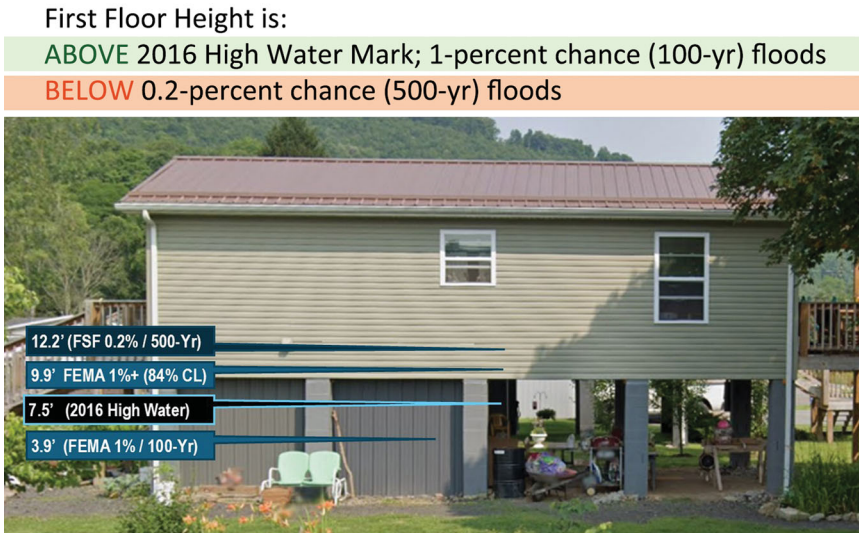


Figure 10 Example of detailed verification of flood mitigation with inundation levels of different scenarios for an elevated structure.

A loss avoidance study (LAS) quantifies the losses avoided (also known as damage prevented or benefits) due to the implementation of mitigation projects. An LAS for these towns revealed mitigation measures from elevating buildings above the base flood and buyouts resulted in a damage loss avoidance amount of \$2.3 million for Rainelle and \$2.6 million for White Sulphur Springs. The loss avoidance was calculated by determining the difference between loss estimates for buildings with a first-floor height of 1 foot (not elevated) and of a scenario in which those are elevated to DFE (2 feet above base flood elevation) or removed entirely. The ratio of areas preserved for open spaces in floodplains of both communities is lower than the average ratio for all incorporated areas statewide (5 percent), indicating limited use of this mitigation strategy.

Participatory GIS Activities

Geospatial visualizations created from the preceding findings were presented at each of the community focus groups with residents and city leaders to seek input and ensure the accuracy and relevance of the maps (Figure 12). The participation of residents allowed for real-time data validation, which was

valuable for refining flood maps and addressing discrepancies to ensure that the data used for decision-making were accurate. Two maps were prepared for each community. These maps delineate the 100-year flood zone, buildings damaged or demolished by the 2016 Greenbrier flood, repaired buildings, flood buyout properties, and critical infrastructures. As a result of community feedback, several modifications were made to the maps, including listing two properties as buyout properties in White Sulphur Springs, removing one structure from the 100-year flood zone in White Sulphur Springs, marking a building as an unrepaired structure in White Sulphur Springs, and identifying a police department as in the flood zone in Rainelle. In addition to the feedback on the maps, participants also improved the mapping process by locating their homes or workplaces, describing the water height, inundated streets, and the location of shelters during the 2016 flood. At the conclusion of the project, dissemination meetings were held and updated maps were given to each community.

Engaging participants in the GIS process resulted in more reliable flood maps, which in turn can empower residents and local authorities to make more informed decisions regarding flood risk

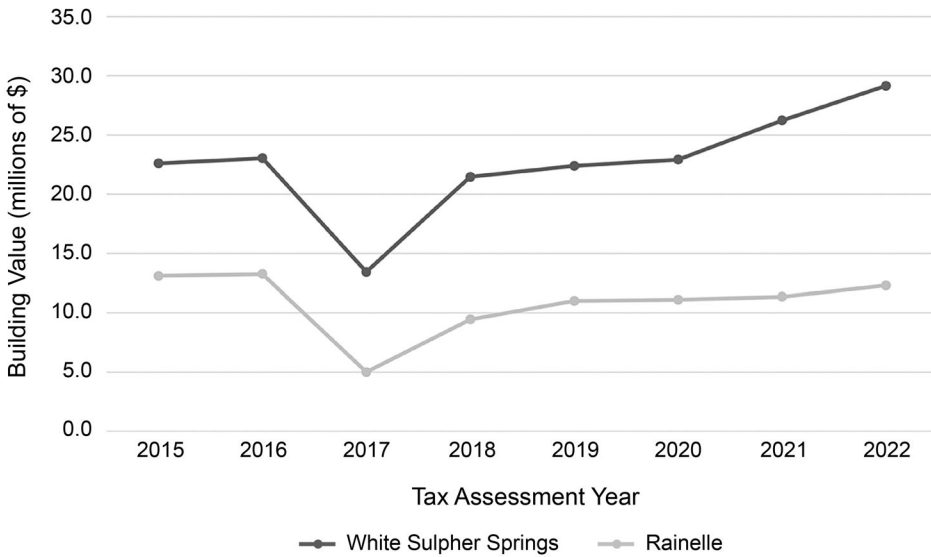


Figure 11 Cumulative building values in the floodplain in Rainelle and White Sulphur Springs, 2015–2022.

management and disaster preparedness, including through identifying critical infrastructure, evacuation routes, and vulnerable areas. More accurate flood maps can also empower individuals and communities to take proactive measures, such as purchasing flood insurance or implementing flood-resistant building practices, to mitigate the impact of future flooding events. As a result, these efforts promote resilience in flood-prone communities.

Discussion and Conclusion: Building Flood Resilience in West Virginia and Beyond

It is well-established that high levels of social vulnerability decrease a community's ability to effectively respond to natural disasters such as floods (Cutter, Mitchell, and Scott 2000; Few 2003). This is due in part to socioeconomic factors related to employment, education, and home ownership rates (Morrow 1999; Cutter, Boruff, and Shirley 2003; Flanagan et al. 2011). Findings from this project show that Greenbrier County, West Virginia is no exception to these trends, even as flood disasters become increasingly likely for the region. The unique mixed-methods community-engaged approach employed by this project went beyond identifying risk factors; it also determined key knowledge gaps that need to be filled, resulting in the creation of geospatial products to communicate flood risk, as well as a set of community-informed recommendations for increasing resilience to future flood disasters (Table 8).

Research participants consistently articulated the need for improved flood risk education for everyone

from residents to local officials. The PGIS approach used in this project not only provided critical knowledge about unique flood risk factors, but it also harnessed community knowledge to increase the accuracy of the products, a process that is known to increase ownership and use of the final outputs (Zolkafli, Brown, and Liu 2017; Yusuf et al. 2018; Ndzabandzaba 2020). As one focus group participant said, “You can only work with the tools that are given to you And if you're not given the tools to make change before an event happens, then you are forever going to be saying, okay, well, what can we do differently?”

In addition to the geospatial tools, findings also resulted in several recommendations that are community-informed but also have broad application for other rural inland communities at risk of flooding. These recommendations articulate a clear need for improved comprehensive predisaster preparation and capacity building, which are known to be key aspects of improving disaster response (Phillips and Jenkins 2010; Stajura et al. 2012). Although findings from the two case study sites—Rainelle and White Sulphur Springs—make clear that socioeconomic differences between communities contribute to uneven flood recovery processes, focus groups in both communities generated similar recommendations for improving future flood response. This indicates that these recommendations are relevant to rural communities of varying socioeconomic contexts.

Flooding events are expected to become increasingly severe in the coming decades due to climate change, resulting in an urgent need to build flood resilience in underserved areas of the country. Although findings from this project are broadly relevant to rural flood-prone communities elsewhere, “one-size-fits-all” solutions are likely to be



Figure 12 Participatory geographic information systems (PGIS) activities during a community focus group in Rainelle.

Table 8 Recommendations for building flood resilience in West Virginia

Recommendation	Level of focus
Educate individuals and communities on their flood risk	Household/community
Educate individuals and communities on Federal Emergency Management	Household/ community/county
Agency floodplain maps and the National Flood Insurance Program	Community
Confirm shelters are safely out of the floodplain and relocate if needed	Community
Create plan for long-term relocation of key facilities (e.g., police and fire stations, schools, town halls) out of floodplain	Community/county
Create plans for disaster response management, including communications, community asset mapping, volunteer coordination, and provision of mental health care	Community/county/state
Increase proactive floodplain mitigation, management, and permitting with integration of efforts from local to state levels	Community/state
Increase training and funding for disaster recovery case managers at local and state levels	Community/state

Note: A complete set of recommendations, along with a summary of findings and full appendix of project results, were compiled into a report and delivered to leadership and residents at community meetings in May 2023. They are available at https://data.wvgis.wvu.edu/pub/RA/HL/RA-L/STUDY/6-Places/CIVIC-2023/Report/NSF_CIVIC_Stage_1_Report_202305.pdf.

ineffective. Generation of data, tools, and knowledge for sustained and meaningful use in communities requires engagement, interaction, and knowledge exchange at the local level. We encourage other researchers interested in contributing to community disaster resilience to take a similar mixed-methods approach to identify not only the factors that put places at risk, but also potential solutions for increasing their resilience. The results can—and do—have meaningful impacts for communities living with a high risk of flooding and other natural disasters. ■

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Literature Cited

- Adger, W. 2006. Vulnerability. *Global Environmental Change* 16 (3):268–81. doi: [10.1016/j.gloenvcha.2006.02.006](https://doi.org/10.1016/j.gloenvcha.2006.02.006).
- Agency for Toxic Substances and Disease Registry. 2020. CDC/ATSDR Social Vulnerability Index (SVI). Last modified December 1, 2022. https://www.atsdr.cdc.gov/placeandhealth/svi/interactive_map.html.
- Alvey, T. 2020. Counting up red numbers at the Greenbrier. *The Register-Herald*, March 21. https://www.register-herald.com/health/counting-up-the-red-numbers-at-the-greenbrier/article_ddd059db-69fa-5e9c-9019-7f3f58896072.html.
- American Society of Civil Engineers. 2020. West Virginia infrastructure report card. Accessed February 2, 2023. <https://infrastructurereportcard.org/state-item/west-virginia/>.
- Brandt, K., L. Graham, T. Hawthorne, J. Jeanty, B. Burkholder, C. Munisteri, and C. Visaggi. 2020. Integrating sketch mapping and hot spot analysis to enhance capacity for community-level flood and disaster risk management. *The Geographical Journal* 186 (2):198–212. doi: [10.1111/geoj.12330](https://doi.org/10.1111/geoj.12330).
- Buckland, J., and M. Rahman. 1999. Community-based disaster management during the 1997 Red River flood in Canada. *Disasters* 23 (2):174–91. doi: [10.1111/1467-7717.00112](https://doi.org/10.1111/1467-7717.00112).
- Burton, I. 1993. *The environment as hazard*. New York: Guilford.
- Caretta, M. A., R. Fernandez, N. Zegre, and J. Shinn. 2021. Flooding hazard and vulnerability. An interdisciplinary experimental approach for the study of the 2016 West Virginia floods. *Frontiers in Water* 3:17. doi: [10.3389/frwa.2021.656417](https://doi.org/10.3389/frwa.2021.656417).
- Chandra, A., J. Acosta, S. Howard, L. Uscher-Pines, M. Williams, D. Yeung, J. Garnett, and L. S. Meredith. 2011. Building community resilience to disasters: A way forward to enhance national health security. *Rand Health Quarterly* 1 (1):6. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4945213/>.
- Cruz-Bello, G. M., and M. Alfie-Cohen. 2022. Capturing flood community perceptions for social vulnerability reduction and risk management planning. *Environmental Science & Policy* 132:190–97. doi: [10.1016/j.envsci.2022.02.029](https://doi.org/10.1016/j.envsci.2022.02.029).
- Cutter, S. 2016. The landscape of disaster resilience indicators in the USA. *Natural Hazards* 80 (2):741–58. doi: [10.1007/s11069-015-1993-2](https://doi.org/10.1007/s11069-015-1993-2).
- Cutter, S. L., B. J. Boruff, and W. L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84 (2):242–61. doi: [10.1111/1540-6237.8402002](https://doi.org/10.1111/1540-6237.8402002).
- Cutter, S. L., and C. Finch. 2008. Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the National Academy of Sciences of the United States of America* 105 (7):2301–06. doi: [10.1073/pnas.0710375105](https://doi.org/10.1073/pnas.0710375105).
- Cutter, S. L., J. T. Mitchell, and M. S. Scott. 2000. Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers* 90 (4):713–37. doi: [10.1111/0004-5608.00219](https://doi.org/10.1111/0004-5608.00219).
- Di Liberto, T. 2016. “Thousand-year” downpour led to deadly West Virginia floods. National Oceanic and Atmospheric Administration. <https://research.noaa.gov/2016/07/08/039thousand-year039-downpour-led-to-deadly-west-virginia-floods/>.
- Dilling, L., and M. C. Lemos. 2011. Creating usable science: Opportunities and constraints for climate

- knowledge use and their implications for science policy. *Global Environmental Change* 21 (2):680–89. doi: 10.1016/j.gloenvcha.2010.11.006.
- Environmental Protection Agency. 2016. What climate change means for West Virginia. <https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-wv.pdf>.
- Federal Emergency Management Agency (FEMA). 2016. Designated areas: Disaster 4273. <https://www.fema.gov/disaster/4273/designated-areas>.
- Federal Emergency Management Agency (FEMA). 2018a. Fact sheet: Natural hazard mitigation saves interim report. Department of Homeland Security. https://www.fema.gov/sites/default/files/2020-07/fema_mitsaves-fact-sheet_2018.pdf.
- Federal Emergency Management Agency (FEMA). 2018b. Understanding flood dangers in central West Virginia: Lessons learned from the June 2016 flood. Department of Homeland Security. https://www.fema.gov/sites/default/files/documents/Region_III_WV_FloodReport.pdf.
- Federal Emergency Management Agency (FEMA). 2021. Milestones mark West Virginia's road to recovery five years after 2016 disaster. R3-20-NR-092, Department of Homeland Security, Charleston, WV. <https://www.fema.gov/press-release/20210623/milestones-mark-west-virginias-road-recovery-five-years-after-2016-disaster>.
- Federal Emergency Management Agency (FEMA). 2025. National Risk Index: Expected annual loss. <https://hazards.fema.gov/nri/map>.
- Fedeski, M., and J. Gwilliam. 2007. Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology. *Landscape and Urban Planning* 83 (1):50–61. doi: 10.1016/j.landurbplan.2007.05.012.
- Few, R. 2003. Flooding, vulnerability and coping strategies: Local responses to a global threat. *Progress in Development Studies* 3 (1):43–58. doi: 10.1191/1464993403ps049ra.
- First Street Foundation. 2020. The first national flood risk assessment: Defining America's growing risk. https://assets.firststreet.org/uploads/2020/06/first_street_foundation_first_national_flood_risk_assessment.pdf#page=154.
- Flanagan, B. E., E. W. Gregory, E. J. Hallisey, J. L. Heitgerd, and B. Lewis. 2011. A social vulnerability index for disaster management. *Journal of Homeland Security and Emergency Management* 8 (1):92. doi: 10.2202/1547-7355.1792.
- Hallegatte, S. 2014. *Natural disasters and climate change: An economic perspective*. Washington, DC: Springer.
- Haworth, B. T., E. Biggs, J. Duncan, N. Wales, B. Boruff, and E. Bruce. 2018. Geographic information and communication technologies for supporting smallholder agriculture and climate resilience. *Climate* 6 (4):97. doi: 10.3390/cli6040097.
- Hendricks, M. D., M. A. Meyer, and S. M. Wilson. 2022. Moving up the ladder in rising waters: Community science in infrastructure and hazard mitigation planning as a pathway to community control and flood disaster resilience. *Citizen Science: Theory and Practice* 7 (1):1–12. doi: 10.5334/cstp.462.
- Hersher, R., H. Jingnan, and S. Schmidt. 2021. A looming disaster: New data reveal where flood damage is an existential threat. *National Public Radio*. Accessed February 2, 2023. <https://www.npr.org/2021/02/22/966428165/a-looming-disaster-new-data-reveal-where-flood-damage-is-an-existential-threat>.
- Juhász, L., H. H. Hochmair, S. Aguilar de Santana, and Z. J. Fu. 2020. Sea level rise impact assessment tool—A web-based application for community resilience in Coral Gables, Florida. *International Journal of Spatial Data Infrastructure Research* 15:36–55. doi: 10.2902/1725-0463.2020.15.art2.
- Kaplowitz, M. D., F. Lupi, M. P. Couper, and L. Thorp. 2012. The effect of invitation design on web survey response rates. *Social Science Computer Review* 30 (3):339–49. doi: 10.1177/0894439311419084.
- Kaźmierczak, A., and G. Cavan. 2011. Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. *Landscape and Urban Planning* 103 (2):185–97. doi: 10.1016/j.landurbplan.2011.07.008.
- Kemp, R. B. 2008. Public participatory GIS in community-based disaster risk reduction. *tripleC: Communication, Capitalism & Critique* 6 (2):88–104. doi: 10.31269/triplec.v6i2.81.
- Land Use and Sustainable Development Law Clinic, WVU. 2022. Voluntary floodplain buyout along Elkhorn Creek/Tug Fork River. Accessed February 2, 2023. https://data.wvgis.wvu.edu/pub/RA/_resources/NRCS/Elkhorn/2022.03.07.WV_PlanEA_Elkhorn_draft_with_maps.pdf.
- Lilly, J. 2021. Five years after 2016 flood, there's still work to do. West Virginia Public Broadcasting. Accessed February 2, 2023. <https://www.wvpublic.org/health-science/2021-06-23/five-years-after-2016-flood-theres-still-work-to-do>.
- Liu, W., S. Dugar, I. McCallum, G. Thapa, L. See, P. Khadka, N. Budhathoki, S. Brown, R. Mechler, S. Fritz, et al. 2018. Integrated participatory and collaborative risk mapping for enhancing disaster resilience. *ISPRS International Journal of Geo-Information* 7 (2):68. doi: 10.3390/ijgi7020068.
- Morrow, B. H. 1999. Identifying and mapping community vulnerability. *Disasters* 23 (1):1–18. doi: 10.1111/1467-7717.00102.
- Ndzabandzaba, C. 2020. Participatory geographic information system (PGIS): A discourse toward a solution to traditional GIS challenges. In *Handbook of the changing world language map*, ed. S. D. Brunn and R. Kehrein, 3825–35. Cham, Switzerland: Springer.
- Nkoana, E. M., A. Verbruggen, and J. Hugé. 2018. Climate change adaptation tools at the community level: An integrated literature review. *Sustainability* 10 (3):796. doi: 10.3390/su10030796.
- Nofal, O. M., and J. W. Van De Lindt. 2022. Understanding flood risk in the context of community resilience modeling for the built environment: Research needs and trends. *Sustainable and Resilient Infrastructure* 7 (3):171–87. doi: 10.1080/23789689.2020.1722546.
- Patterson, B. 2020. After deadly floods, West Virginia created a resiliency office: It's barely functioning. *Inside Climate News*, February 4. <https://insideclimatenews.org/>

- news/04022020/west-virginia-flooding-climate-change-resiliency/.
- Pecl, G. T., J. Stuart-Smith, P. Walsh, D. J. Bray, M. Kusetic, M. Burgess, S. D. Frusher, D. C. Gledhill, O. George, G. Jackson, et al. 2019. Redmap Australia: Challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. *Frontiers in Marine Science* 6:349. doi: 10.3389/fmars.2019.00349.
- Phillips, B., and P. Jenkins. 2010. The roles of faith-based organizations after Hurricane Katrina. In *Helping families and communities recover from disaster: Lessons learned from Hurricane Katrina and its aftermath*, ed. R. P. Kilmer, V. Gil-Rivas, R. G. Tedeschi, and L. G. Calhoun, 215–38. Washington, DC: American Psychological Association. doi: 10.1037/12054-009.
- Poling, K., and T. Shealy. 2024. Barriers to long-term disaster recovery in rural Appalachia: A retrospective analysis of the 2016 West Virginia flood. *International Journal of Disaster Risk Reduction* 110:104648. doi: 10.1016/j.ijdr.2024.104648.
- Shinn, J. E. 2024. Storytelling in precarious landscapes: Insights from a photovoice project in rural Appalachia. *Journal of Political Ecology* 31 (1):234–56. doi: 10.2458/jpe.5290.
- Shinn, J. E., and M. A. Caretta. 2020. “If it wasn’t for the faith-based groups, we wouldn’t be where we are today”: Flooding response and recovery in Greenbrier County, WV. *Southeastern Geographer* 60 (3):235–53. doi: 10.1353/sgo.2020.0019.
- Stajura, M., D. Glik, D. Eisenman, M. Prelip, A. Martel, and J. Sammartinova. 2012. Perspectives of community- and faith-based organizations about partnering with local health departments for disasters. *International Journal of Environmental Research and Public Health* 9 (7): 2293–2311. doi: 10.3390/ijerph9072293.
- Thieken, A. H., A. Olschewski, H. Kreibich, S. Kobsch, and B. Merz. 2008. Development and evaluation of FLEMOps—A new flood loss estimation model for the private sector. *WIT Transactions on Ecology and the Environment* 118:315–24. doi: 10.2495/FRIAR080301.
- Turner, M. 2016. Climate vulnerability as a relational concept. *Geoforum* 68:29–38. doi: 10.1016/j.geoforum.2015.11.006.
- U.S. Census Bureau. 2023a. Advanced search: American Community Survey 2019. <https://data.census.gov/all?d=ACS±5-Year±Estimates±Detailed±Tables>.
- U.S. Census Bureau. 2023b. Quick facts: Greenbrier County, WV. Accessed May 1, 2024. <https://www.census.gov/quickfacts/greenbriercountywestvirginia>.
- Verplanke, J., M. K. McCall, C. Uberhuaga, G. Rambaldi, and M. Haklay. 2016. A shared perspective for PGIS and VGI. *The Cartographic Journal* 53 (4):308–17. doi: 10.1080/00087041.2016.1227552.
- Watson, A., and K. E. Till. 2010. Ethnography and participant observation. In *The Sage handbook of qualitative geography*, ed. E. DeLyser, S. Herbert, S. Aitken, M. Crang, and L. McDowell, 121–37. Thousand Oaks, CA: Sage.
- West Virginia Division of Homeland Security and Emergency Management. 2018. West Virginia statewide standard hazard mitigation plan. Accessed February 2, 2023. <https://emd.wv.gov/MitigationRecovery/Pages/Hazard-Mitigation-Planning.aspx>.
- Williams, M., N. Pauli, and B. Boruff. 2020. Participatory GIS and community-based adaptation to climate change and environmental hazards: A Cambodian case study. In *Climate-induced disasters in the Asia-Pacific region: Response, recovery, adaptation, community, environment and disaster risk management*, ed. A. Neef and N. Pauli, 113–34. Bingley, UK: Emerald. doi: 10.1108/S2040-726220200000022005.
- Yusuf, J. E., P. Rawat, C. Considine, M. Covi, B. St. John, J. G. Nicula, and K. A. Anuar. 2018. Participatory GIS as a tool for stakeholder engagement in building resilience to sea level rise: A demonstration project. *Marine Technology Society Journal* 52 (2):45–55. doi: 10.4031/MTSJ.52.2.12.
- Zolkafli, A., G. Brown, and Y. Liu. 2017. An evaluation of the capacity-building effects of participatory GIS (PGIS) for public participation in land use planning. *Planning Practice & Research* 32 (4):385–401. doi: 10.1080/02697459.2017.1329470.

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