Flood Justice: Past, Present, & Future

Lessons from the Stormwater Infrastructure Resilience and Justice (SIRJ pronounced surge) Lab

UNIVERSITY OF MARYLAND 18 56

Marccus D. Hendricks, Ph.D., MPH

Director and Associate Professor

Stormwater Infrastructure Resilience & Justice (SIRJ) Lab

School of Architecture, Planning, and Preservation

University of Maryland

Urban Flooding is an increasingly discussed phenomenon both in national reporting and the academic literature.

Urban Flooding Published Papers 1956 – 2018 (From Web of Science)
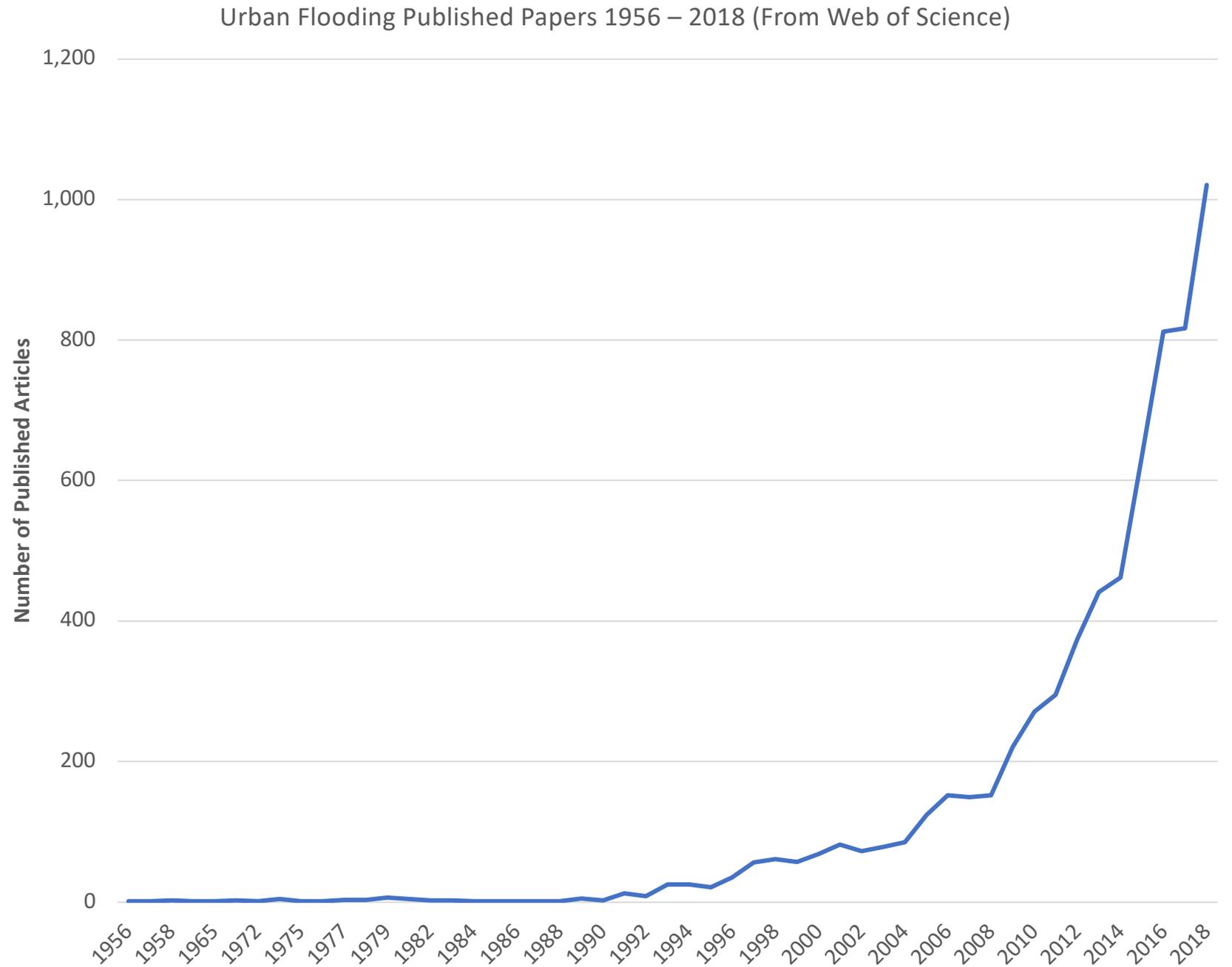
Major U.S. Urban Flooding Events

Tropical Storm Harvey – Houston (2017)

Photo Credit: Paul Jordan Anderson/DoubleHorn Photography

California Floods (2022-2023)

Photo Credit: MARK RIGHTMIRE/MEDIANEWS GROUP

- Some parts of Houston received more than 50 inches of rainfall

- Total damages were estimated at **$125 billion**

- Directly responsible **for 68 deaths**, the largest number of direct deaths from a hurricane in Texas since 1919

- **68% of flooded homes** were outside of the 100-year riverine floodplain

- Southern, Central Coast, and Northern California were impacted

- **6K** individuals ordered to evacuate

- **200K** homes and businesses lost power

- The flooding resulted in property damage and at least **22** fatalities

Mid-Atlantic U.S. Flooding – Carolinas, Virginia, D.C., Maryland, & Penn. Et. Al. (Summ/Fall 2023)

Photo Credit: Jason Crighton

Photo Credit: Photo by Lokman Vural Elibol/Anadolu via Getty Images

- 8+ states impacted along the eastern seaboard of the U.S.

- Over 600K customers lost power in the Northeast

- In DC, 20 people rescued from under bridge on Rhode Island Ave. and 10 dogs drowned at District Dogs

- In Maryland, a flash flood emergency was issued for the entire Baltimore area as 3–5 in (76–127 mm) of rain fell. Several roads and highways, including portions of the Capital Beltway (I-495) and US 29 were closed due to floodwaters on the roadway, and flooding also stranded drivers on several roads in the city. More than 1,500 power outages occurred across the state.. Damage in Maryland totaled to $548,000.

Global Commonalities Amongst "Urban Flooding" Events

- Rainfall was a major contributing factor, spreading the impact out beyond coastal or river flood zones.

- The amount and location of impervious cover is most predominant in high density areas, increasing stormwater runoff.

- **Stormwater infrastructure** was unable to cope with the amount of stormwater runoff during the events, leading to further flooding.

- **Social and physical vulnerability** of communities located in flood-prone areas. – New Explicitly Mentioned Factor

Alves, P. B. R., Amanguah, E., McNally, D., Espinoza, M., Ghaedi, H., Reilly, A., & **Hendricks, M. D.** (2024). Navigating the definition of urban flooding: a conceptual and systematic review of the literature. *Water Science & Technology*, https://doi.org/10.2166/wst.2024.351

What is the infrastructure crisis?

1. From lead-lined pipes in Flint, MI to the failing water treatment facilities in Jackson, MI, systems are past their prime and decaying infrastructure is omnipresent.

2. The American Society of Civil Engineers gave the U.S. infrastructure a C- in their most recent report card, just shy of a failing score.

3. Phenomenon has been well-documented

4. Social stratification is inherent

Disparities within the infrastructure crisis

1. Attention to where and on whom the burdens of decaying infrastructure fall heaviest is **relatively new for a long-standing problem**.

2. The just implementation and on-going maintenance is TBD.

Environmental Injustice and Social Vulnerability

1. the nation's environmental laws, regulations, and policies have not been applied fairly across all segments of the population.

2. social stratification based on race, income, disability, gender, age, nationality, among others contributes to differential risks and impacts from disasters
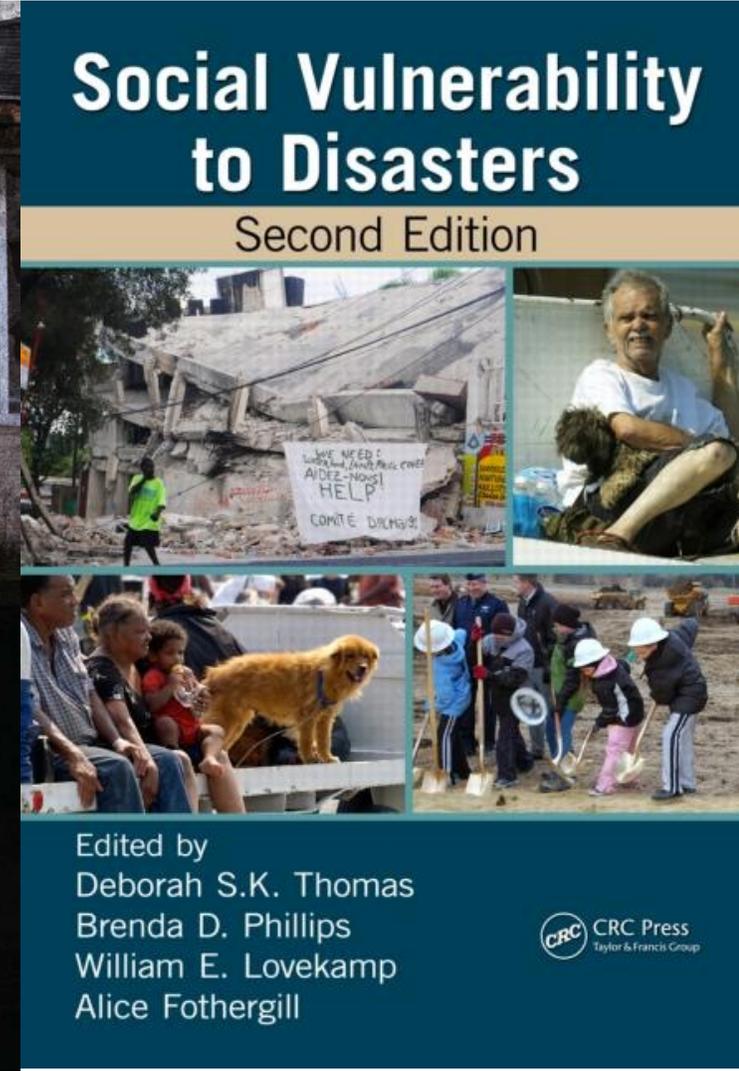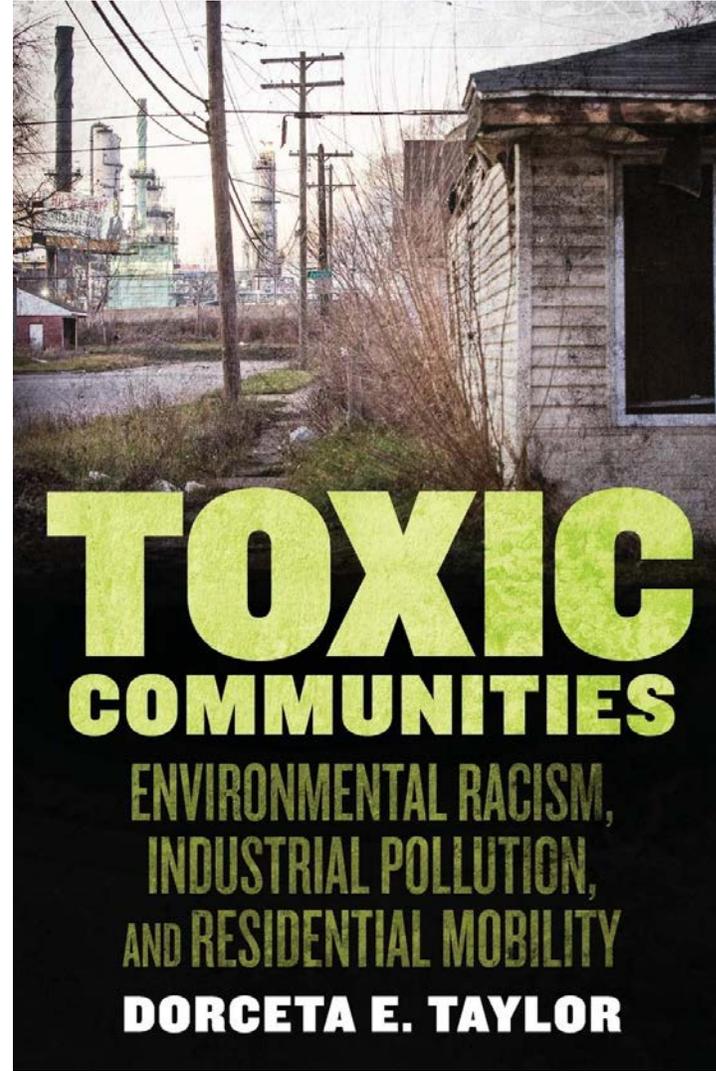
Selected mentions of infrastructure in the environmental justice literatures

"**The nation must redefine "environment" to include infrastructure** problems that threaten the fabric of our cities and their inhabitants. An inadequate sewer treatment plant is an environmental and health threat. The repairing or replacing of decayed sewer lines and upgrading existing and building new sewer plants are investments in America"

- Bullard, 1994

"The foundation of vulnerability analysis… generally focuses on a community's exposure to hazard agents such as floods, etc. Such assessments identify the potential exposure of populations, businesses, and the built environment (housing, **infrastructure**, critical facilities, and so on). Also important are the physical characteristics of the built environment such as wind design features of buildings, the height of structures relative to potential floods, as well as natural and engineered **environmental features** such as wetlands, dams, levees or sea walls, because they **can modify vulnerabilities and concomitant risk**."

- Van Zandt et al., 2012

"**The failure of municipalities to install up-to-code sewer and water infrastructure** (i.e., underground sewage and drinking water pipes of the adequate size and material) **can lead to vulnerabilities in the sewer and water systems**, increased levels of harmful microbes and chemicals in residential drinking and surface water supplies, elevated exposure risks, increased occurrence of gastrointestinal (GI) and other illnesses, reduced neighborhood quality of life, and higher stress levels **among poor people of color residents**."
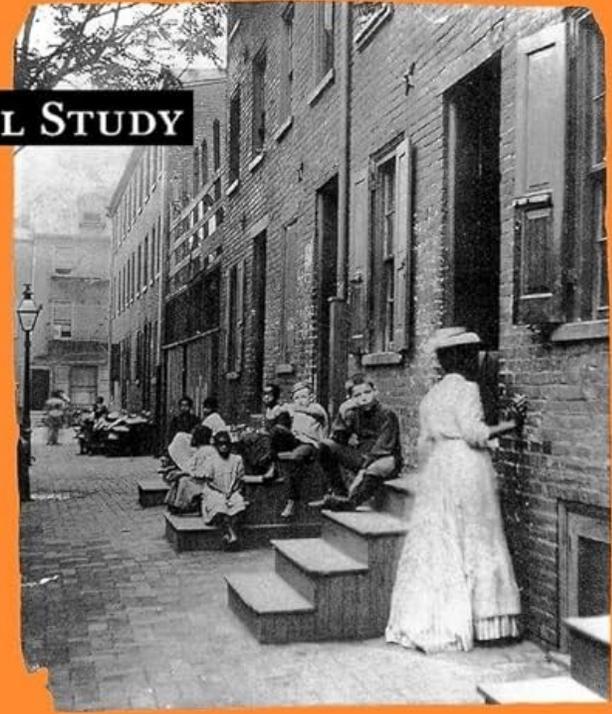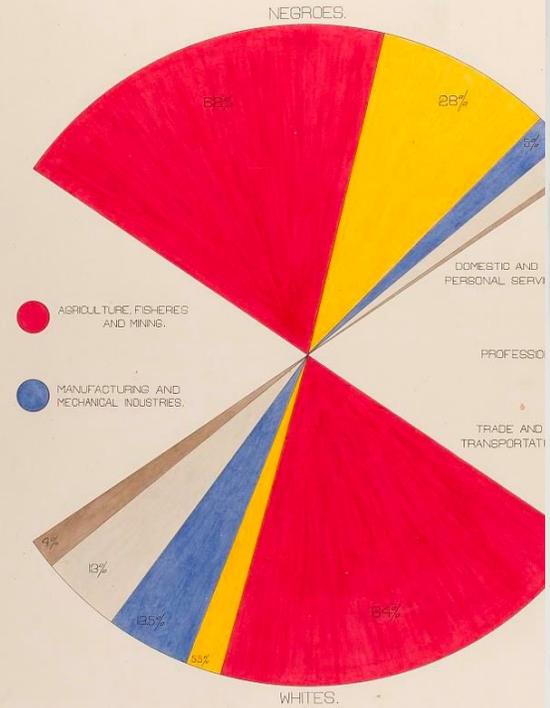
- Wilson et al., 2008

OCCUPATIONS OF NEGROES AND WHITES IN GEORGIA.

NEGROES.

68% | 28% | 5%

- AGRICULTURE, FISHERIES AND MINING.
- MANUFACTURING AND MECHANICAL INDUSTRIES.

DOMESTIC AND PERSONAL SERVICE

PROFESSIONAL

TRADE AND TRANSPORTATION

4% | 13% | 13.5% | 4.5% | 64%

WHITES.

INCOME AND EXPENDITURE OF 150 NEGRO FAMILIES IN ATLANTA, GA., U.S.A.

ANNUAL INCOME

UNITED STATES OF AMERICA
ONE DOLLAR

ANNUAL EXPENDITURE FOR

		RENT.	FOOD.	CLOTHES.	DIRECT TAXES.	OTHER EXPENSES AND SAVINGS.

DIETARY OF WELL-TO-DO NEGRO FAMILY FROM BULLETIN U.S. DEPARTMENT OF AGRICULTURE NO 71.

THE STATE TAX RATE IS:
1880 – $3.50 PER $1,000
1885 – $3.50 "
1890 – $3.98 "
1895 – $4.56 "
1899 – $5.36 "

STATE AND COUNTY TAXES RAISE THIS TO $21 PER $1,000 IN ATLANTA.

THE HIGHER LIFE.
RELIGION.
ART.
EDUCATION.
SICKNESS.
SAVINGS.
AMUSEMENTS.
BOOKS AND PAPERS.
TRAVEL.

CLASS.	ACTUAL AVERAGE						
$100-200	$139.10	19%	43%	28%		9.9%	POOR.
$200-300	$249.45	22%	47%	23%	4%	4%	
$300-400	$335.66	23%	43%	18%	4.5%	11.5%	FAIR.
$400-500	$433.82	18%	37%	15%	5.5%	24.5%	
$500-750	$547	13%	31%	17%	5%	34%	COMFORTABLE.
$750-1000	$880		37%	19%	8%	36%	
1,000 AND OVER	$1125		29%	16%	4.5%	50.5%	WELL-TO-DO
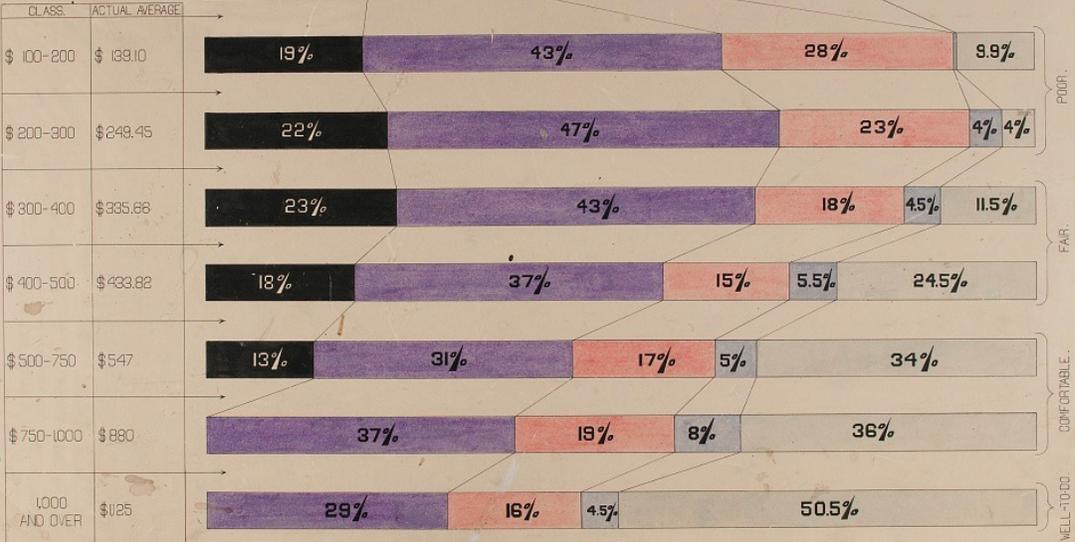
FOR FURTHER STATISTICS RAISE THIS FRAME.

ASSESSED VALUE OF HOUSEHOLD AND KITCHEN FURNITURE OWNED BY GEORGIA NEGROES.
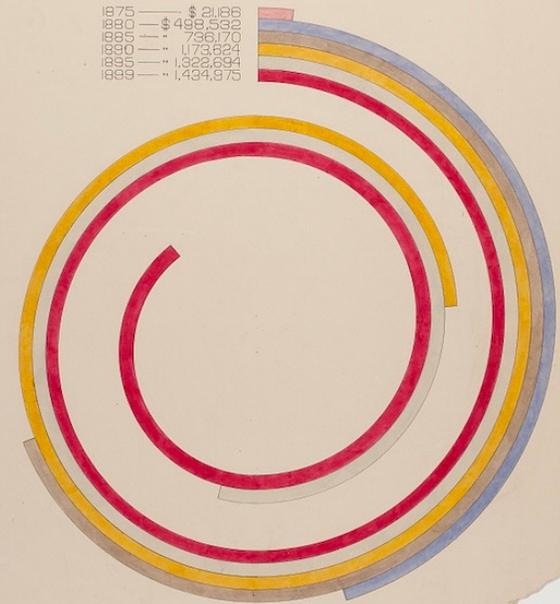
1875 ——— $ 21,186
1880 ——— $ 498,532
1885 ——— 736,170
1890 ——— 1,173,624
1895 ——— 1,322,694
1899 ——— 1,434,975

The Seventh Ward of Philadelphia

SPRUCE

PENNSYLVANIA HOSPITAL

CLINTON

PINE

LOMBARD

BROAD

SOUTH

The Distribution of Negro Inhabitants throughout the Ward, and their social condition.

- Grade 1. Middle Classes and those above.
- Grade 2. The Poor.
- Grade 3. The Working People-Fair to Comfortable.
- Grade 4. Vicious and Criminal Classes.
- Residences of Whites, Stores, Public Buildings, &c.

social forces/ phenomena

- how did we get here?

- development patterns shaped by power and privilege

- what contributes to environmental injustice and hazard vulnerability?

High Poverty Rates

Discriminatory Planning

Ongoing Economic Disinvestment

Redlining & Racial Zoning

Residential Segregation

Chronic Unemployment

Substandard Housing

infrastructural processes

- why social and infrastructural processes?

- these same forces instruct the provision of infrastructure (newer areas get more attention), as well as the designation of maintenance and upkeep funding in the Capital Improvements Program (CIP) of each city.
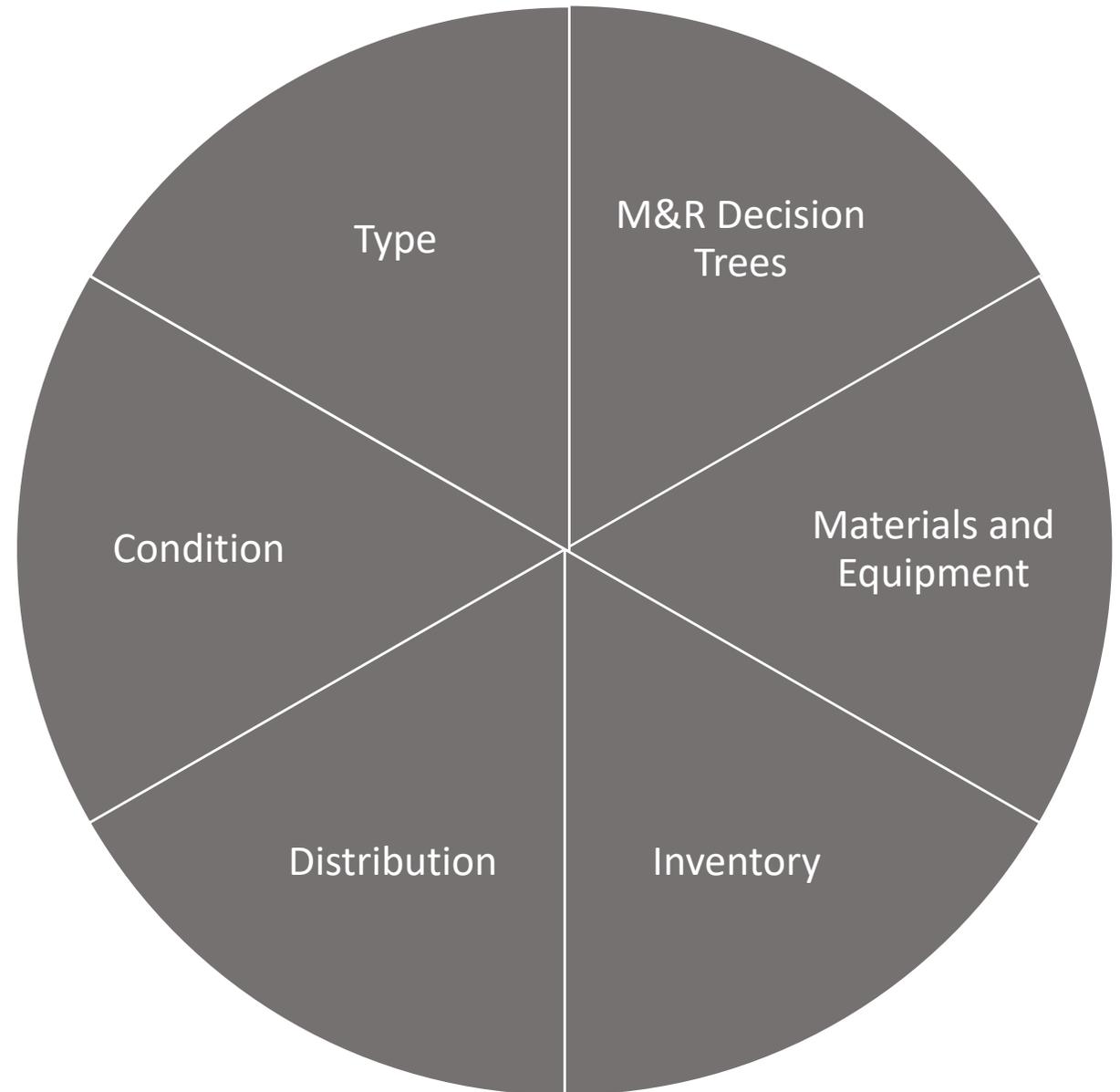
Unequal Protection Revisited:
Planning for Environmental Justice, Hazard Vulnerability, and Critical Infrastructure in Communities of Color

Marccus D. Hendricks and Shannon Van Zandt

ABSTRACT

Existing environmental justice (EJ) and hazard vulnerability literatures inadequately address key texts and topics related to critical physical infrastructure, including stormwater, green space, sewerage, energy, and roads, among other systems. This scoping review demonstrates how fundamental principles of EJ can bolster and compliment those of social vulnerability (SV) with a focus on stormwater systems and flood risks. The discussion and conceptual framework provide in-depth insight to how neighborhoods are not inherently vulnerable, but occupy built environments that are systematically sequestered, neglected, and underserved. Social processes and larger planning and development patterns shaped by power and privilege create areas of both prosperity and disadvantage. These outcomes are brought about specifically by early racial zoning, segre-

Social Vulnerability and Environmental Justice

Neighborhood Factors and Inequalities

Physical Vulnerability and Critical Infrastructure

Hazard Risks, Exposure, and Recovery

Social Vulnerability

Race/Ethnicity (e.g. racism)
Class (e.g. classism)
Gender (e.g. sexism)
Education
Poverty
Housing Tenure

Neighborhood Factors

- Residential Segregation
- Racial Zoning & Development Patterns
- Disinvestment
- Discriminatory Planning

Environmental Justice

Race (e.g. racism)
Class (e.g. classism)
National Origin (e.g. nationalism)

Inequalities

- Distribution of neighborhood investment
- Distribution of planning
- Distribution of material wealth
- Distribution of employment opportunities
- Distribution of land uses
- Distribution of political influence

Interdependencies

Transportation Systems

Water Systems

Public Health Systems

Energy Systems

Interconnectedness

Hazard Risks, Exposure, and Recovery

- Natural/Climate
- Environmental
- Technological
- Public Health

Hendricks, Marccus D. & Van Zandt, S. (2021). "Unequal Protection Revisited: Planning for Environmental Justice, Hazard Vulnerability, & Critical Infrastructure in Communities of Color." *Environmental Justice.*

THE INFRASTRUCTURES OF EQUITY AND

ENVIRONMENTAL JUSTICE

A Dissertation

by

MARCCUS D HENDRICKS

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY
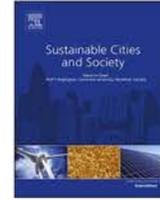
The development of a participatory assessment technique for infrastructure: Neighborhood-level monitoring towards sustainable infrastructure systems

Marccus D. Hendricks[a,*], Michelle A. Meyer[b], Nasir G. Gharaibeh[c], Shannon Van Zandt[d], Jaimie Masterson[d], John T. Cooper Jr.[d], Jennifer A. Horney[e], Philip Berke[d]

[a] Urban Studies and Planning Program, University of Maryland, College Park, MD, 20742, USA
[b] Department of Sociology, Louisiana State University, Baton Rouge, LA, USA
[c] Zachry Department of Civil Engineering, Texas A&M University, College Station, TX, USA
[d] Department of Landscape Architecture and Urban Planning, Texas A&M University, College Station, TX, USA
[e] School of Public Health, Texas A&M University, College Station, TX, USA

ARTICLE INFO

ABSTRACT

Climate change and increasing natural disasters coupled with years of deferred maintenance have added pressure to infrastructure in urban areas. Thus, monitoring for failure of these systems is crucial to prevent future impacts to life and property. Participatory assessment technique for infrastructure provides a community-based approach to assess the capacity and physical condition of infrastructure. Furthermore, a participatory assessment technique for infrastructure can encourage grassroots activism that engages residents, researchers, and planners in the identification of sustainable development concerns and solutions. As climate change impacts disproportionately affect historically disenfranchised communities, assessment data can further inform planning, aiming to balance the distribution of public resources towards sustainability and justice. This paper explains the development of the participatory assessment technique for infrastructure that can provide empirical data about the condition of infrastructure at the neighborhood-level, using stormwater systems in a vulnerable neighborhood in Houston, Texas as a case study. This paper argues for the opportunity of participatory methods to address needs in infrastructure assessment and describes the ongoing project testing the best use of these methods.
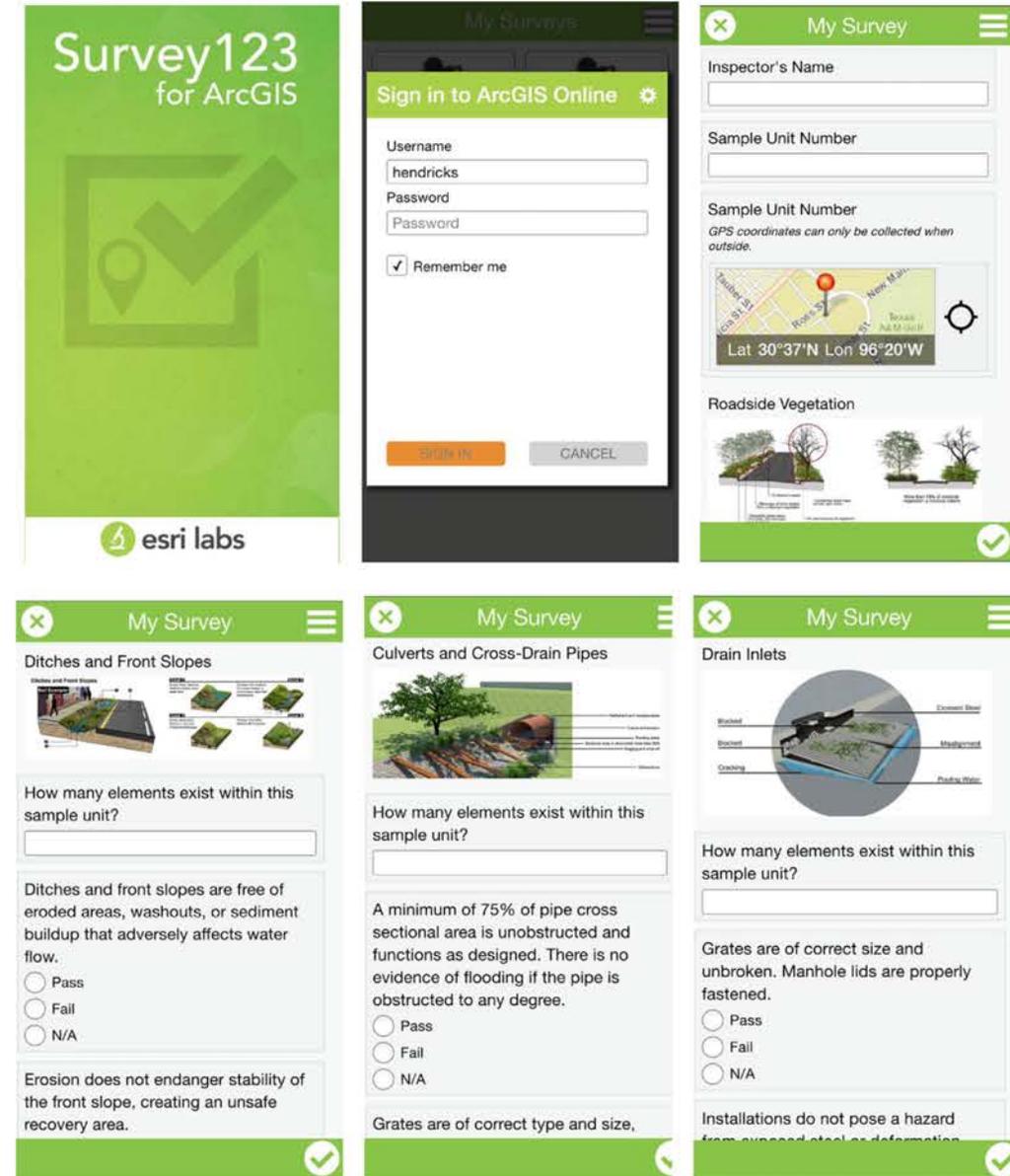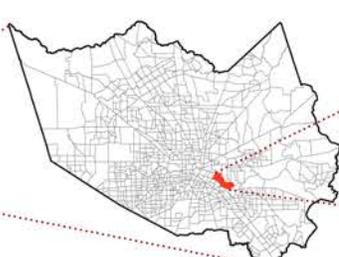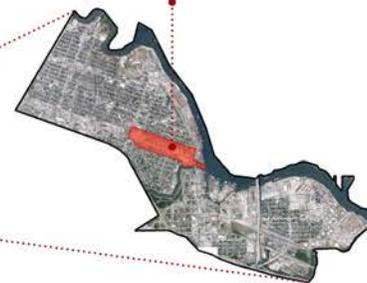
Fig. 3. PATI using ESRI's Survey 123 platform.

United States   Texas   Harris County (Houston)   Manchester Neighborhood

Validity and Reliability of Drainage Infrastructure Monitoring Data Obtained from Citizen Scientists

Isaac C. Oti[1]; Nasir G. Gharaibeh, Ph.D., P.E., M.ASCE[2]; Marccus D. Hendricks, Ph.D.[3];
Michelle A. Meyer, Ph.D.[4]; Shannon Van Zandt, Ph.D.[5]; Jaimie Masterson[6];
Jennifer A. Horney, Ph.D.[7]; and Philip Berke, Ph.D.[8]

Abstract: Data on the quality of small-scale infrastructure assets at the neighborhood level tend to be scarce, delayed, or even nonexistent, limiting the ability of local communities to better manage assets, identify risks, and improve performance. Participatory methods, common in ecology and environmental science, provide an opportunity for producing these fine data. However, very little is known about the validity and reliability of infrastructure data collected by volunteer members of the public. In this paper, we examine the validity and reliability of local drainage infrastructure monitoring data obtained from citizen scientists. The volunteer citizen scientists were high school students collecting data about the condition of stormwater infrastructure in their local community. The study took place in an environmental justice neighborhood in Houston with a long history of flooding and exposure to environmental hazards. The results suggest that with adequate planning, training, and organized community engagement efforts, the validity and reliability of data collected by citizen scientists can be comparable to physical measurements and data obtained from trained inspectors. **DOI: 10.1061/(ASCE)IS.1943-555X.0000495.** © 2019 American Society of Civil Engineers.

Author keywords: Community infrastructure; Citizen science; Data reliability; Data validity; Stormwater infrastructure; Infrastructure monitoring; Participatory research; Community engagement.

Introduction

In the pursuit of sustainable and reliable infrastructure systems, monitoring data are collected to assess the condition, usage, and in-service performance of these systems (Buchheit et al. 2005). For major infrastructure assets, monitoring data are systematically collected using professional inspectors and a variety of sensor technologies (Law et al. 2014). However, for small-scale assets at the neighborhood level, monitoring data are scarce, delayed, or even nonexistent (Pantelias et al. 2009; Halfawy 2008). While participatory research methods provide an opportunity for producing these data (Hendricks et al. 2018), very little is known about the validity and reliability of infrastructure data collected by members of the public.

In this paper, the authors examine the validity and reliability of local drainage infrastructure monitoring data collected by citizen scientists. Citizen science is a process by which volunteer members of the public, who commonly lack advanced training in science, engage in scientific activities (e.g., data collection) that might otherwise be beyond the reach of professional researchers or practitioners due to time and resource constraints (Bonney et al. 2009, 2014; Corburn 2005; Goodchild and Li 2012). The study took place in an environmental justice neighborhood in Houston with a long history of localized flooding and exposure to environmental contaminants. Environmental justice neighborhoods are comprised of populations that have increased risks of negative health outcomes related to socioeconomic factors such as low socioeconomic status and environmental pollution (Bullard and Wright 1993). The volunteer citizen scientists were high school students collecting data about the condition of stormwater infrastructure in their community. The students who participated in this study as citizen scientists were selected by their teachers (not by the researchers) and were subject to the Institutional Review Board (IRB) approval process to ensure compliance with the rules governing human subject research.

Background

Citizen science is beginning to find more diverse applications beyond its original domain in natural and environmental studies. At the same time, opportunities to use citizen science to achieve pos

[1]Graduate Research Assistant, Zachry Dept. of Civil Engineering, Texas A&M Univ., 3136 TAMU, College Station, TX 77843 (corresponding author). ORCID: https://orcid.org/0000-0002-4887-7915. Email: isaacoti@tamu.edu

[2]Associate Professor, Zachry Dept. of Civil Engineering, Texas A&M Univ., 3136 TAMU, College Station, TX 77843. Email: ngharaibeh@tamu.edu

[3]Assistant Professor, Urban Studies and Planning Program, Univ. of Maryland, 3835 Campus Dr., College Park, MD 20742. Email: mdh1@umd.edu

[4]Assistant Professor, Dept. of Sociology, Louisiana State Univ., 126 Stubbs Hall, Baton Rouge, LA 70803. Email: mmeyer@lsu.edu

[5]Professor, Dept. of Landscape Architecture and Urban Planning, Texas A&M Univ., 3137 TAMU, College Station, TX 70803. Email: svanzandt@arch.tamu.edu

[6]Program Coordinator, Dept. of Landscape Architecture and Urban Planning, Texas A&M Univ., 3137 TAMU, College Station, TX 70803. Email: jmasterson@arch.tamu.edu

[7]Associate Professor, School of Public Health, Texas A&M Univ., 1266 TAMU, College Station, TX 70803. Email: horney@sph.tamhsc.edu

[8]Professor, Dept. of Landscape Architecture and Urban Planning, Texas A&M Univ., 3137 TAMU, College Station, TX 70803. Email: pberke@arch.tamu.edu
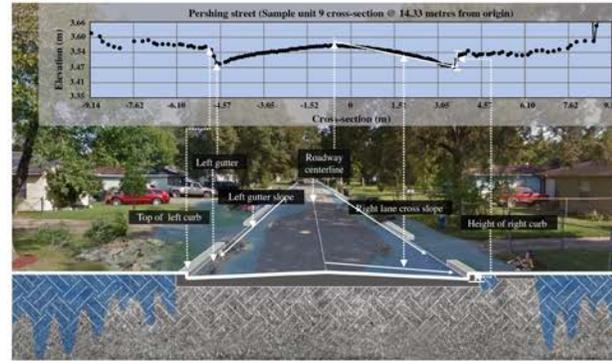
Fig. 2. Example curb-and-gutter transverse cross section generated from LiDAR data. (Image by Isaac C. Oti.)
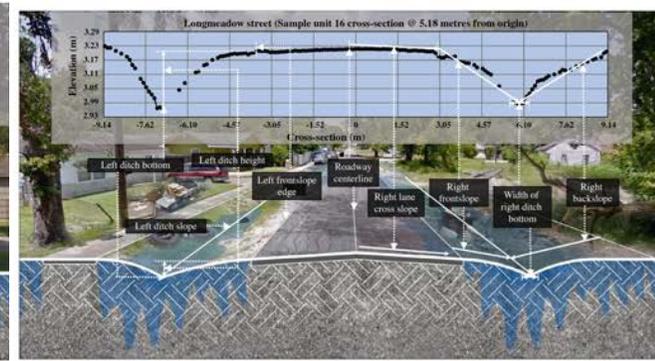
Fig. 3. Example open-ditch transverse cross section generated from LiDAR data. (Image by Isaac C. Oti.)
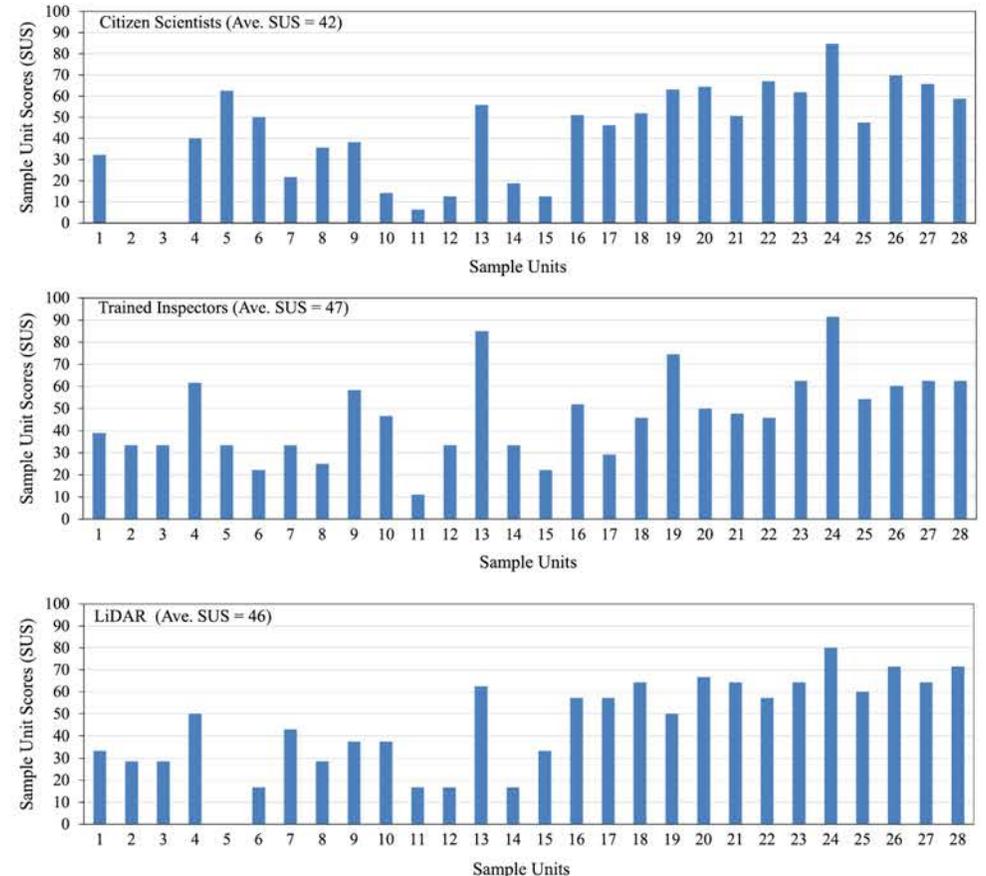

Fig. 6. SUS values computed using data obtained from citizen scientists, trained inspectors, and LiDAR survey.

Stormwater Infrastructure Resilience and Justice (SIRJ) Lab

the nexus

Environmental Planning

Infrastructure Planning

Hazard Mitigation and Disaster Recovery Planning

Participatory Planning

1. effects of infrastructure on the natural, built, and social environment

2. the role of infrastructure in modifying hazard risks and public health outcomes

3. infrastructure design, resilience (e.g. adaptation) and sustainable development

4. equity and environmental justice issues in infrastructure and public works management (e.g. procedural, distributive, and restorative justice)

5. civic participation, action, and community science in overseeing and provisioning infrastructure

Photo Credit: DC DOEE/ Nspire Green
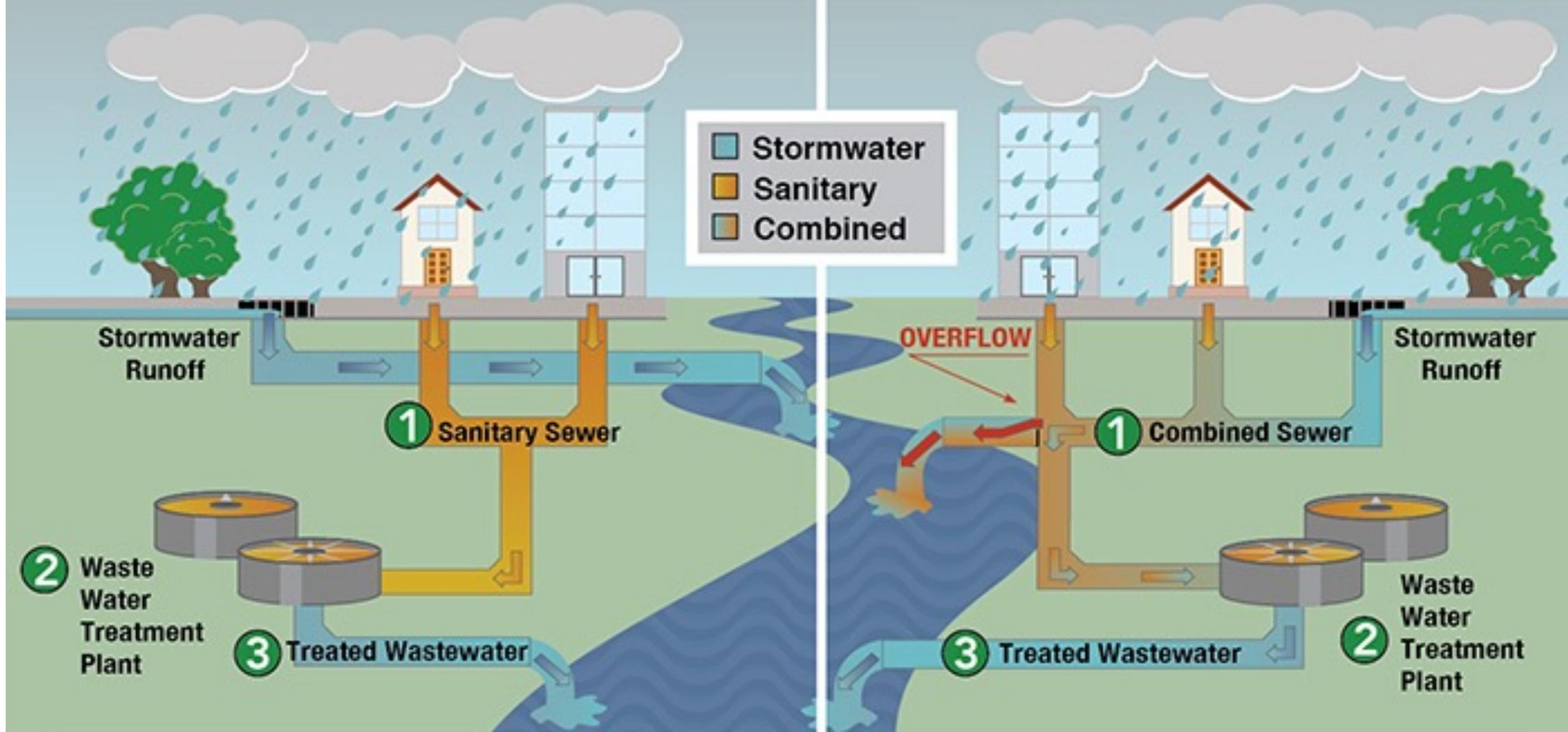
Slow violence to disasters: Exploring racialized topographies and contextualizing social vulnerability to flood and other environmental risks

Asia V. Jones, Priscila B.R. Alves, Brittany Drakeford, Marccus D. Hendricks [*]

Stormwater Infrastructure Resilience and Justice (SIRJ) Lab, School of Architecture, Planning and Preservation, University of Maryland, College Park, United States
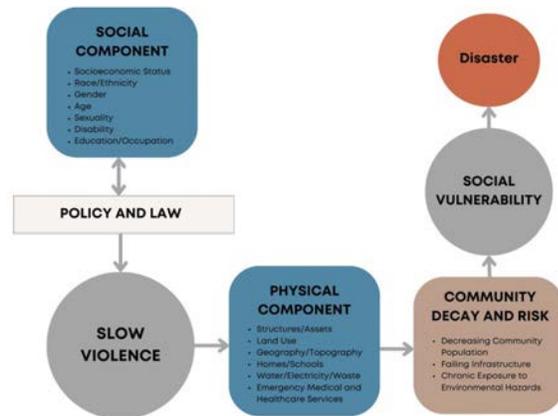
ARTICLE INFO

Fig. 3. Conceptual Framework of Slow Violence and Social Vulnerability. The figure combines Figs. 1 and 2 by illustrating how the relationship between social and physical components and slow violence can lead to community decay and risk, social vulnerability, and disaster risk.

ABSTRACT

In traditional disaster scholarship, social vulnerability is a framework that leverages individual variables to explore stratification in the instance of disaster. As this body of literature has grown, we have lost more context as to why these variables are used within various applications. However, slow violence is another framework that does not necessarily focus on disasters traditionally but provides the social and political context to understand why certain individuals may be of greater risk. In this article, we combine social vulnerability and slow violence in a framework to demonstrate how individuals and groups are not inherently vulnerable to hazards. We leverage documentation from public media and related literature to contextualize the history of slow violence in two US case studies, Bonton - Texas and North Brentwood - Maryland. Despite the spatial differences between the two African-American communities, they share many similarities in how planning policy, practice, and implementation, over time, perpetrate slow violence through urban form and create social vulnerabilities and ultimately, disasters. We hope future literature can utilize the combined framework included in this manuscript to investigate and explain how a community's vulnerable predisposition to disaster is created by social and political forces at the community-level.

Legacy effects of redlining on the distribution of greenspaces in US cities

Travis Gallo[1,2*], Mason Fidino[3], Christopher J. Schell[4], Marccus D. Hendricks[5], and Seth B. Magle[3]

1. Department of Environmental Science and Technology, University of Maryland, College Park, MD USA
2. Department of Environmental Science and Policy, George Mason University, Fairfax, VA USA
3. Urban Wildlife Institute, Conservation and Science, Lincoln Park Zoo, Chicago, IL USA
4. Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA USA
5. Urban Studies and Planning, School of Architecture, Planning, and Preservation, University of Maryland, College Park, MD USA

Abstract

We investigated how a discriminatory housing policy – redlining – has shaped the spatial patterns and configurations of greenspaces throughout 177 U.S. cities. Housing segregation has been a long-term development practice that has sequestered communities of color to areas with heightened environmental and public health risks. While the lasting environmental, social, and economic impacts of redlining are clear, the impact of redlining on ecosystems is still unfolding. We found that neighborhoods that were historically redlined have less greenspace and that individual greenspaces were smaller and less connected. We also found that residents living in these neighborhoods with less greenspace were predominantly communities of color and/or had lower income. Thus, the legacy of redlining can be seen in the modern spatial patterns of urban greenspaces, and ecosystem services provided by greenspaces have been systematically absent from redlined communities for decades.

Supplementary Table 1

Predicted percent change of each response variable with a 1 standard deviation increase from mean human population density.

			95% Credible intervals	
		Median	Lower	Upper
Mean area	Best	3.02	-9.09	13.39
	Still Desirable	-6.09	-24.01	7.92
	Definitely Declining	-18.76	-41.76	-1.85
	Hazardous	-29.02	-58.89	-8.19
Mean core area	Best	4.63	-12.95	18.5
	Still Desirable	-10.75	-67.43	17.9
	Definitely Declining	-37.41	-162.88	4.13
	Hazardous	-56.81	-266.5	-4.39
Perimeter:area	Best	-0.07	-2.32	2.09
	Still Desirable	0.67	-1.1	2.4
	Definitely Declining	0.94	-0.75	2.61
	Hazardous	1.84	0.07	3.61
Effective mesh size	Best	4.73	-30.79	30.86
	Still Desirable	-37.94	-81.06	-5
	Definitely Declining	-87.7	-144.98	-43.32
	Hazardous	-127.95	-201.9	-72.86
Total greenspace	Best	-4.95	-23.61	10.87
	Still Desirable	-21.31	-39.97	-5.45
	Definitely Declining	-46.31	-68.19	-27.24
	Hazardous	-59.87	-85.21	-38.21

Supplementary Figure 1. To investigate a regional effect on each response variable we explored model residuals on a subset of model results and found no clear difference between the South (open circles), West (open squares), Northeast (open diamonds), and Midwest (open triangles). Colors match the HOLC grades (A = green, B = blue, C = yellow, and D = red). Patch density was not included in the final analysis.
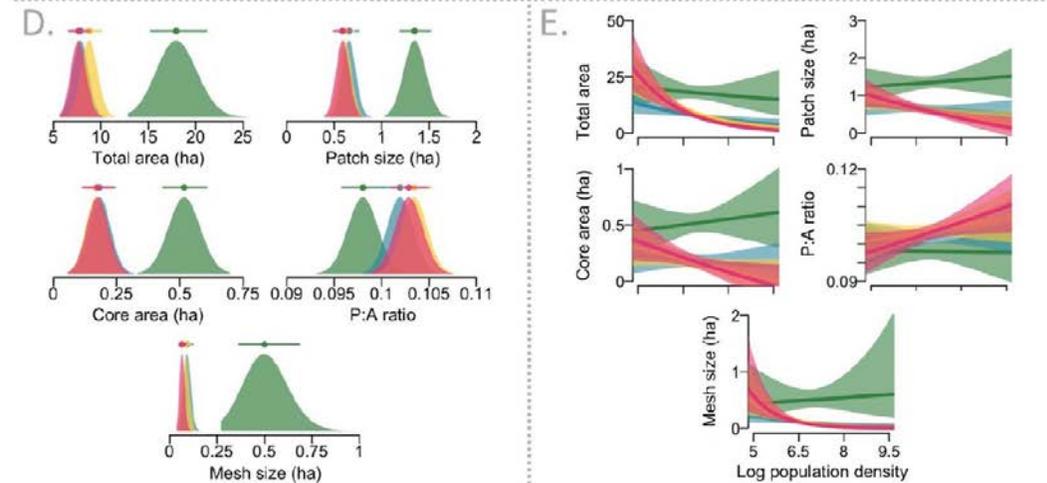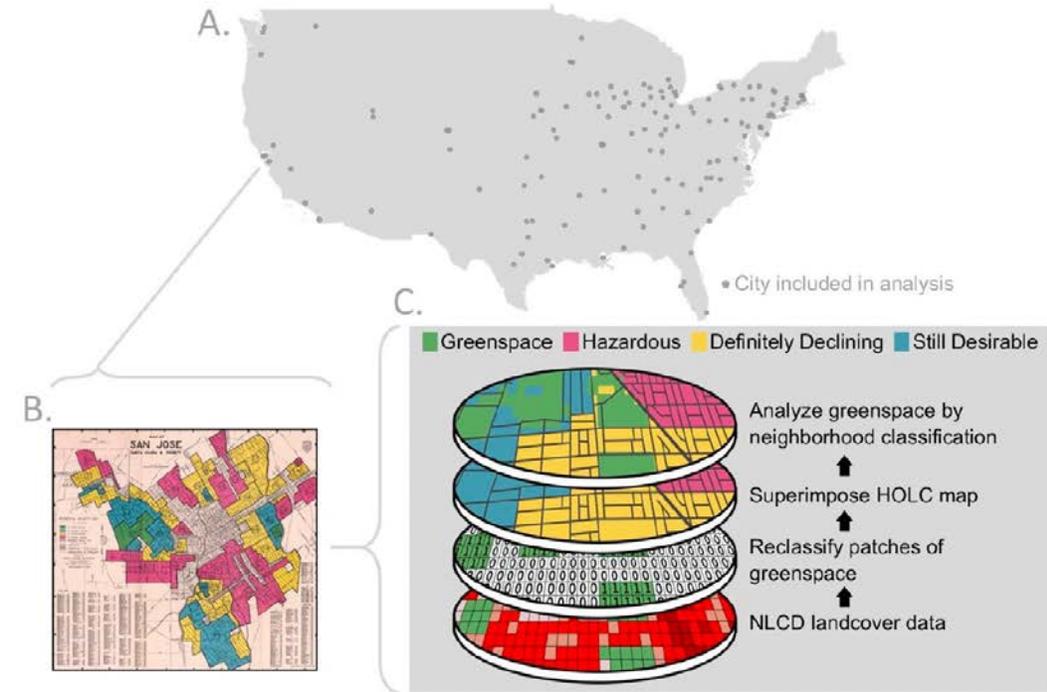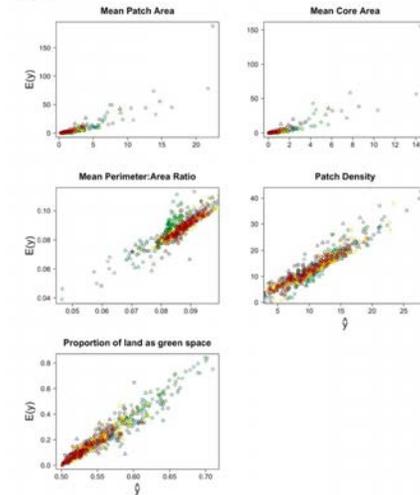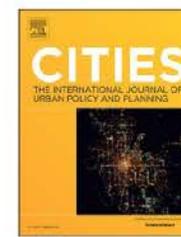

Figure 1. To this day neighborhoods categorized as "Best" by the HOLC have more greenspace, larger greenspaces, and more natural landscapes. Location of the 177 cities used in this analysis (**A**). An example of an historical HOLC map for San Jose, CA (**B**). Maps like these were available for all 177 cities and digitized by the Digital Scholarship Lab at the University of Richmond [48]. Procedure for data processing (**C**), the posterior distributions of the average of each response variable by each HOLC category (**D**), and the relationship between the population density of a city and each response variable (**E**).

ELSEVIER

CITIES
THE INTERNATIONAL JOURNAL OF URBAN POLICY AND PLANNING

Check for updates

Socially vulnerable people and stormwater infrastructure: A geospatial exploration of the equitable distribution of gray and green infrastructure in Washington D.C.

Minkyu Park [a,*], Priscila Barros Ramalho Alves [b], Rachel Marie Whiteheart [c], Marccus D. Hendricks [d]

[a] Urban and Regional Planning and Design, School of Architecture, Planning and Preservation, University of Maryland, College Park, United States of America
[b] School of Architecture, Planning and Preservation, University of Maryland, College Park, United States of America
[c] Department of Planning, Baltimore City, United States of America
[d] University of Maryland, College Park, United States of America

ARTICLE INFO

ABSTRACT

Green Infrastructure (GI) has gained recognition for its notable role in climate change mitigation and urban resilience. Meanwhile, there is a growing body of literature revealing the uneven distribution of GI from environmental justice perspective. Given the role of GI, the distribution should also be explored in a social vulnerability context and combining green and gray infrastructure. However, the distribution of GI, sewer pipelines, and their relationship with social vulnerability remain underexplored. This study fills this gap by assessing stormwater infrastructure in Washington, D.C., against a backdrop of historical discriminatory sewage practices. It investigates whether disparities exist in the distribution of sewer pipelines and green infrastructure among communities with differing social vulnerabilities, using a comprehensive approach that encompasses GI, underground pipelines, and social vulnerability. The analysis reveals significant insights into the relationships between stormwater infrastructure, social vulnerability, and urbanization, offering valuable implications for stormwater management planning. This research contributes to the field of environmental justice and urban planning by shedding light on the complex interplay between infrastructure allocation, community vulnerability, and the urgent need for equitable infrastructure management, especially stormwater and sewer systems, in the face of climate-related challenges.

Table 2. Regression Results

Sample size: 450

	Coefficient	Standard Error	t statistic
Dependent variable: length of sewers			
F-statistic: 59.97 / p-value: < 2.2e-16			
Adjusted R-squared: 0.5661			
Constant*	11.5000	0.2090	55.0281
Impervious Rate*	-0.9520	0.2452	-3.8800
Building Height	0.0121	0.0369	0.3300
Slope	-0.0945	0.0581	-1.6262
Elevation*	-0.0604	0.0134	-4.5000
Residential use	-0.1734	0.0614	-2.8241
Commercial use	0.2416	0.1332	1.8143
Federal use	-0.2715	0.1306	2.0801
MS4 sewer shed	0.0436	0.0590	0.7390
Population density*	-2.54E-05	1.91E-06	-13.2870
Social Vulnerability*	-0.0160	0.0039	-4.1239
Dependent variable: Area of sewers			
F-statistic: 36.45 / p-value: < 2.2e-16			
Adjusted R-squared: 0.4412			
Constant*	15.1034	0.3376	44.7330
Impervious Rate*	-0.8874	0.3960	-2.2408
Building Height	0.0249	0.0592	0.3711
Slope	0.0271	0.8754	-0.2890
Elevation*	-0.1442	0.0202	-6.6491
Residential use	-0.0285	0.0952	-2.8690
Commercial use	0.0105	0.1999	0.4987
Federal use	-0.2647	0.2015	1.2551
MS4 sewer shed	-0.1816	0.0887	-1.9050
Population density*	-3.06E-05	3.09E-06	-9.8872
Social Vulnerability*	-0.0169	0.0058	-2.6974
Dependent variable: The Number of GSI			
F-statistic: 19.84 / p-value: < 2.2e-16			
Adjusted R-squared: 0.2955			
Constant*	11.5634	1.1870	9.7374
Impervious Rate*	-3.3203	1.3920	-2.3010
Building Height	-0.4280	0.2083	-2.0551
Slope	-1.0610	0.3299	-3.2160
Elevation*	0.2156	0.0762	2.8288
Residential use	0.2837	0.3487	0.8140
Commercial use	1.4360	0.7536	1.8977
Federal use	0.3459	0.7413	0.4670
MS4 sewer shed	-0.2099	0.3510	-0.6261
Population density*	-8.88E-05	1.09E-06	-8.1800
Social Vulnerability*	-0.0542	0.0220	-2.4620

*Statistically significant at the 99 percent confidence level

Discover Water

Research
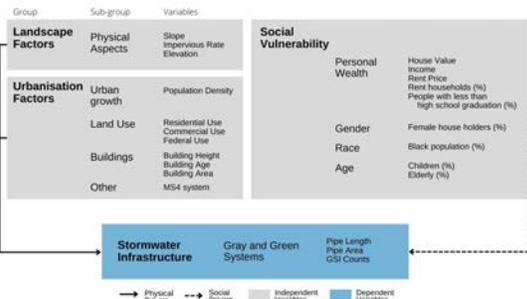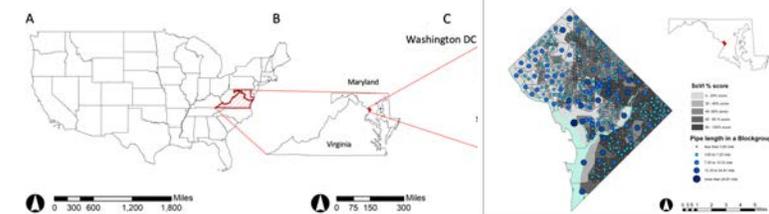
GIS-based spatial approaches to refining urban catchment delineation that integrate stormwater network infrastructure

Qianyao Si[1] · Higor C. Brito[2] · Priscila B. R. Alves[3] · Mitchell A. Pavao-Zuckerman[1] · Iana A. A. Rufino[2] · Marccus D. Hendricks[3]

Abstract

Rapid urbanization and escalating climate change impacts have heightened stormwater-related concerns (e.g., pluvial flooding) in cities. Understanding catchment dynamics and characteristics, including precise catchment mapping, is essential to accurate surface water monitoring and management. Traditionally, topography is the primary data set used to model surface water flow dynamics in undisturbed natural landscapes. However, urban systems also contain stormwater drainage infrastructure, which can alter catchment boundaries and runoff behavior. Acknowledging both natural and built environmental influences, this study introduces three GIS-based approaches to enhance urban catchment mapping: (1) Modifying DEM elevations at inlet locations; (2) Adjusting DEM elevations along pipeline paths; (3) Applying the QGRASS plug-in to systematically incorporate infrastructure data. Our evaluation using the geographical Friedman test ($p > 0.05$) and Dice Similarity Coefficient (DSC = 0.80) confirms the statistical and spatial consistency among the studying methods. Coupled with onsite flow direction validation, these results support the feasibility and reliability of integrating elements of nature and built infrastructure in urban catchment mapping. The refined mapping approaches explored in this study offer improved and more accurate and efficient urban drainage catchment zoning, beyond using elevation and topographic data alone. Likewise, these methods bolster predictive stormwater management at catchment scales, ultimately strengthening urban stormwater and flooding resilience.
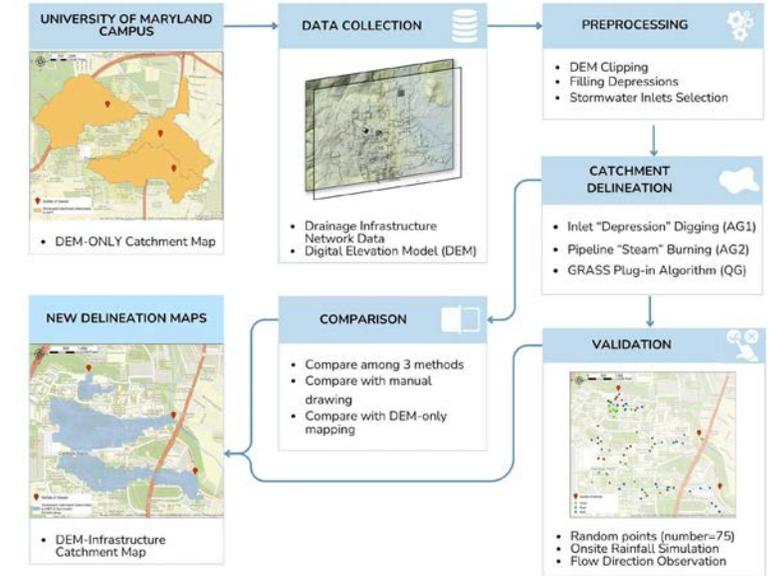
Fig. 2 Flowchart of the methodology

Fig. 4 Boxplot of Dice Similarity Coefficients comparing resulting catchment maps among delineation methods, including 3 GIS-based stormwater catchment mapping methods (AG1, AG2, QG), manual drawing (MN), and DEM-only delineation method (DEM)
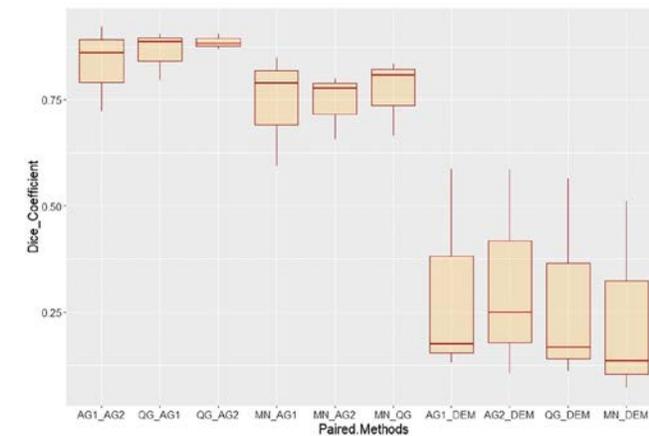

Table 1 The geographical Friedman testing results—comparing the catchment boundary maps created by different GIS approaches explored in this study

|	Friedman Chi-squared	P-value
Catchment area size	2.6	0.4575
Catchment boundary perimeter	3.4	0.3340

A Smart, Connected, and Sustainable Campus Community: Using the Internet of Things (IoT) and Low-Cost Sensors to Improve Stormwater Management at UMD/Greater College Park

Qianyao Si*, Priscila B. R. Alves*, Mitchell A. Pavao-Zuckerman, … and Marccus D. Hendricks

Stormwater Infrastructure Resilience and Justice (SIRJ) Lab, School of Architecture Planning and Preservation, University of Maryland, College Park, United States

Abstract

To lessen the challenges from growing urban hazards, adaptive management has been named as an opportunity to ensure the resilience of urban systems. Internet of Things (IoT) technologies may facilitate urban adaptive management via shared, continuous monitoring data and multi-stakeholder collaboration. This article details the pilot implementation of an IoT Stormwater Monitoring Framework at the University of Maryland.
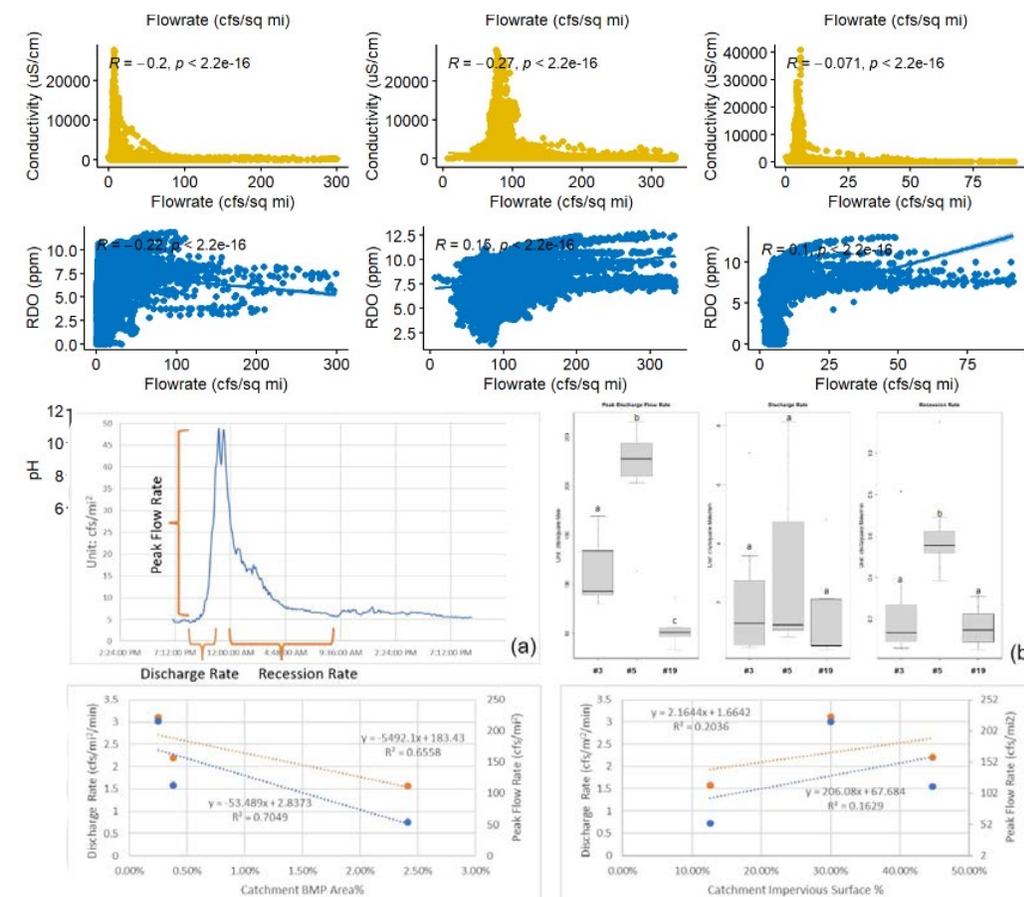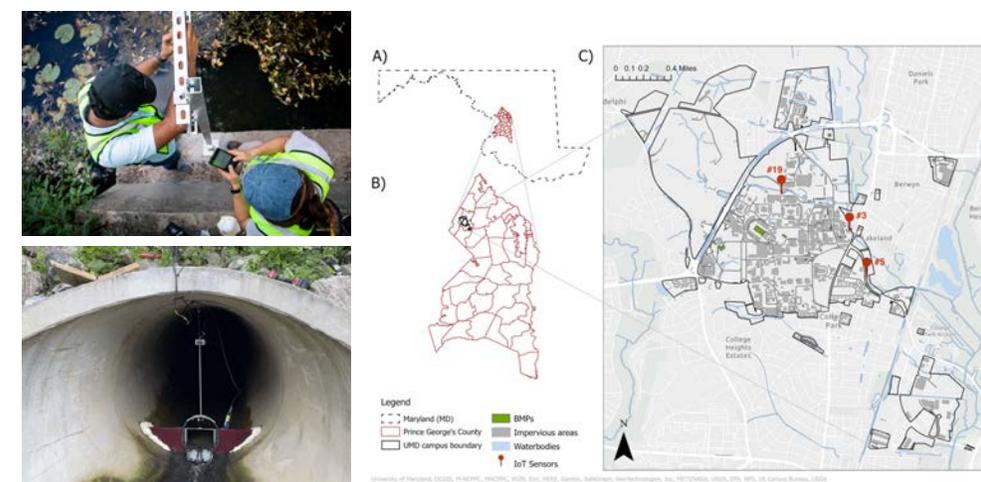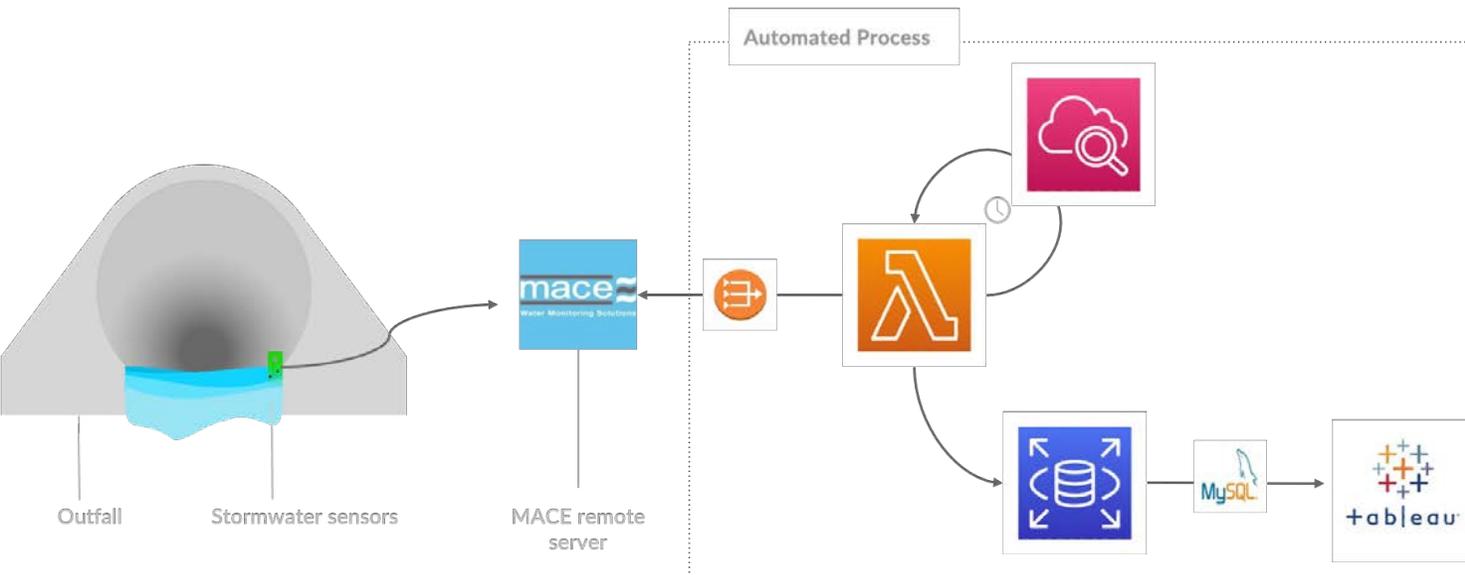
Built Surfaces and Shallow Waters: Simulating Urban Flood Risks and LULCs in Washington, D.C., USA

Higor C. Brito*, Priscila B. R. Alves*, Iana A.A. Rufino, … and Marccus D. Hendricks

Stormwater Infrastructure Resilience and Justice (SIRJ) Lab, School of Architecture Planning and Preservation, University of Maryland, College Park, United States

Abstract

Cities, are global centers of socio-economic, financial, and industrial development, and with high population density, face hydrological changes resulting from urban land use, which makes them vulnerable to flooding. With climate change, the frequency of flood events and the number of communities at risk will likely increase. This leads to a deeper understanding that it is impossible to eliminate flooding completely and that traditional structural protection measures are insufficient to ensure the resilience of communities against these natural disasters.
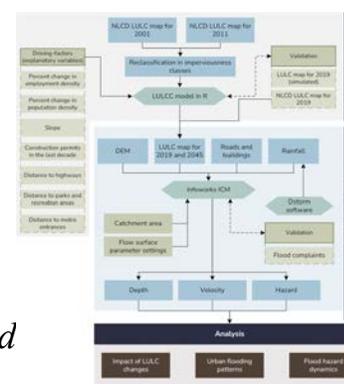
| Year	Scenario	Return period (years)	Rainfall duration (min)	Max water depth (m)	Average water depth (m)	Area of water accumulation (km²)
2019	1	5	60	3.229	0.010	0.982
	2	25	60	3.514	0.010	1.232
	3	100	60	3.859	0.010	1.574
	4	5	180	3.537	0.012	0.822
	5	25	180	3.806	0.012	0.997
	6	100	180	3.897	0.013	1.105
2045	7	5	60	3.272	0.013	1.059
	8	25	60	3.326	0.013	1.482
	9	100	60	3.727	0.012	1.869
	10	5	180	3.536	0.011	0.837
	11	25	180	3.806	0.012	1.012
	12	100	180	3.896	0.012	1.117
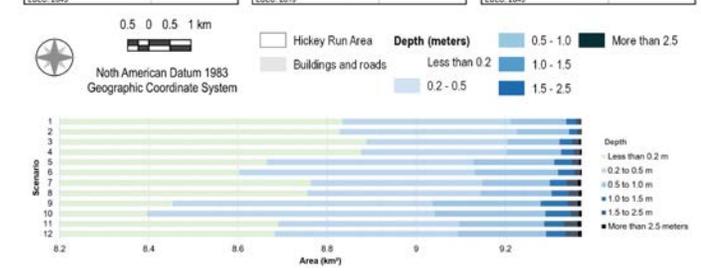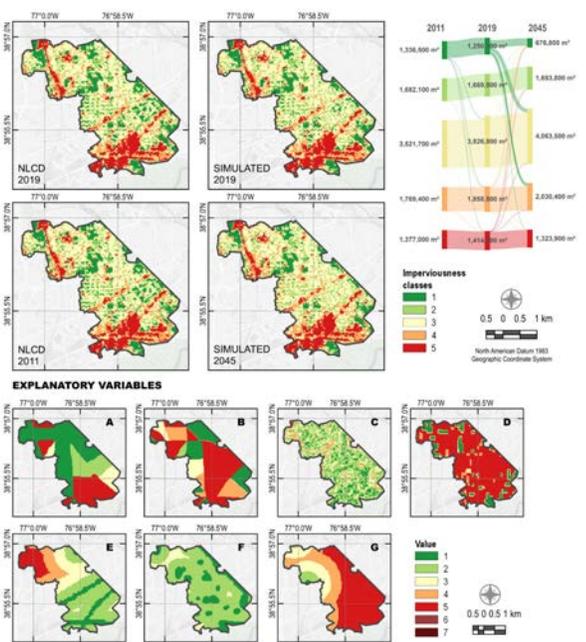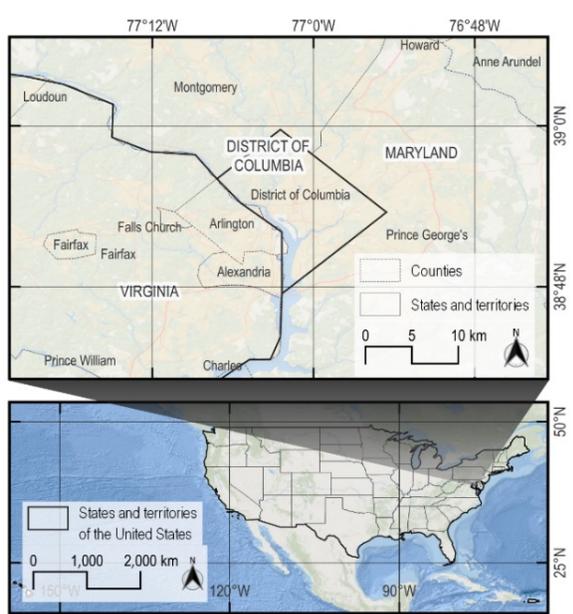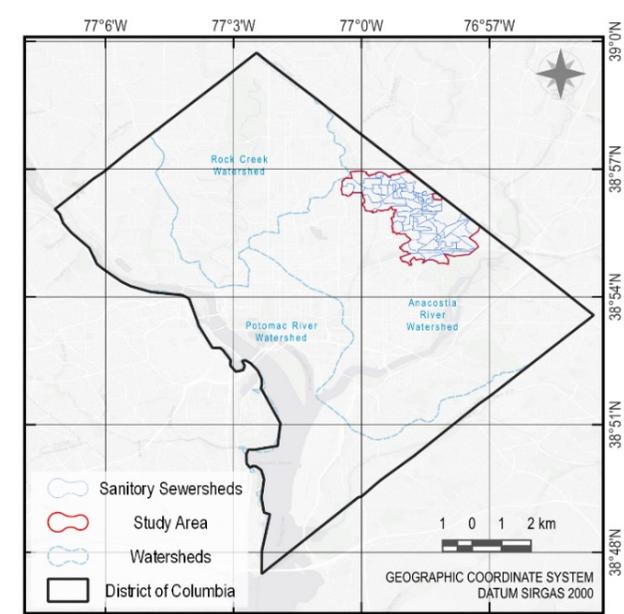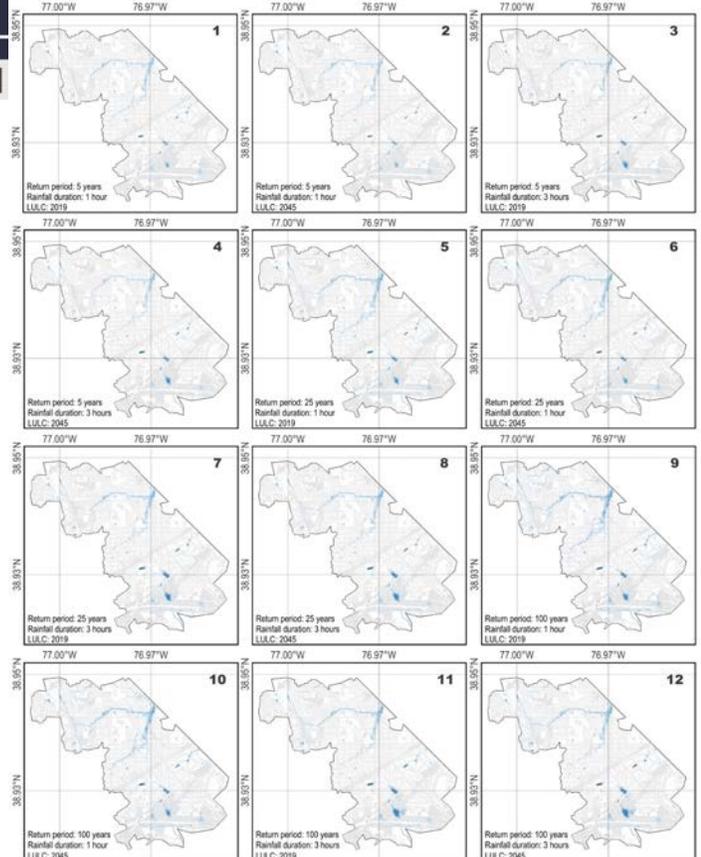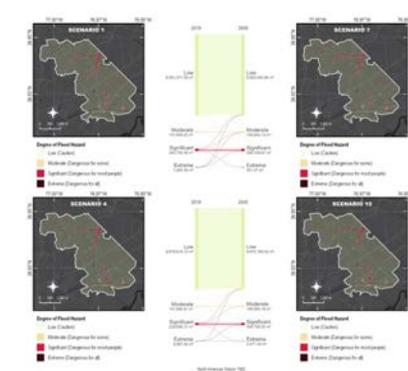
Urban Planning, Water, and Environmental Health Share Historical Roots

19th Century – Public health was part of municipal planning; tackled infectious diseases (e.g., water, sanitation, rodent, mosquito control)

20th Century – Injury and disease prevention (e.g., building permits and zoning for ventilation, exposure to toxic substances, development, separating residences from industrial areas)

21st Century – Need to consider chronic health problems AND/OR infectious disease???
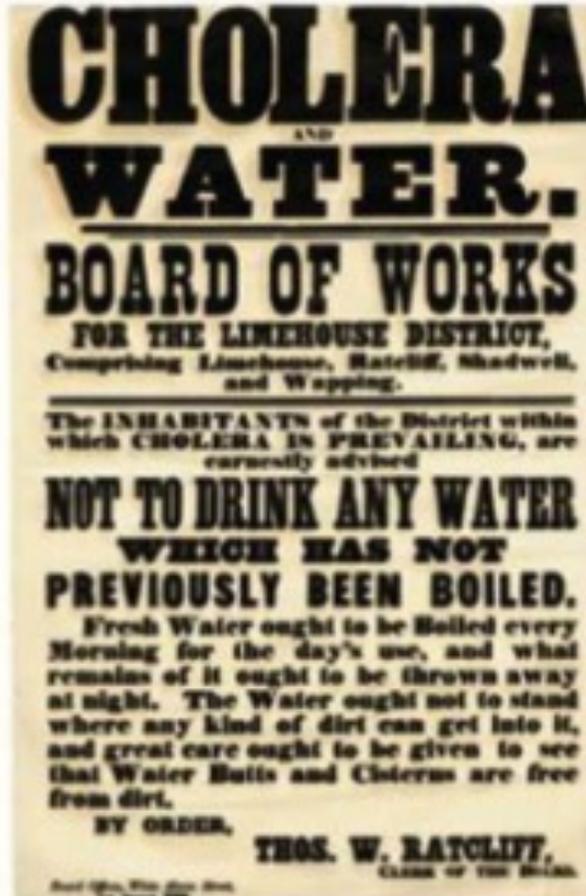
Is coronavirus hiding in your sewage system? | COMMENTARY

By MARCCUS D. HENDRICKS
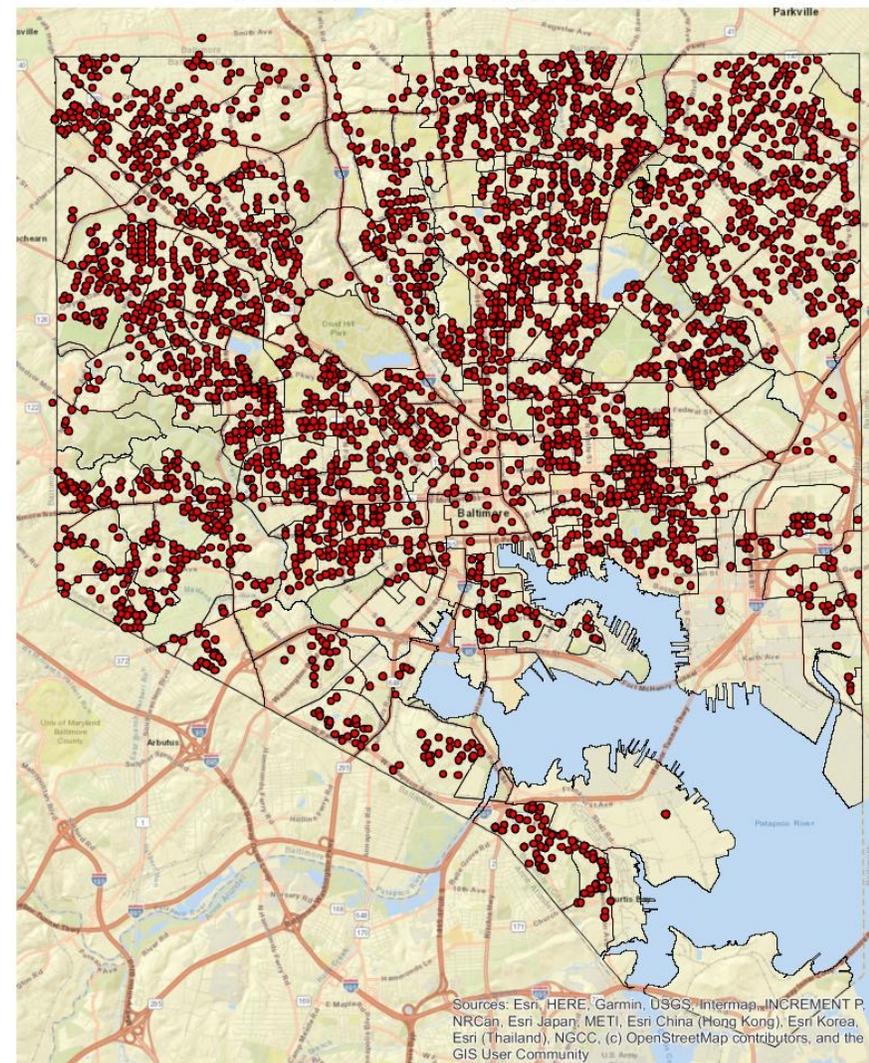FOR THE BALTIMORE SUN | JUL 06, 2020

Aging infrastructure can result in sewage backups that can breed disease. (Barbara Haddock Taylor / Baltimore Sun)

Past studies in public health have demonstrated an association between disease and poor sanitation, such as illnesses from exposure to sewage-laden waters. Modern sanitary infrastructures were an innovation that transformed how we mitigate waterborne risks.

However, failure to maintain and rehabilitate these systems over the years, as well as changing environmental conditions, have created some pre-modern circumstances in cities across the world including Baltimore, which has frequent sanitary sewer overflows (SSOs) due to an aged and declining system and more frequent and intense rainfall events further overwhelming the system.

Basement Backups in Baltimore City
October 2017 - March 2019

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Legend

☐ Baltimore City Neighborhoods

• Basement Backup Locations

Megan Allison
Clean Water Action
Data Compiled From Modified Consent
Decree Calendar Quarterly Reports

MRSA Discovered in U.S. Wastewater Treatment Plants

Researchers, led by scientists from the University of Maryland School of Public Health, confirmed that methicillin-resistant *Staphylococcus aureus*, or MRSA, exists in the U.S. wastewater treatment plants.

Staphyloccoccus aureus, or staph, is a bacterium responsible for infections contracted in hospital settings that are noted for being difficult to treat and potentially fatal. The bacteria can be present without causing an active infection.

Beginning in the late 1990s, MRSA has also been infecting otherwise healthy people in community settings, which is known as community-associated MRSA.
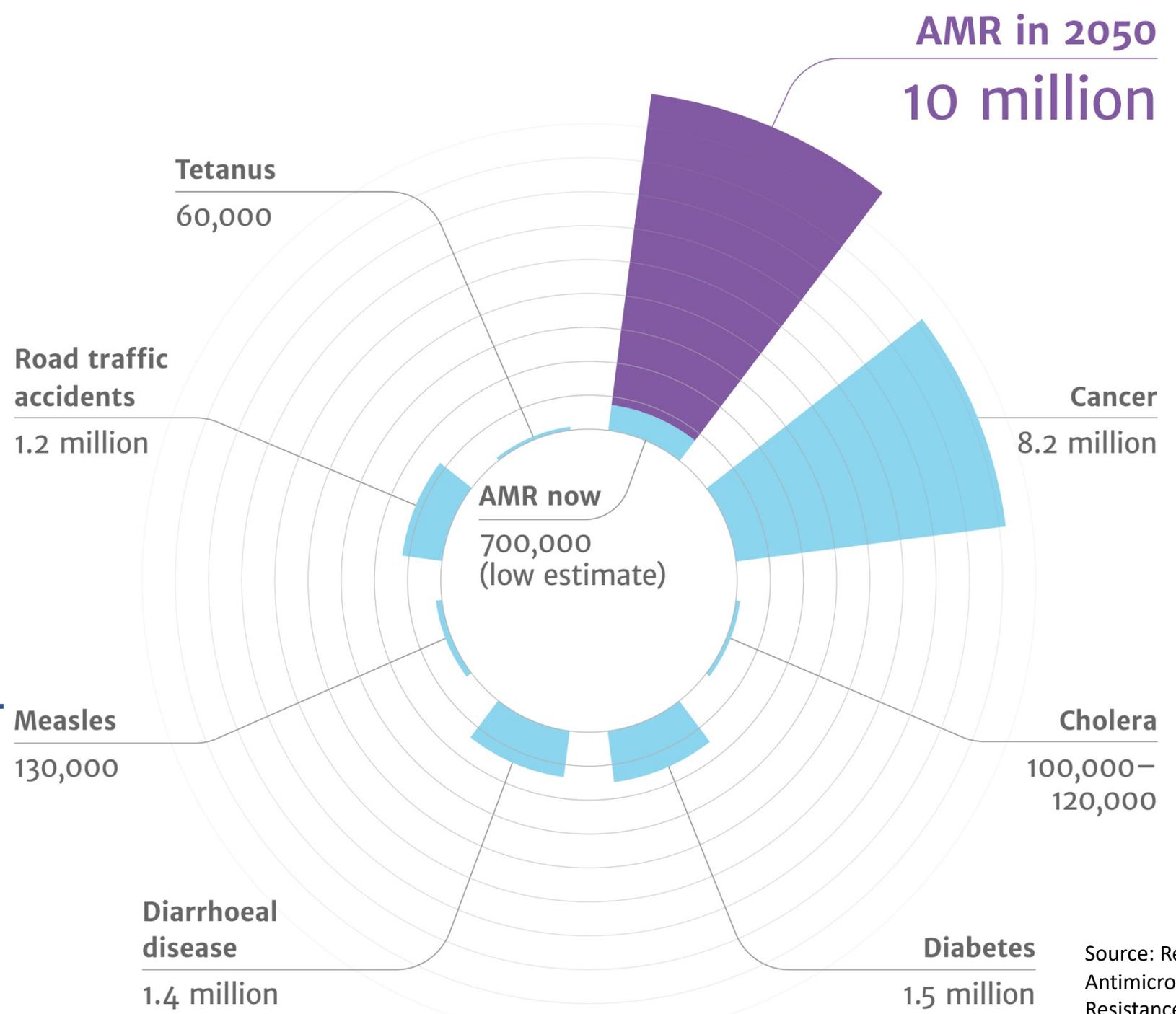
Amy R. Sapkota, assistant professor in the Maryland Institute for Applied Environmental Health, who headed the study, explains:

> " *MRSA infections acquired outside of hospital settings — known as community-acquired MRSA or CA-MRSA — are on the rise and can be just as severe as hospital-acquired MRSA. However, we still do not fully understand the potential environmental sources of MRSA or how people in the community come in contact with this microorganism. [...] This was the first study to investigate U.S. wastewater as a potential environmental reservoir of MRSA.*

Antimicrobial and Antibiotic Resistant *Bacteria Death Projections 2050*

AMR in 2050
10 million

Tetanus
60,000

Road traffic accidents
1.2 million

AMR now
700,000
(low estimate)

Cancer
8.2 million

Cholera
100,000–120,000

Measles
130,000

Diabetes
1.5 million

Diarrhoeal disease
1.4 million

Source: Review on Antimicrobial Resistance 2016

Assessing the impact of flooding on bacterial community structure and occurrence of potentially pathogenic bacteria in Texas Rivers after Hurricane Harvey

Sina V. Moghadam [1], Kiran Kumar Vadde [1], Duc C. Phan [2], Arash Jafarzadeh, Vikram Kapoor [*]

School of Civil & Environmental Engineering, and Construction Management, University of Texas at San Antonio, San Antonio, TX 78249, USA

ARTICLE INFO

ABSTRACT

Hurricanes and extreme stormwater events can transport fecal contaminants and a wide range of bacterial pathogens to receiving rivers and streams, threatening public health. This study investigated the impact of flooding on bacterial diversity and the occurrence of fecal and potential bacterial pathogens in Texas Rivers over a short (3 weeks and 3 months) and long time (12 months) after Hurricane Harvey. Water samples were collected from 8 sampling sites of Guadalupe and San Antonio Rivers during three sampling events and bacterial community structure was evaluated using next-generation sequencing (NGS). Results showed that Proteobacteria, Actinobacteria, Bacteroidetes, and Cyanobacteria were the predominant phyla in the water samples. Hierarchal cluster analysis and principal coordinate analysis indicated that bacterial community structure was significantly different in the water samples collected from flooded and non-flooded sites. At genus level, eight fecal-associated and twelve potentially pathogenic bacterial genera were detected in water samples, mainly from flooded sites collected during short-term sampling events. Overall, results suggest that NGS-based microbial water quality monitoring of environmental samples after flooding events could provide critical information about the wide range of pathogens, which can be further assessed by specific methods to identify the risk of exposure.
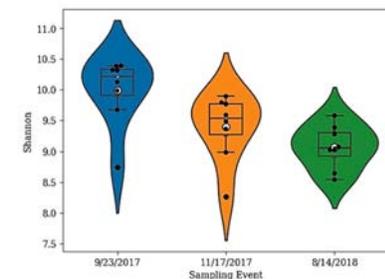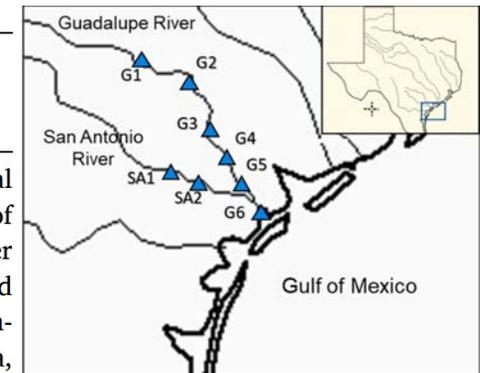
The Water Emergency (WET) Team: Environmental and Community-Driven Methodology

W.E.T.
Water Emergency Team
https://research.umd.edu/wet
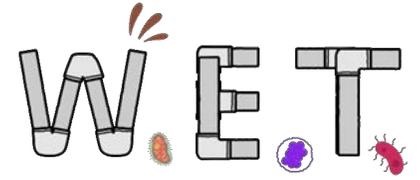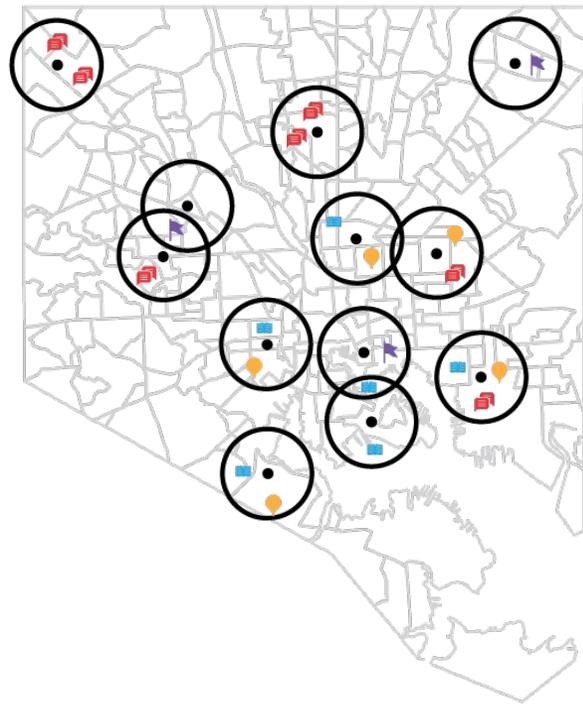
A Obtain Context-Specific Information
- • SSO Event
- ◯ SSO Radius

B Stakeholder Identification and Engagement

- 📍 Meetings
- 💬 Door-to-Door Recruitment
- 🚩 Community Fairs & Events
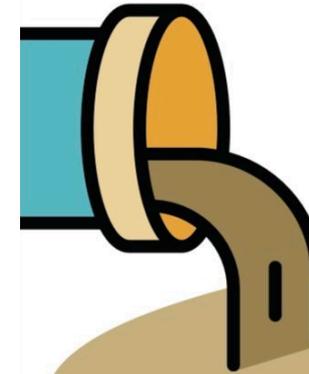- 📖 Educational Sessions

C Applying Strategies with Community Members

- ① Resident Survey
- ② Visual Household Inspection Tool
- ③ Sample Collection

D Reporting Back to Community Members

- A+ Individual Report-cards Submission
- 👥 Workshops

Community Engagement

Environmental and Community-Driven Methodology

1 **Resident Survey**
Surveying about previous experiences, physical and mental health, communication and remediation, and demographic information.

Understanding the social context

2 **Visual Household Inspection**
Assessing household characteristics, including exterior and interior, kitchen and bathrooms.

Assessing current infrastructure

3 **Environmental Sample Collection**
Sampling households that have had sewage overflows and backups in the past. Two types of samples are collected: wall surface, and standing water (bottle).

Evaluating health exposure

4 **Household and Microbiological Lab Data Analysis**
Applying an interdisciplinary approach for analyzing resident survey, visual household inspection tool and bacteria sample.

Combining health & social concerns

5 **Results**
Disseminate results within the community.

💧 Collect Surface & Water Samples

🚗 Transport Sample to Laboratory on Ice

❄ Keep Samples Refrigerated

🏢 Begin Processing within 24 Hours

🦠 Isolate Target Bacteria from Samples

⏱ 5-Day Laboratory Process

✓ Antimicrobial Resistance Presence Confirmation

〰 Survey and Inspection Tool Statistical Analysis

Stakeholder Involvement

Household Sampling Kits, Equipment, and Protocol

PPE
- Gloves
- Mask
- Shoe Covers

Survey
- Participant Compensation
- Electronic Tablet

Sample Collection Kit
- Insulated Storage Container
- Ice Packs
- Marker
- Sterile Bottle
- Cloth
- Sampling Liquid
- Sterile Bag
- eSwab/ Tube Holder
- Sampling Squares

Sample Collection Guide

Included in your kit: Gloves, eSWAB packet, white and black sampling squares, swiffer cloth square, Whirl-Pak bag, plastic bottle, green foam block, blue capped plastic tube with water

Wall Sample #1
1. Select a wall near a sewage backup to sample. Place the ESWAB packet and the BLACK sampling square on a flat surface nearby.
2. Put on the gloves and open the eSWAB packet.
3. Remove the tube from the packet and remove the cap. When you set down the cap, make sure the TOP is touching the table to avoid contamination.
4. Press the end of the tube into the GREEN FOAM BLOCK to hold the tube upright.
5. Remove the swab by the PLASTIC END, making sure not to touch the cotton side.
6. Dip the cotton end into the liquid at the bottom of the tube.
7. Stick the BLACK sampling square against your selected wall using the double-sided tape, swab the entire area inside the square using the cotton end.
8. Break the swab in half at the red line and place cotton end into the tube. Screw on cap to seal. **Do not touch the cotton end.**
9. Place the tube back in the Ziploc bag.

Wall Sample #2
1. Keep your gloves on. Open the WHIRL-PAK bag by tearing off the plastic on the top and set aside.
2. Unwrap the SWIFFER CLOTH SQUARE. Do not set this down.
3. Stick the WHITE sampling square on your selected wall using the double-sided tape on the back of the square.
4. Wipe the SWIFFER CLOTH SQUARE over the area inside the WHITE sampling square using a back and forth motion.
5. Place the SWIFFER CLOTH SQUARE in the WHIRL-PAK bag.
6. Add the water from the BLUE-CAPPED TUBE to the WHIRL-PAK bag by folding the top over and twisting the twist ties together
7. Place the sealed WHIRL-PAK bag into the Ziploc bag.

Water Sample
*** Only complete this step if you have STANDING WATER in your home from a sewage backup event.
1. Label the plastic bottle with the date and the time.
2. Keep your gloves on. Open the plastic bottle, being careful not to the inside of the bottle or the lid.
3. Scoop up as much water as possible with the bottle.
4. Seal the plastic bottle with the cap.
5. Place into the Ziploc bag.

NOTIFY THE RESEARCH TEAM OF THE EVENT, COMPLETE THE SAMPLE, CONTACT US FOR COLLECTION OF YOUR SAMPLES
Contact: Marcus Hendricks, Priscila Alves sirj@umd.edu,
Rachel Goldstein rerosenb@umd.edu
Taylor Smith-Hams tsmithhams@bluewaterbaltimore.org
Malika Brown mbrown@chdcmd.org,
Rita Crews ritacrews@verizon.net

Scan for a Video Tutorial

ENVIRONMENTAL RESEARCH
HEALTH

PERSPECTIVE

Sanitary sewer overflows, household sewage backups, and antibiotic-resistant bacteria: the new frontier of environmental health risks and disasters

Marccus D Hendricks[1],* [ID] and Rachel E Rosenberg Goldstein[2] [ID]

[1] Urban Studies and Planning Program, University of Maryland, College Park, Maryland, United States of America
[2] Department of Global, Environmental, and Occupational Health, University of Maryland, College Park, Maryland, United States of America
* Author to whom any correspondence should be addressed.
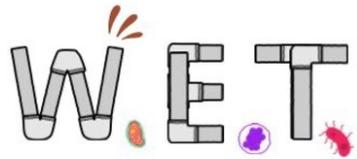
E-mail: mdh1@umd.edu

Abstract
Untreated sewage discharges leading to environmental contamination are increasingly common in communities across the globe. The cause of these discharges ranges from sewer lines in disrepair, blockages, and in the era of more extreme wet weather events, the infiltration of stormwater into the system during heavy downpours. Regardless of the driver of these events, the aftermath results in raw sewage spilling into local waterways, city streets, and commercial and residential structures. Historical research in public health has thoroughly documented the connection between exposure to untreated sewage and waterborne disease. Recent research has detected antibiotic-resistant bacteria at wastewater treatment facilities at a time when deaths by antibiotic-resistant infections are on the rise. However, no research has explored the exposure pathways of antibiotic-resistant bacteria during sanitary sewer overflows and household-level sewage backups. In this commentary, we aim to introduce this new frontier of environmental health risks and disasters. To do this, we describe the history of modern sanitation and sewer infrastructure with a particular focus on wastewater infrastructure in the U.S. We also explore emerging risks and current methods for identifying antibiotic-resistant bacteria in the environment. We end with future directions for interdisciplinary scholarship at the nexus of urban planning, engineering, and public health by introducing the Water Emergency Team (WET) Project. WET is a community-based multi-method effort to identify environmental risks in the aftermath of household backups through (1) residential surveys, (2) indoor visual inspections, (3) environmental sampling, and (4) laboratory processing and reporting. Our hope is that by introducing this comprehensive approach to environmental risks analysis, other scholars will join us in this effort and ultimately towards addressing this grand challenge of our time.

Reporting Back to Households – *Report Cards*
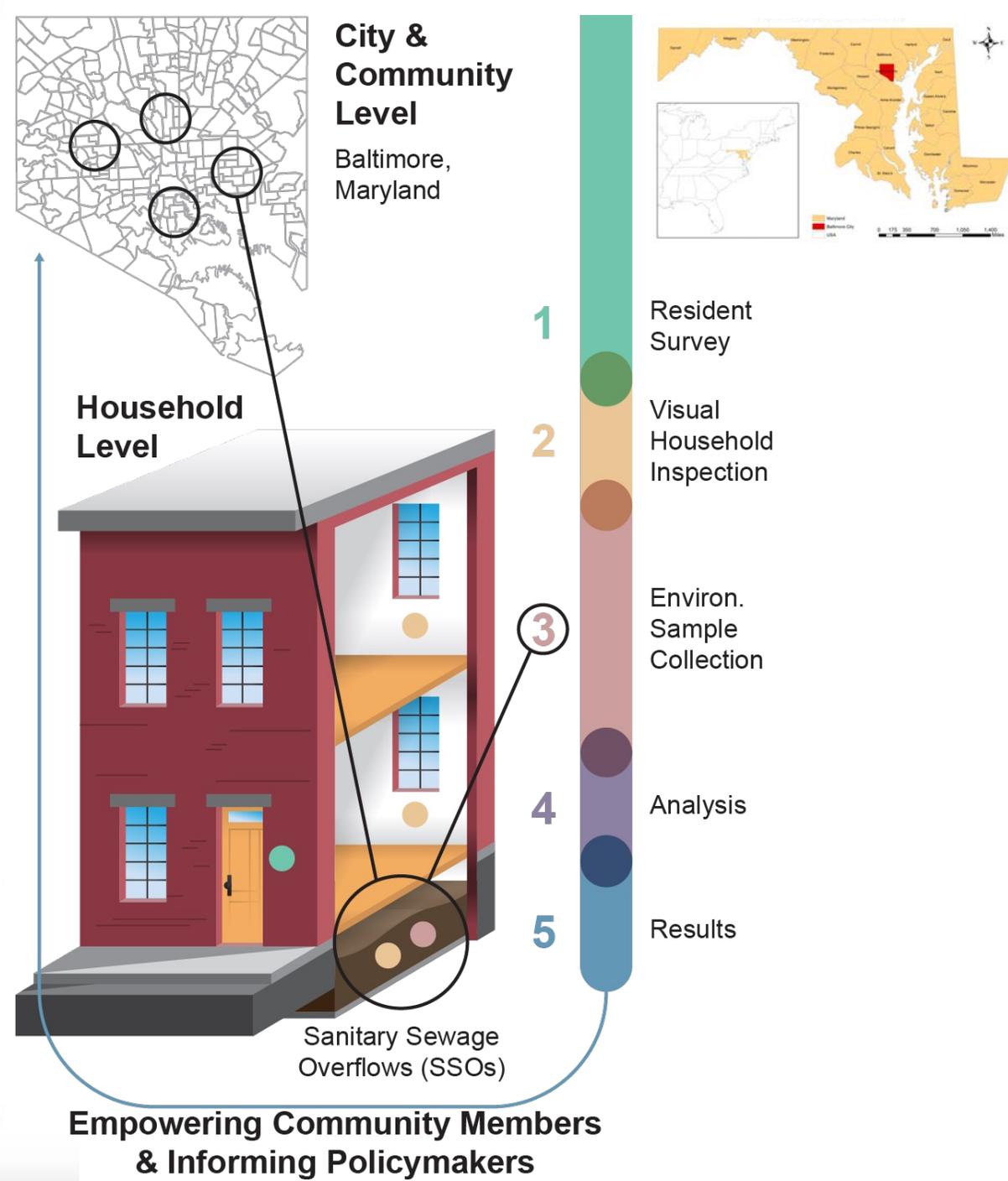
Home Surface Sample

TEST RESULTS

255 Valley Drive, College Park MD 20742   Drs. Rachel Goldstein or Marccus Hendricks, 301-314-1588

Results

Test	Sample Result (Basement)	Source of Standard
Surface Swab Sample		
E. coli Bacteria (CFU)	PRESENT	No standards exist
Methicillin-resistant *Staphylococcus aureus* (MRSA)	ABSENT	No standards exist
Methicillin- susceptible *Staphylococcus aureus* (MSSA)	PRESENT	No standards exist
Coagulase-negative Staphylococcus (CoNS)	ABSENT	No standards exist
Methicillin-resistant *Staphylococcus aureus* (MRSA)	ABSENT	No standards exist

Note: At this time, there are no standards for *E. coli*, MRSA, MSSA, CoNS, or MR-CoNS on surfaces or MRSA, MSSA, CoNS, or MR-CoNS in water. There are still significant knowledge gaps concerning the impact of sanitary sewer overflows on human health. To fill in these gaps, we are analyzing surface swab and water samples collected for the bacteria listed above. If you would like to further discuss the sample results, please contact Dr. Rachel Goldstein, at 301-405-5509 or rerosenb@umd.edu or Dr. Marccus Henricks at 301-405-2234 or mdh1@umd.edu.

Leveraging Critical Infrastructure Within an Environmental Justice Framework for Public Health Prevention

Marccus D. Hendricks, PhD, MPH

ABOUT THE AUTHOR

Marccus D. Hendricks is with the Urban Studies and Planning Program and the Stormwater Infrastructure Resilience and Justice Lab in the School of Architecture, Planning, and Preservation, University of Maryland, College Park.

I f we think of communities as a stage play production, land use would represent the markers on the stage, and

Hence, scholars have documented that, above any individual physiological indicator of health, zip code is one of the best

is that infrastructure and public health challenges in America are omnipresent, especially in communities of color.

In this editorial, I provide a high-level portrayal of the relationship between critical infrastructure systems and public health in the context of environmental justice. I begin by discussing the legacy of infrastructure development at the neighborhood scale in terms of how racism, redlining, and residential segregation have led to environmental injustice in infrastructure and how this phenomenon is a sociophysical determinant of public health. I then provide more contemporary illustrations of infrastructure, environmental injustice, and implications for public health. Last, I discuss how infrastructure can act as an intervention for not only environmental justice but also public health.

Environmental Justice, Vulnerability, & Infrastructure – Takeaways

- Equity in infrastructure includes procedural, distributive, and restorative justice.

- The built environment (e.g. stormwater or public health infrastructure) must be recognized as a continuation of social circumstances.

- Infrastructure dynamics have direct implications for risk exposure, ecological and public health outcomes (e.g. water quantity and quality).

- Community science, civic participation, and university-community partnerships are a pillar in planning, engineering, and public health and the democratic gateway to a more informed, healthy, just, and resilient society.

THE JPB FOUNDATION
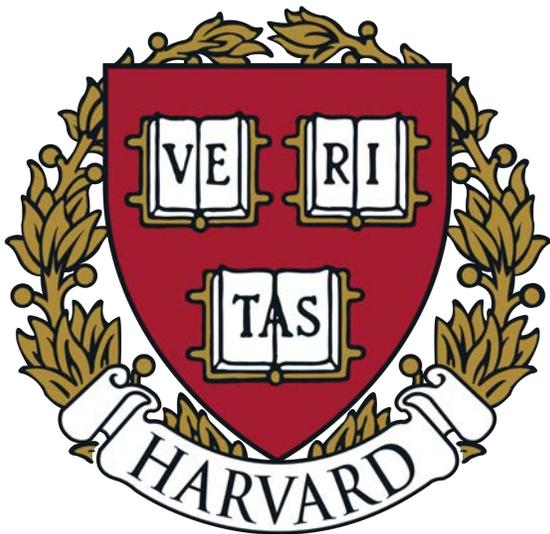
GRAND CHALLENGES GRANTS

HARVARD
VE RI TAS

NIH
National Institutes
of Health

Current/Recent Projects

- Water Emergency Team: Community-Driven Rapid Response to Sanitary Sewer Overflows, Household Backups, and Environmental Contamination

- A Historical Content Analysis and Photo Elicitation Approach to Examine Racialized Topographies and Contextualize Flood Risk in North Brentwood, MD

- Urban Flooding and Infrastructure: A Place-based Study in Washington D.C.

- Internet of Things (IoT) Enabled: A hyper-local stormwater living laboratory at UMD

- Water Security of Paraíba Municipalities: An Integrated Modeling of Climate Variability and Natural and Anthropogenic Dynamics

- Exploring the environmental justice and equity context and ramifications of the adoption of anaerobic digestion, input cover crops, and the production of renewable natural gas in the Delmarva peninsula, including the resilience of switch grass specifically to sea-level rise and saltwater intrusion

Thank You!

Marccus D. Hendricks, PhD, MPH
Urban Studies and Planning Program
University of Maryland
College Park, Maryland
mdh1@umd.edu

@mdhDuBois

Marccus D Hendricks

arch.umd.edu/sirj