Milwaukee Flood and Health Vulnerability Assessment

The Milwaukee Flood Health Vulnerability Assessment

Fall 2022

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Contributors

Groundwork Milwaukee
Young Kim
Keviea Guiden
Jess Haven
Lawrence Hoffman

Urban Systems Lab, The New School
Pablo Herreros Cantis
Christopher Kennedy
Timon McPhearson

Wisconsin Health Care Professionals for Climate Action
Joanne Bernstein (Wisconsin Health Professionals for Climate Action)
Joel Charles (Wisconsin Health Professionals for Climate Action)
Victoria Gillet (Wisconsin Health Professionals for Climate Action)
Rene S. Robinson (Wisconsin Health Professionals for Climate Action)
Alexandria Zielinski (Wisconsin Health Professionals for Climate Action)

Other institutions and organizations
Anne Getzin
Danya Littlefield (Data You Can Use)

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1

EXECUTIVE SUMMARY

Executive Summary

The Milwaukee Flood and Health Vulnerability Assessment (FHVA) is a collaborative effort between Groundwork Milwaukee and The New School's Urban Systems Lab to develop an assessment tool which identifies communities across Milwaukee where exposure to urban flooding and pre-existing health, housing and socioeconomic conditions intersect and create disproportionate vulnerabilities to the impacts caused by extreme flooding. The aim of the project is to provide critical information on both flood exposure and social vulnerability to support community-based advocacy and future planning to mitigate potential flood and health risks. The development of the FHVA is co-led by a diverse team of researchers, healthcare providers, data analysts, and local community organizations who provided their expertise in identifying relevant health variables that may correspond to higher vulnerability to flooding.

Two indices have been generated during the assessment. First, we developed vulnerability indices based on three vulnerability categories (health, socioeconomic, and housing), where each vulnerability category consists of a set of selected indicators. Meanwhile, we generated flood hazard maps combining data from the Federal Emergency Management Agency and a surface runoff modeling approach (Figure 1). The three vulnerability indices and the flood hazard map were then used to produce a social vulnerability and an exposure index. The two indices were then used to identify hotspots (census tracts within the top quartile for each index) (Figure 2). Finally, we identified locations in Milwaukee where vulnerability and exposure co-occur, flagging them as potential priority locations due to their higher risk.

The results of this analysis show that several census tracts in the central portion of Milwaukee are both exposure and vulnerability hotspots. As per the 2010 Census, ~47,800 people live in these census tracts. In addition, another ~86,600 people live in census tracts identified as vulnerability hotspots, and up to ~100,700 people live in exposure hotspots. In total, we estimate that ~39% of Milwaukee's population lives in an exposure, vulnerability, or both exposure and vulnerability hotspot.

FIGURE 1: Flooding at the intersection of Edgewood and Oakland in Shorewood, WI, during the flooding that took place on July 22nd, 2010. Source: Umesh Dhimal/for The Milwaukee Journal Sentinel

In addition, the data developed are useful to identify key vulnerability indicators for each census tract, supporting the development of tailored interventions in collaboration with local communities.

Mapping Flood Exposure and Vulnerability Index

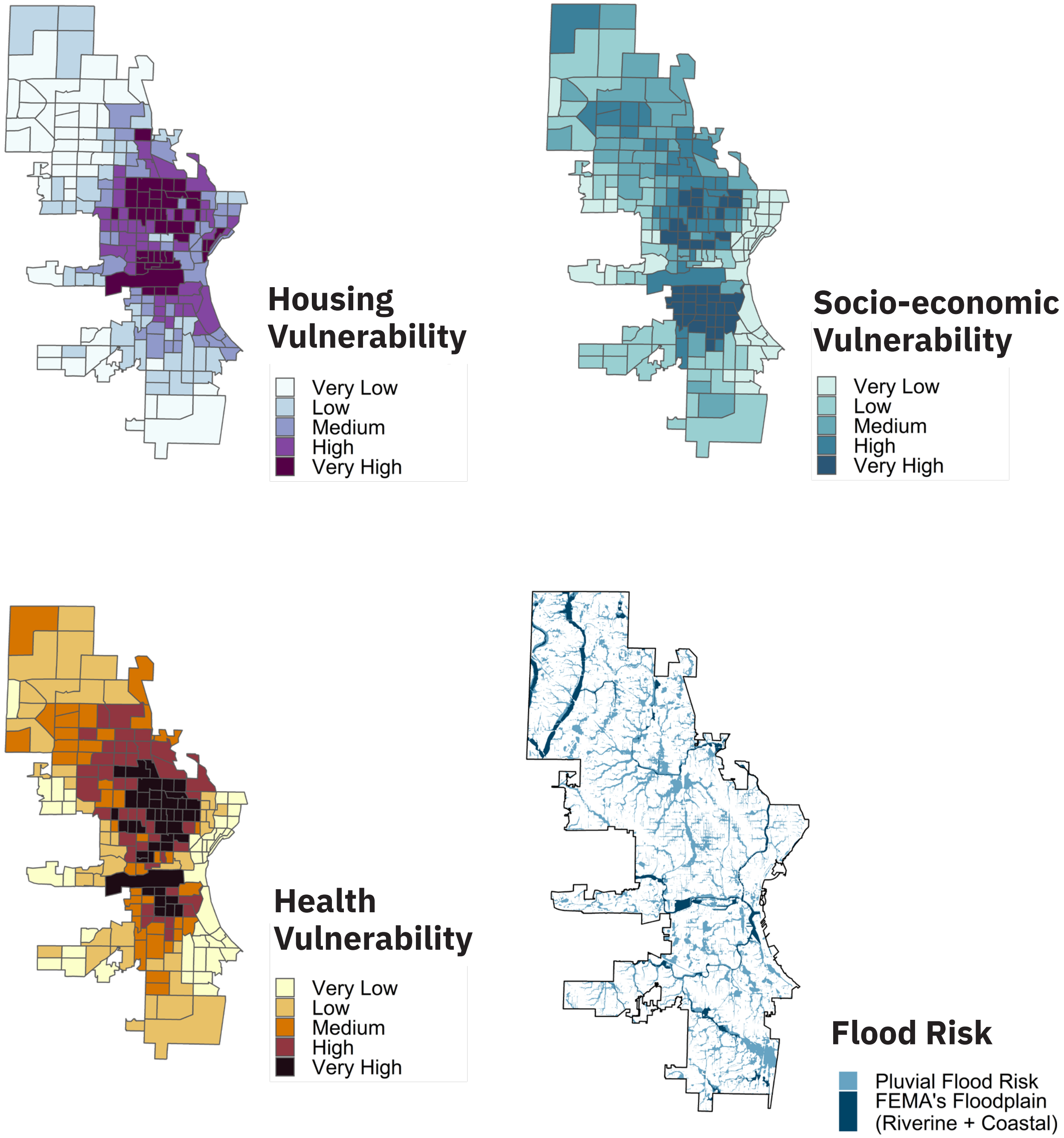

FIGURE 2: Maps showing the three dimensions considered to map social vulnerability, and the flood hazard map developed to evaluate exposure to flooding, including pluvial flooding due to surface runoff.

Mapping Flood-Health Vulnerability Hotspots

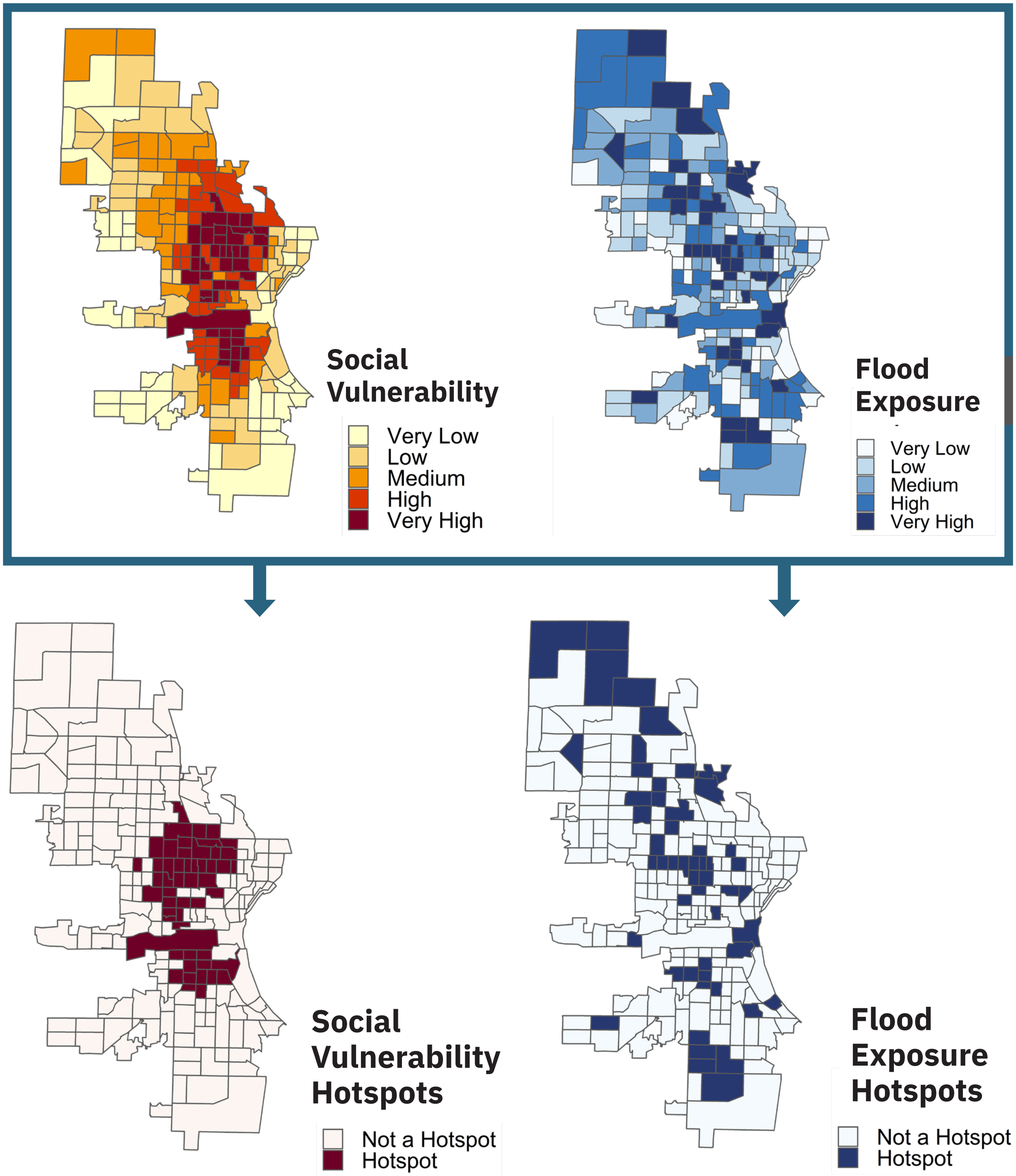

FIGURE 3: Social vulnerability and exposure indices (top) and the identified hotspots for each index (bottom). Census tracts were considered as hotspots if their index value fell within the twop quartile (top 25%).

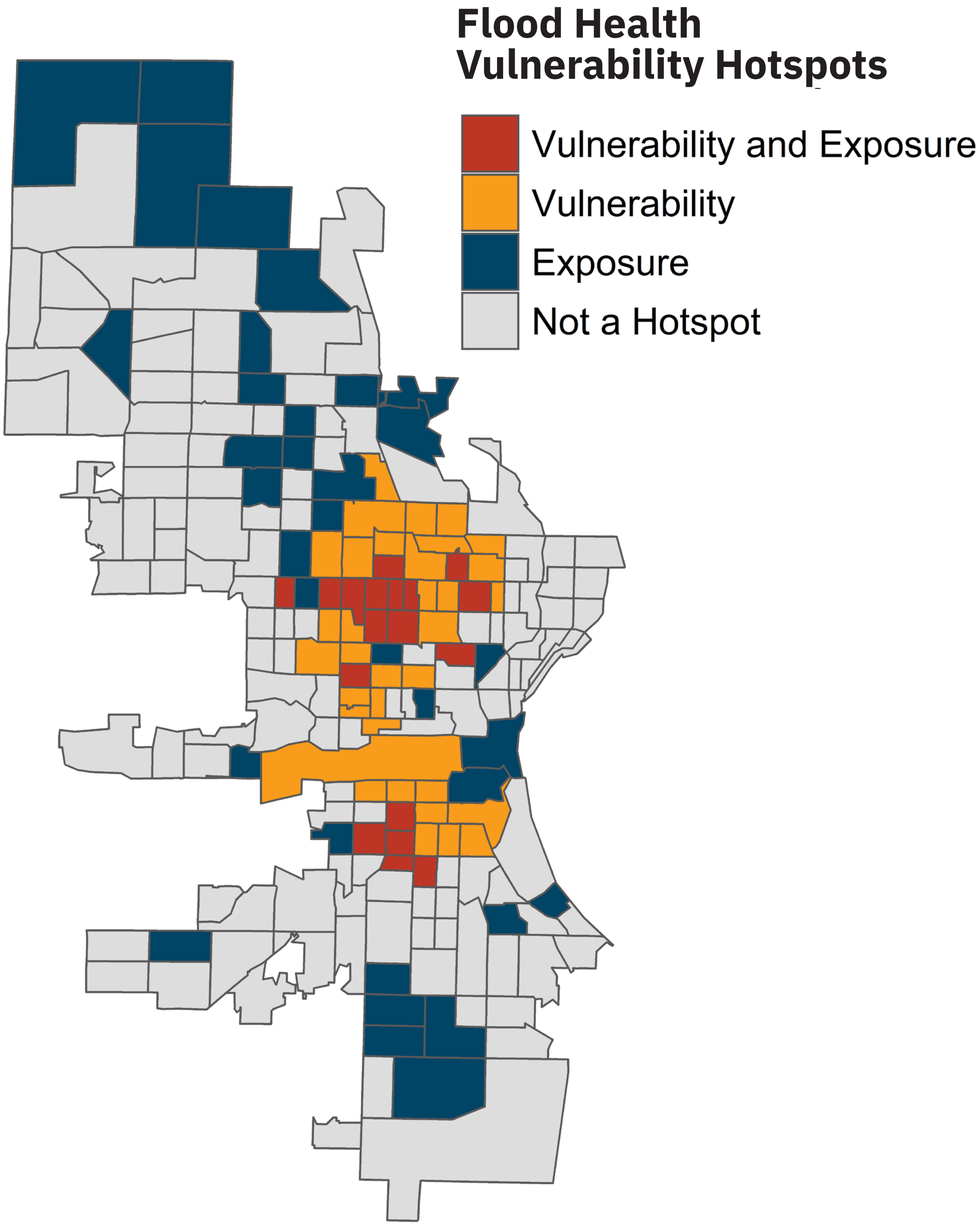

FIGURE 4: Overlap between Flood Exposure and Social Vulnerability hotspots across Milwaukee's census tracts.

2

INTRODUCTION

2.0 Introduction

This report provides information on the development of an assessment tool that integrates data on urban flooding, public health and social vulnerability in the city of Milwaukee, WI. The aim of the initiative is to develop a tool that identifies communities across the City of Milwaukee where exposure to urban flooding and pre-existing health, housing and socioeconomic conditions intersect and create disproportionate vulnerabilities to the impacts caused by extreme flooding. Informed by a similar effort in San Francisco, the tool also aims to support Groundwork Milwaukee's Climate Safe Neighborhoods Initiative, which will "work closely with residents and stakeholders to organize, mobilize, and effect systems change to make communities more resilient to extreme heat and flooding". In the following sections we provide an overview of key concerns related to climate change and health in Milwaukee, information on the development of a vulnerability assessment and the process of mapping and visualizing data, as well as next steps regarding outreach and engagement.

The development of the Milwaukee Flood Vulnerability Assessment is a joint effort between Groundwork Milwaukee, the Urban Systems Lab at The New School, the Wisconsin Health Professionals for Climate Action, and Data You Can Use, among others.

2.1 Climate Change and Health

According to the 4th National Climate Assessment (1) the Midwest is experiencing more frequent and intense extreme weather events such as extreme heat and precipitation. For instance, the amount of rain falling during extreme precipitation events in the Midwest has increased 42% during the 1956 - 2016 period, and additional increases are projected (Figures 1 and 2). In cities, extreme weather events can cause severe impacts due to the concentration of people, infrastructure, assets, and economic activity. The dense built environment in cities can exacerbate risks due to extreme weather events due to its interactions with the climate (e.g. increasing local heat due to the urban heat island effect)

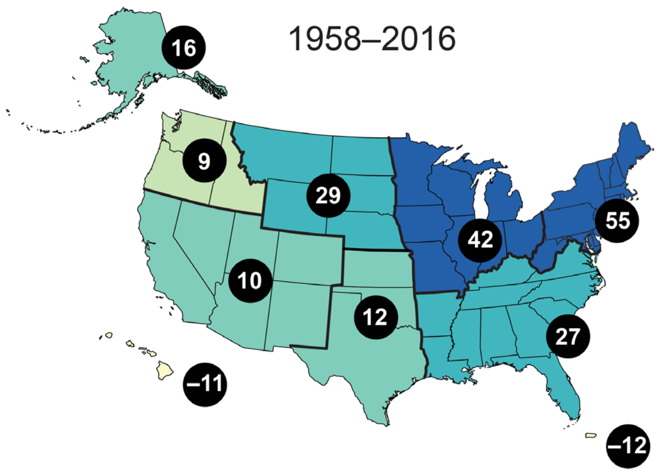

FIGURE 5: Observed changes in the total annual precipitation falling in the heaviest precipitation events across the United States according to the 4th National Climate Assessment (2).

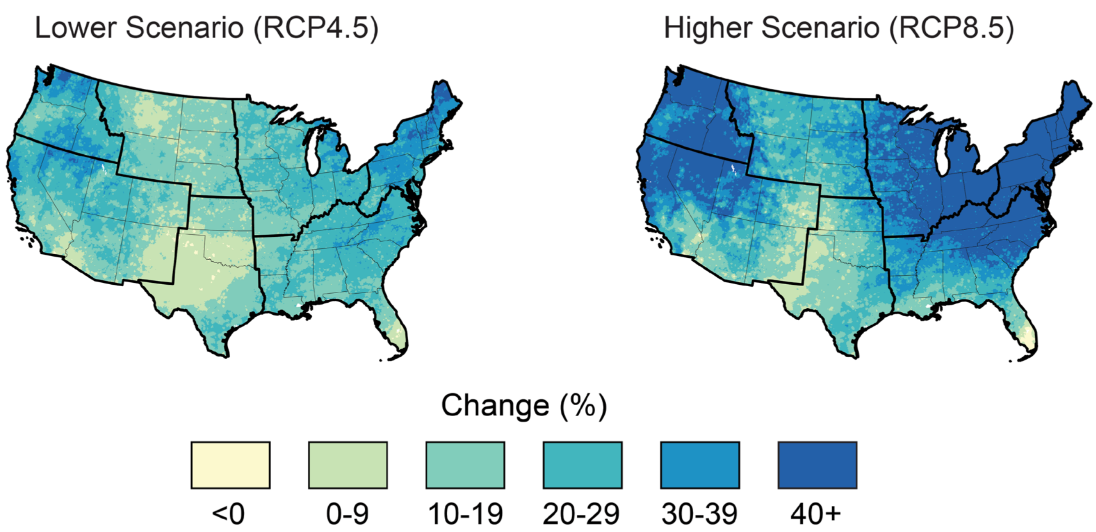

FIGURE 6: Projected changes in the total annual precipitation falling in the heaviest (top 1%) precipitation events across the United States by the end of the 21st Century according to the 4th National Climate Assessment (2).

and the influence of impervious surfaces on the local hydrology which generates higher quantities of surface runoff that flows and accumulates faster than in natural landscapes. Urban areas, in addition, are challenged by the aging of their infrastructure, designed to manage stormwater by swiftly removing it from the streets. With the increase in the intensity of extreme weather events, drainage infrastructure is more susceptible to failure, leading to combined sewer overflows, sewer backups, and urban flooding.

Extreme precipitation and other climate drivers impact human health (3) (Figure 2). Additionally, extreme weather events, long-term increased temperatures, and sea level rise can create or exacerbate existing exposure pathways[1]. For instance, urban flooding can increase the exposure of people to untreated stormwater and sewage, creating new pathways for waterborne diseases. Homes affected by flooding may develop mold, which exacerbate respiratory problems such as asthma, and may disproportionately affect

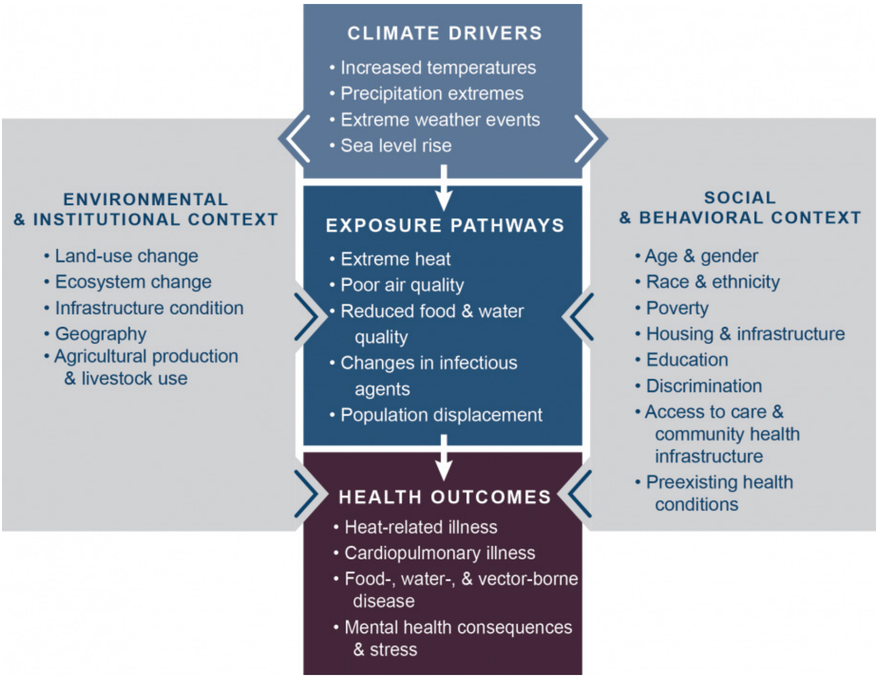

FIGURE 7: Influence of climate drivers, subject to changing due to climate change, on specific health outcomes according to the 4th National Climate Assessment (3) across the United States by the end of the 21st Century according to the 4th National Climate Assessment (2).

[1] In this report, we define exposure pathways as the different ways a person may come into contact with a hazardous substance, such as an atmospheric pollutant, or environmental condition, such as extreme heat.

people who have pre-existing conditions. Flooding events are also especially impactful on people's mental health both through exposure to acute, immediate events that may generate traumatic stress and delayed, prolonged exposures that may even be transmitted across generations (4).

Extreme weather events are also known to disproportionately impact minority and low-income populations. First, these groups tend to experience higher exposure to extreme events like heat and urban flooding. Second, communities with low access to resources, pre-existing health conditions, and living in precarious housing situations are more likely to be negatively affected when exposed to an extreme event like urban flooding. Previous work by the Urban Systems Lab in Milwaukee showed that Black and African American residents are more represented in the city's locations that experience the highest exposure to flooding than according to the city's average. The same study also highlighted that communities with highest exposure to flooding are more vulnerable according to indicators such as poverty, unemployment, and access to healthcare [2]. This uneven distribution of the impacts of climate change is known as distributional injustice, and is a key component of environmental justice. Distributional justice should be considered when assessing the risks faced by a city, because it can inform what locations should be prioritized when implementing policies and interventions to mitigate hazard risk. In addition, distributional injustices do not take place by chance, and need to be understood in their current context as well as the historic legacies of former policies and decisions. For instance, the distribution of BIPOC communities, which influences uneven exposure to flooding and other hazards such as extreme heat, is the fruit of former segregating policies such as redlining, which limited accessibility to home ownership and wealth in predominantly black neighborhoods (5).

2.2 Current and Future Green Infrastructure Planning in the City of Milwaukee

The City of Milwaukee has long been aware of its unique relationship with water. Built at the confluence of three rivers, atop wetlands and buried streams, and alongside Lake Michigan, it is no wonder that Milwaukee has developed its identity as a Water Centric City.

However, Milwaukee's water-centric identity has a complicated history, fraught with issues such as urban flooding, basement backups, and the danger of sewers overflowing into Lake Michigan from the combined sewer system during storm events. Beginning in 1993, in response to lawsuits from the State of Illinois and through an agreement with the Department of Natural Resources (DNR), the Milwaukee Metropolitan Sewerage District (MMSD) began the installation of a deep tunnel system to hold excess stormwater during storm events so that it can be properly treated before it is released into the lake. Even though the deep tunnels hold 520 million gallons, more needs to be done to keep the city and the lake safe during storm events, especially in the face of a changing climate.

Over the past few years the City of Milwaukee and MMSD have begun to look towards green infrastructure as a primary component of their stormwater and flooding planning. In 2013, MMSD published their Regional Green Infrastructure Plan, outlining a vision of zero basement backups, overflows, and improved

[2] To learn more about the Urban Systems Lab's previous research in Milwaukee, check this factsheet that explores the distributional injustice of flood risk.

water quality by capturing the first 0.5 inches of rainfall on impervious surfaces across all of the watersheds in the region - the equivalent of 740 gallons of new storage capacity across the region. In 2019, the City of Milwaukee released its own Green Infrastructure Plan with a city-specific goal of 36 million gallons of water capture through GI, including a spatial analysis of the areas where green infrastructure could be implemented effectively across the city. In addition to these centralized planning efforts, nonprofits and neighborhood organizations across the city have taken a more localized approach to planning green infrastructure with the City of Milwaukee and MMSD's support, focusing on specific neighborhoods and parks to create new community green spaces that also store stormwater, often working in neighborhoods that have experienced a historic lack of investment.

In the City of Milwaukee, city planners and others are working to address equity concerns in various ways. This includes key recommendations as part of Milwaukee's Climate and Equity Plan which highlights "unacceptable racial disparities" and a range of threats from climate-related hazards. Since launching the effort to develop the plan, the City has completed greenhouse gas inventories and identified programs that could address key concerns ranging from a green and healthy homes initiative, a program to increase electric vehicle infrastructure or new building performance standards, among others. Echoing the Green Infrastructure Plan (2019), the Climate and Equity Plan outlines a strategy for adding approximately 36 million gallons of stormwater storage through GI, which is the equivalent of adding 143 acres of green space throughout the City.

Milwaukee and MMSD's centralized green infrastructure plans have been pivotal in focusing and reshaping Milwaukee's relationship with water and climate change adaptation. Although the social benefits of green

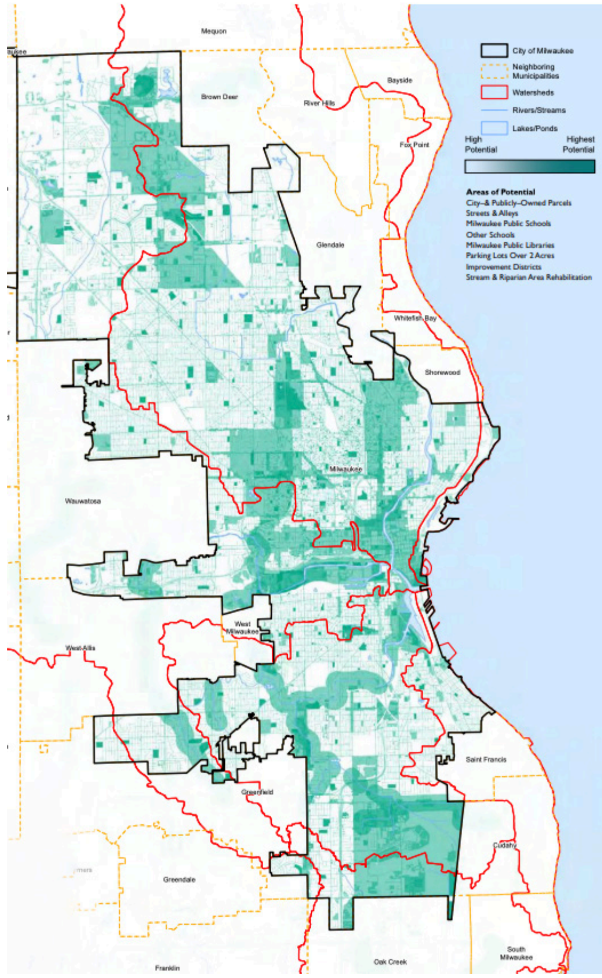

FIGURE 8: Map of potential for green infrastructure implementation from the City of Milwaukee's Green Infrastructure Plan, 2019

infrastructure in the City and region are widely referenced and acknowledged in the plans and among local partners, social vulnerability and health have thus far not been included in a city-wide or regional quantitative and spatial prioritization of green infrastructure projects. Acknowledging the spatial injustice of urban flooding and the health impacts of storm events to Milwaukeeans will allow the City to further refine the prioritization of Green Infrastructure projects, ensuring they are benefiting those most in need of protection against dangerous flooding and water quality issues. The analysis presented here aims to do just that; building on the GI work done in Milwaukee and offering an additional lens to evaluate potential projects across the city.

2.3. Objective: from an index to an assessment

Having identified a clear need to center environmental justice and social vulnerability in city-wide adaptation planning, this project aims to develop data insights and tools to prioritize communities for interventions and engagement based on different dimensions of vulnerability, including health, and exposure to different types of flooding. A common way to tackle these challenges is through social vulnerability indices, which are non-dimensional score metrics that result from aggregating a selection of indicators identified as linked to or correlated with higher sensitivity to suffering negative impacts if exposed to a given hazard. Some social vulnerability indices are readily available across the Contiguous United States, and are commonly used to identify vulnerable neighborhoods for interventions aimed at mitigating climate risks. These indices, like the CDC's Social Vulnerability Index (SOVI), tend to be generalistic rather than focused on a particular hazard, like flooding. Recent studies argue that generalistic social vulnerability indices may be problematic due to their over-simplified approach to vulnerability, making them unable to properly predict which communities may be more impacted by specific types of events (6). Furthermore, the CDC's SOVI does not include direct health-related variables that might be especially relevant due to their influence on vulnerability to the impacts of flooding. Because of this, it is necessary to develop an assessment focused on social vulnerability to flooding, with the novel incorporation of specific health indicators that may imply higher sensitivity to flooding.
The objective of the Milwaukee Flood and Health Vulnerability Assessment is to identify communities across the city of Milwaukee where urban flooding may cause direct and indirect impacts that disproportionately harm vulnerable populations due to their socioeconomic and health conditions. At first, this study intended to replicate the methods followed by the city of San Francisco to generate a flood-health vulnerability index (7). During this study, the pathways connecting flooding and health were examined (Figure 4), making it a good starting point for this project.

However, a series of initial conversations with the report's original authors and staff at Wisconsin's Department of Health Services highlighted concerns that integrating a suite of vulnerability and exposure indicators into a single aggregated value may generate a hard to interpret outcome and thus make it difficult to understand if high index values are caused by high exposures, high vulnerability, or a combination of both. Consequently, while this project builds upon the methodology developed in the San Francisco case, the index development was reframed as a flood - health vulnerability assessment. By assessment, we mean that we do not aim to reduce the outcome of this study to a single metric, but to build a set of indicators aggregated in different key dimensions that can inform the nuances and complexities of Milwaukee's neighborhoods regarding their exposure and vulnerability to, ultimately, provide suggestions for locally tailored interventions and engagement strategies.

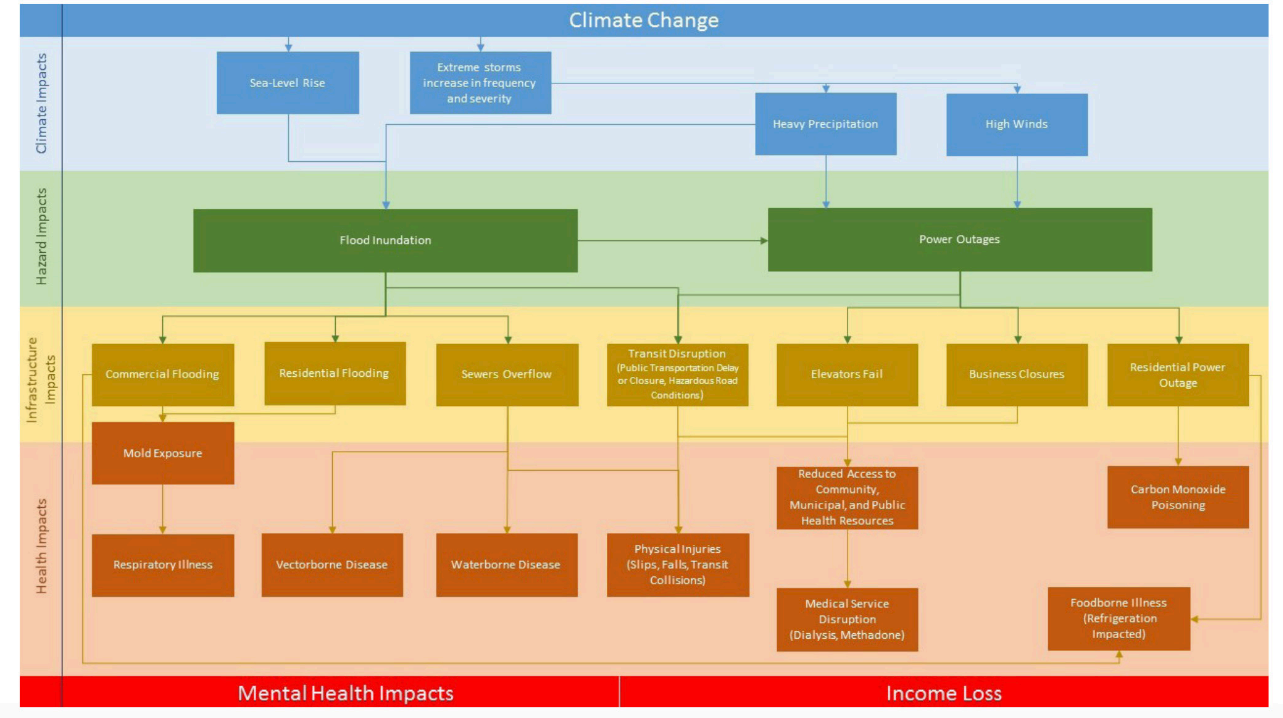

FIGURE 9: City of San Francisco Flood Inundation and Extreme Storm Health Pathways. Extracted from Wolff & Commerford (7).

In the assessment, two indices are generated - a vulnerability index that results from aggregating three vulnerability categories (health, socioeconomic, and housing), and an exposure index. By assessing both variables separately, we are able to identify locations in Milwaukee where high vulnerability and exposure co-occur, as well as locations where each variable shows a higher value separately. This process aims to understand what type of interventions may be most necessary in different communities, such as measures to assist vulnerable populations, and hazard mitigation measures like green and gray infrastructure for stormwater management.

This assessment was co-developed in close collaboration with Milwaukee-based healthcare practitioners whose on-the-ground experience was crucial in selecting relevant health variables that may correspond to higher vulnerability to flooding, as well as identifying the most representative indicators for each variable.

3

METHODS & RESULTS

3.0 Methods & Results

3.1 Flooding exposure index

Mapping flood hazards is critical to evaluate exposure to flooding across the city of Milwaukee. The Federal Emergency Management Agency (FEMA) is responsible for generating flood hazard maps that inform regulations, such as having to purchase flood insurance if a dwelling falls on the high hazard (100-year) floodplain. FEMA's hazard mapping, however, focuses on coastal and riverine flooding, whereas flooding due to extreme precipitation is not considered. In urban areas, intense precipitation can cause severe flooding due to the high concentration of impervious surfaces that avoid water from infiltrating into the ground. Because of this, it is important to account for pluvial flooding[3] when mapping flood hazards in order to generate a comprehensive assessment.

To incorporate pluvial flooding into the assessment, we simulated a 100-year, 1-hour storm in the city of Milwaukee using a surface runoff model called CityCAT, which computes the flow of water in real time accounting for infiltration based on the distribution of pervious / impervious surfaces. As Figure 9 shows, several streets that do not flood according to FEMA's flood hazard map show flooding (flood depth > 4''). In this study, we chose to take a conservative approach by combining FEMA's map and the outcomes of our surface runoff model.

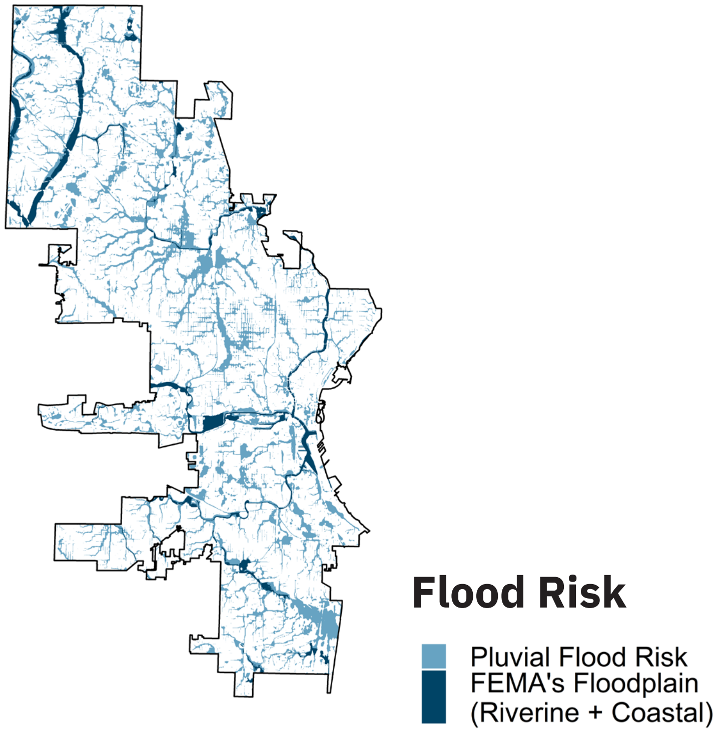

FIGURE 10: Comparison between FEMA's Special Flood Hazard Areas and pluvial flooding in Milwaukee based on a 1-hr, 100-year precipitation event. Pluvial flooding was considered when the maximum flooding depth surpassed 4 inches.

[3] Pluvial flooding refers to flooding caused by the flow of surface runoff when the drainage infrastructure is unable to cope with the amount of rain

Following the creation of a comprehensive flood hazard dataset, we then evaluate what areas across Milwaukee are most exposed to flooding. In this first iteration of the FHVA, we evaluated exposure based on the overlay of the flood hazard layer with roads and residential parcels. For each census tract, we calculated the % of the total road area and the % of the total number of residential units impacted by flooding. Residential units were considered impacted by flooding if their distance to any type of flooding was lower than 32.5 feet in order to account for the resolution of the flood risk simulation (10x10m) and to account for possible indirect impacts on properties such as limited accessibility. To generate the exposure index, each metric was normalized to a 0-100 range to then calculate the average value between both exposure scores in each census tract (Figure 11).

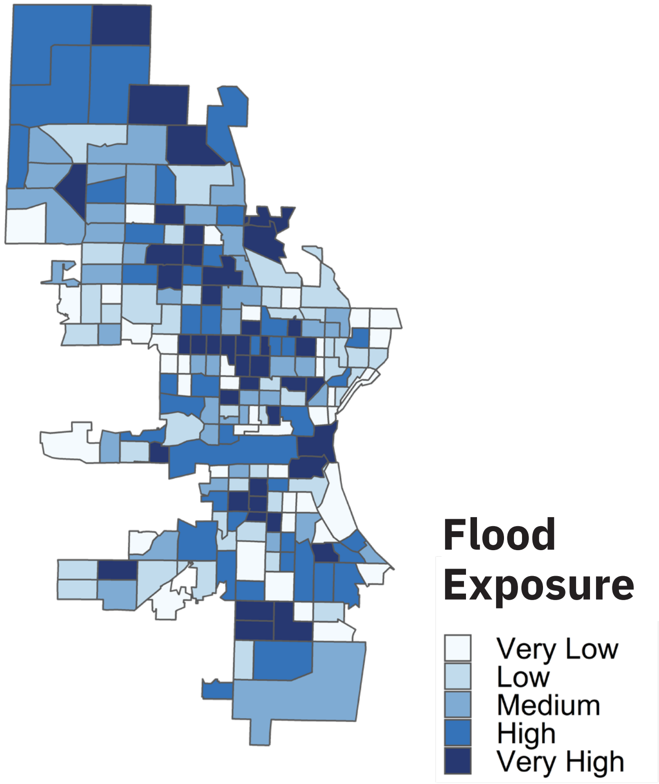

FIGURE 11: Flooding Exposure Index in Milwaukee, with scores sorted in quintiles.

3.2 Vulnerability index

To generate a flood vulnerability index for the city of Milwaukee, we compiled vulnerability indicators and grouped them into three thematic vulnerability categories:

1. Health vulnerability
2. Socioeconomic vulnerability
3. Housing vulnerability

Each of these vulnerabilities represent characteristics that are expected to lead to a higher difficulty of anticipating, reacting, and recovering from the impacts of flooding. Under each category, the number of variables considered was limited in order to facilitate the interpretation of the index and to reduce collinearity of the variables considered. Under each category, indicators were selected by prioritizing metrics used in the San Francisco case. However, these metrics were only considered a starting point, and several indicators were added based on the input provided by members of the team and data availability. Health vulnerability variables were selected under the close supervision of Wisconsin-based health practitioners who provided critical insights to interpret the data and select the appropriate metrics.

3.2.1. Health vulnerability

Health vulnerability considers health related risk factors which make someone more likely to become ill with exposure to flooding. The variables considered to develop the health vulnerability index are:

- % of adults having Diabetes: Flooding exposure can increase risks of complications for diabetics including foot infections and poor blood sugar control. Furthermore, an area with a high rate of diabetes also predicts a high rate of other flood-vulnerable conditions such as heart and kidney disease. People requiring insulin to treat their diabetes are particularly vulnerable to power outages caused by flooding, due to the need for refrigeration to appropriately store most insulin. Data source: Milwaukee Health Compass, 2019[4].
- % of adults reporting having experienced poor mental health over the last 14 days: Flooding can worsen and/or cause depression, anxiety, and PTSD (4). People experiencing poor mental health at baseline can be more vulnerable to worsening symptoms after floods. Source: Milwaukee Health Compass, 2019; Cianconi, P., Betrò, S., & Janiri, L. (2020).
- % people having a disability: People with disabilities may have a harder time reaching safety during flooding. Following floods, individuals with a disability can experience disrupted critical access to food, healthcare, and support services. Data source: American Community Survey 5-year estimates, 2019.
- Age-adjusted ER Rate due to asthma: Flooding causes mold and mildew which worsen asthma. Places where more people frequent the ER with poorly controlled asthma are more vulnerable. Furthermore, an area having a high rate of ER visits for asthma was predictive of also having a high rate of uncontrolled heart failure, another flood-vulnerable condition. Data source: Milwaukee Health Compass, 2019.
- % adults without health insurance: While not a health condition, adults lacking health insurance are more vulnerable to the impacts that flooding may cause on their health due to a lower access to healthcare. Especially in low-income households, lacking health insurance may severely complicate receiving adequate healthcare related to injuries or illness developed during a flooding event due to its high costs. In addition, adults without access to proper healthcare may be additionally vulnerable to the impacts of flooding if presenting undiagnosed or untreated health conditions. Data source: American Community Survey 5-year estimates, 2019.

The five health vulnerability indicators were aggregated by normalizing each variable to a 0-100 range, to then calculate the average score at each tract by adding the indicators and dividing them by 5 (Figure 12).

[4] For a comprehensive list of the data sources used in this assessment, see Appendix A.

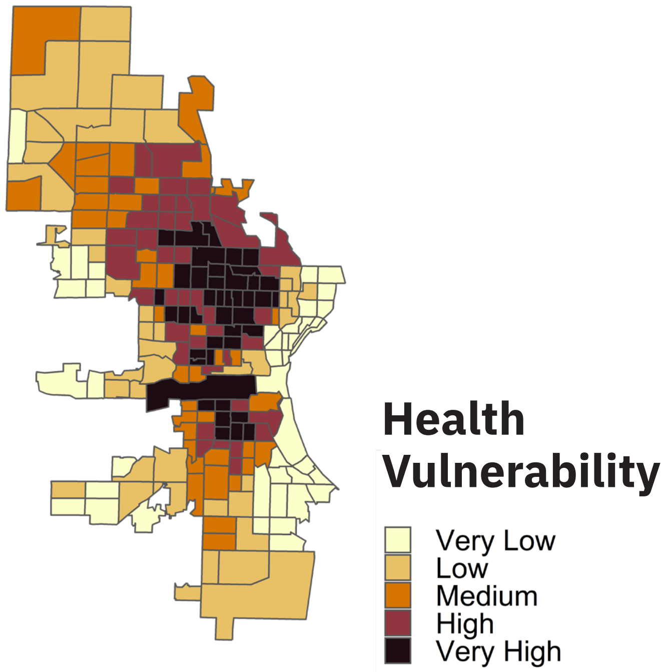

FIGURE 12: Health Vulnerability Index in Milwaukee, with scores sorted in quintiles.

3.2.2 Socioeconomic vulnerability

Socioeconomic vulnerability considers socioeconomic factors that are commonly considered to make it harder to prepare and recover from a flooding event. The variables considered to develop the socioeconomic vulnerability index are:

- % residents aged below 18 and above 65 years old: young and elderly residents face high vulnerability due to a variety of reasons. To begin with, both population groups are especially vulnerable to respiratory, foodborne and waterborne illness. Younger children require special items that may become harder to access during a flooding event such as formula or diapers. Families in charge of an infant may face additional financial stress due to their required care. Elderly residents may be vulnerable to the impacts of power outages if they rely on any sort of equipment for their wellbeing. Young and elderly people account for the majority of fatalities that take place during a flooding event. Data source: American Community Survey 5-year estimates, 2019.
- % people with a salary below twice the federal poverty line: Financially burdened people are more likely to lack the resources to anticipate, react and recover from a flooding event and its potential health impacts. Data source: American Community Survey 5-year estimates, 2019.
- % people aged above 25 years old without a high school diploma: Educational attainment is correlated with health and income security. It may also involve better access to information relevant to anticipate and react to a flooding event. Data source: American Community Survey 5-year estimates, 2019.

- % of the population aged 5 and over who does not speak English (reported to speak English “not well” or “not at all”): In places where most information is shared in English, language isolation can make it harder to receive critical guidelines to prepare for a flooding event and find help when needed. Data source: American Community Survey 5-year estimates, 2019.
- % of residents self-identified as Black, Indigenous or Person of Color according to the US Census: Due to historic and ongoing systemic inequities, communities of color are more likely to experience impoverished health conditions, live in poor quality housing, be exposed to natural hazards, experience harder access to healthy food, and count with lower economic resources. Data source: American Community Survey 5-year estimates, 2019.

The five socioeconomic vulnerability indicators were aggregated by normalizing each variable to a 0-100 range, to then calculate the average score at each tract by adding the indicators and dividing them by 5 (Figure 13).

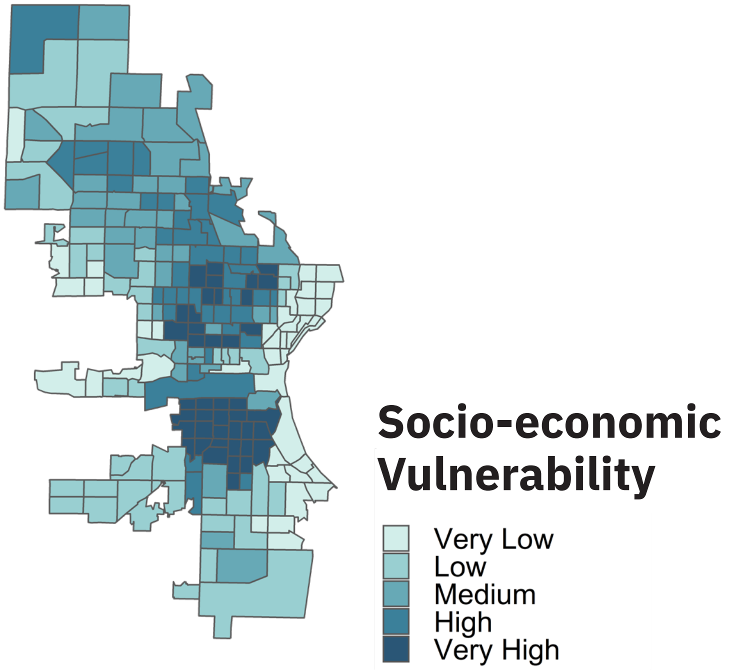

FIGURE 13: Socioeconomic Vulnerability Index in Milwaukee, with scores sorted in quintiles.

3.2.3 Housing vulnerability

Housing vulnerability refers to the characteristics specific to the household configuration:

- % residential units built before 1950: older households are assumed to be less structurally sound, as well as more likely to present construction methods or materials that may have later been recognized as hazardous for human health, such as lead. Data source: Milwaukee Master Property File 2021.

- % households without a car: households without a car may face difficulty to evacuate when needed to do so in a timely manner. Data source: American Community Survey 5-year estimates, 2019.
- % households composed of a single adult living alone: Adults living alone are at higher risk of social isolation, and may face higher difficulty to get help if ill or injured during a flooding event. Data source: American Community Survey 5-year estimates, 2019.
- The three socioeconomic vulnerability indicators were aggregated by normalizing each variable to a 0-100 range, to then calculate the average score at each tract by adding the indicators and dividing them by 3 (Figure 13).
- % of residents self-identified as Black, Indigenous or Person of Color according to the US Census: Due to historic and ongoing systemic inequities, communities of color are more likely to experience impoverished health conditions, live in poor quality housing, be exposed to natural hazards, experience harder access to healthy food, and count with lower economic resources. Data source: American Community Survey 5-year estimates, 2019.

The five socioeconomic vulnerability indicators were aggregated by normalizing each variable to a 0-100 range, to then calculate the average score at each tract by adding the indicators and dividing them by 5 (Figure 14).

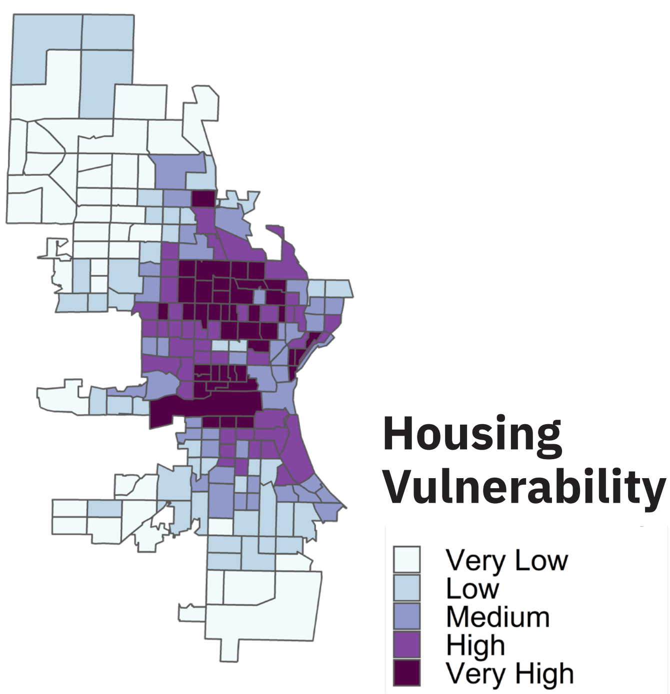

FIGURE 14: Observed changes in the total annual precipitation falling in the heaviest precipitation events across the United States according to the 4th National Climate Assessment (2).

3.2.4 Aggregating vulnerabilities into a single vulnerability index

Having mapped vulnerability to flooding under the categories considered, a final social vulnerability index was generated by averaging the three scores (Figure 15). This final index represents overall vulnerability to flooding across the city of Milwaukee. As the map shows, the highest vulnerability values are concentrated in the city's central tracts. While this index is useful to represent vulnerability as a broad theme, the three categories mapped may also be useful to isolate specific challenges faced by the different communities in Milwaukee.

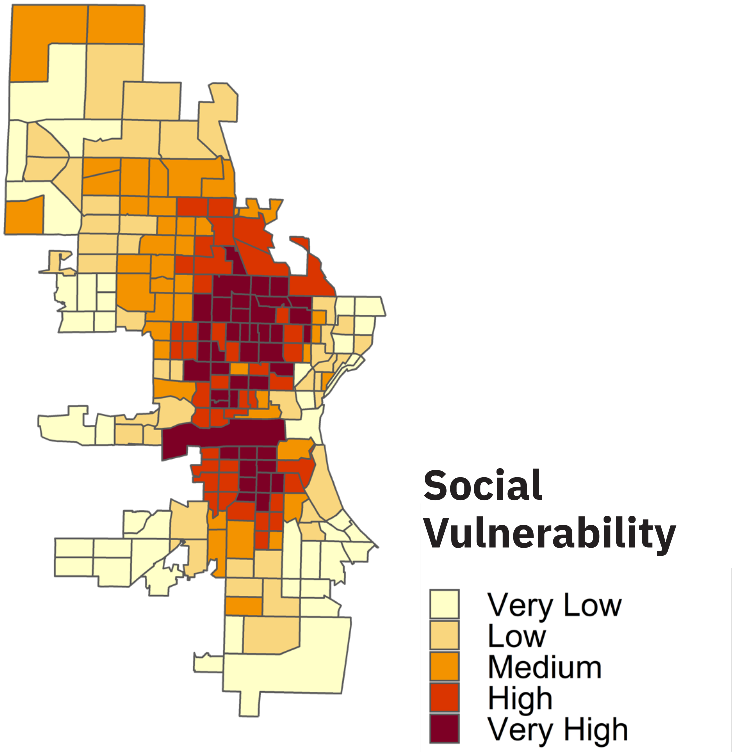

FIGURE 15: Social vulnerability Index in Milwaukee, with scores sorted in quintiles.

3.3. Mapping Flood-Health vulnerability hotspots

Exposure and vulnerability hotspots were defined as the census tracts whose exposure and vulnerability index fell within the top 25% (the top quartile). The comparison between the two hotspot maps (Figure 9) shows an interesting difference in the distribution of exposure and vulnerability in Milwaukee. While exposure hotspots are scattered across the city and slightly overlapped with the location of the primary rivers, vulnerability hotspots are clustered in the center of the city. If we overlap the two maps (Figure 16), we can identify the census tracts that qualify as hotspots according to both indices, making them priority locations in future interventions aiming to reduce the impacts of flooding on the most vulnerable communities. As per the 2010 Census, ~47,800 people live in these census tracts. In addition, another ~86,600 people live in census tracts identified as vulnerability hotspots, and up to ~100,700 people live in exposure hotspots. In total, we estimate that ~39% of Milwaukee's population lives in an exposure, vulnerability, or both exposure and vulnerability hotspot. Table 1 shows what zip codes contain census tracts flagged as hotspots.

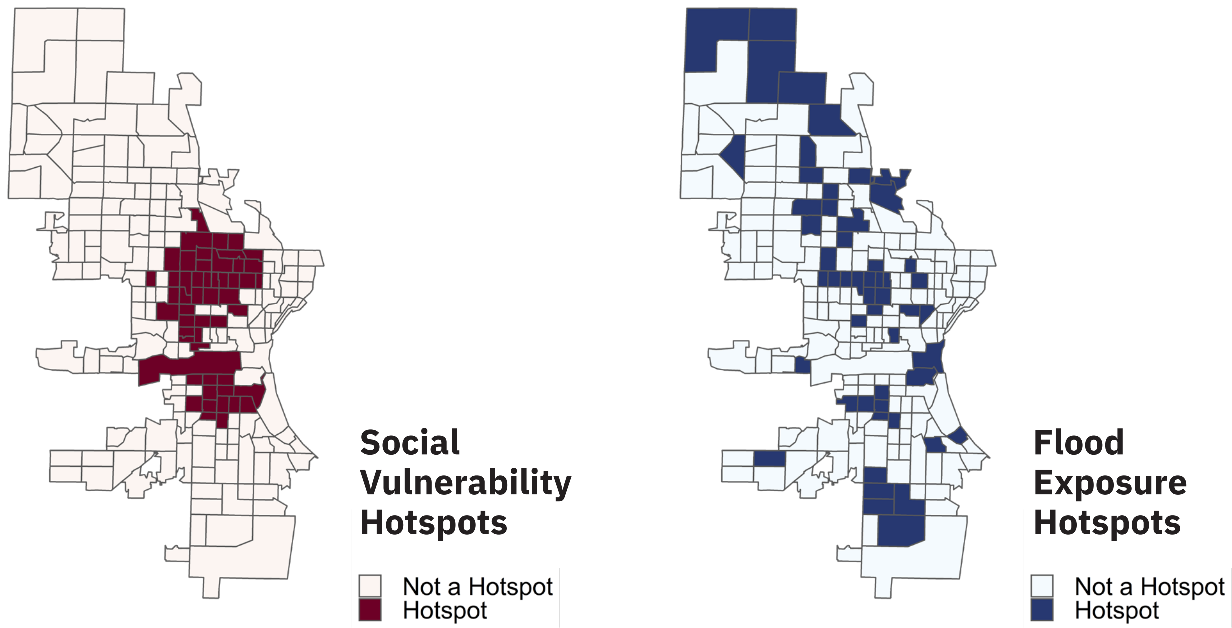

FIGURE 16: Census tracts classified as hotspots based on their Flood Exposure Index (left) and their Social Vulnerability Index (right).

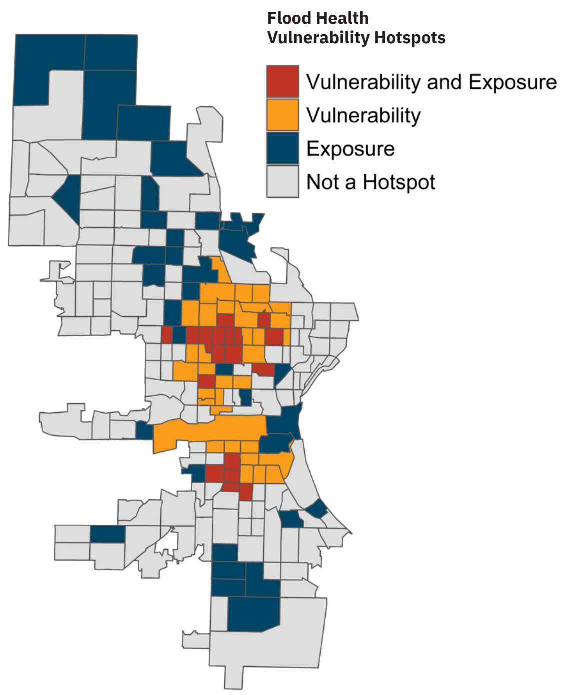

FIGURE 17: Overlap between Flood Exposure and Social Vulnerability hotspots across Milwaukee.

TABLE 1: Hotspots contained by each zip code. Zip codes not listed do not overlap with any type of hotspot. In light red, zip codes containing census tracts identified as hotspots for both exposure and vulnerability, simultaneously.

Zip Code	Types of Hotspots Contained
53224	Exposure
53223	Exposure
53225	Exposure
53218	Exposure
53209	Exposure; vulnerability
53216	Exposure; vulnerability
53206	Exposure and vulnerability; exposure
53212	Exposure and vulnerability; exposure; vulnerability
53210	Exposure and vulnerability; exposure; vulnerability
53208	Exposure and vulnerability; vulnerability
53205	Exposure and vulnerability; exposure; vulnerability
53233	Exposure; vulnerability
53203	Exposure; vulnerability
53202	Exposure
53204	Exposure and vulnerability; exposure; vulnerability
53214	Exposure; vulnerability
53215	Exposure and vulnerability; vulnerability
53219	Exposure
53221	Exposure
53207	Exposure

3.4. Case Study: the Metcalfe Park Neighborhood

The results obtained from the FHVA can be used to identify the risk and vulnerability circumstances of different neighborhoods and communities across Milwaukee. As an illustrative example, consider Metcalfe Park which is located in the North Side of Milwaukee (Figure 18). Metcalfe Park is a neighborhood primarily composed of low-density residential areas (Zip Code 53210). These areas are divided by a railroad line, which is surrounded by an industrial buffer zone. The two sides of the tracks were historically redlined with grades C (definitely declining) and D (hazardous) for the West and East sides, respectively (Figure 19), and show a heavily segregated current population, with ~98% of its residents identified as Black, Indigenous and People of Color. The industrial corridor that separates both sides of the neighborhood also shows a high density of brownfield remediation sites (Figure 20). This neighborhood does not overlap with FEMA's fluvial and coastal flood hazard maps, but is highly exposed to pluvial flooding under an extreme precipitation scenario (Figure 21).

The development and use of the Flood Health Vulnerability Assessment reveals the majority of Metcalfe Park as both a flood exposure and social vulnerability hotspot (Figure 22). This reinforces concerns from local advocacy groups such as Groundwork Milwaukee and other partners which identifies Metcalfe Park as a high priority community for local engagement and building resilience and environmental stewardship. In addition to local engagement, these insights call for further interventions, such as hazard mitigation measures like green, gray and hybrid infrastructures, that require the involvement of multiple stakeholders, and local and state policy makers. The FHVA is one example of a potentially useful approach to help identify other neighborhoods across the city with overlapping vulnerabilities and exposure to both flood and health vulnerability.

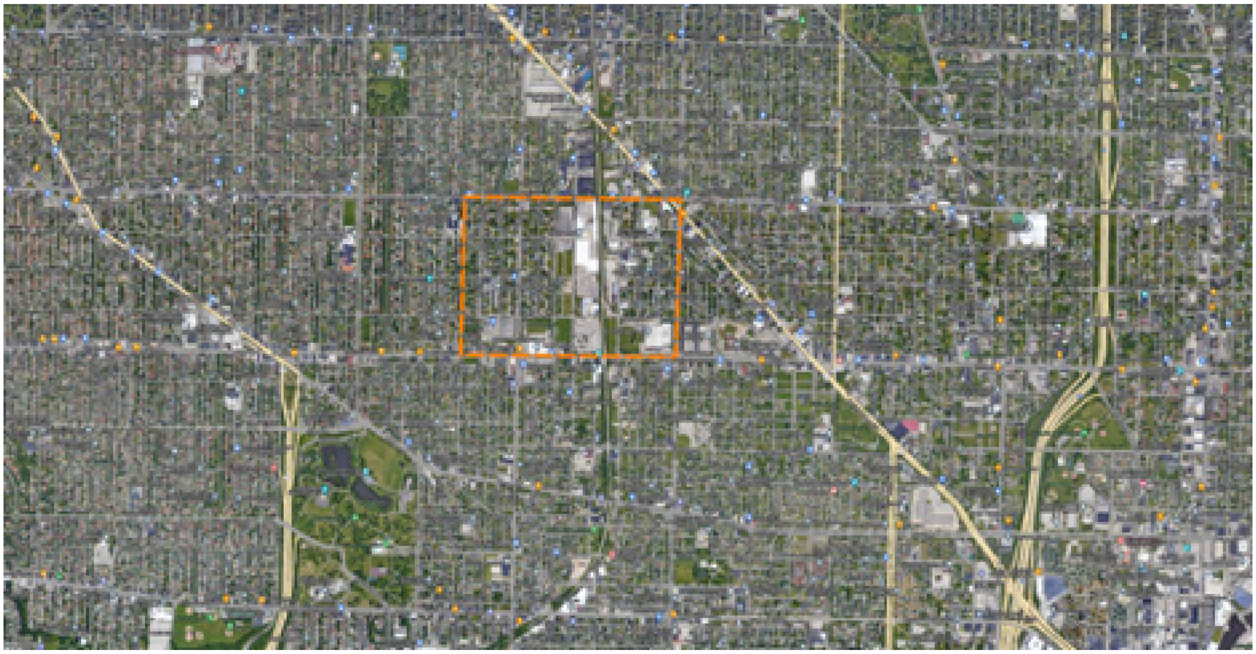

FIGURE 18: Location of Metcalfe Park in Milwaukee, according to the boundaries suggested by Google Maps. Located in the North Side, Metcalfe Park is located between N 38th St and N 27th St, and W Center st and W North Ave.

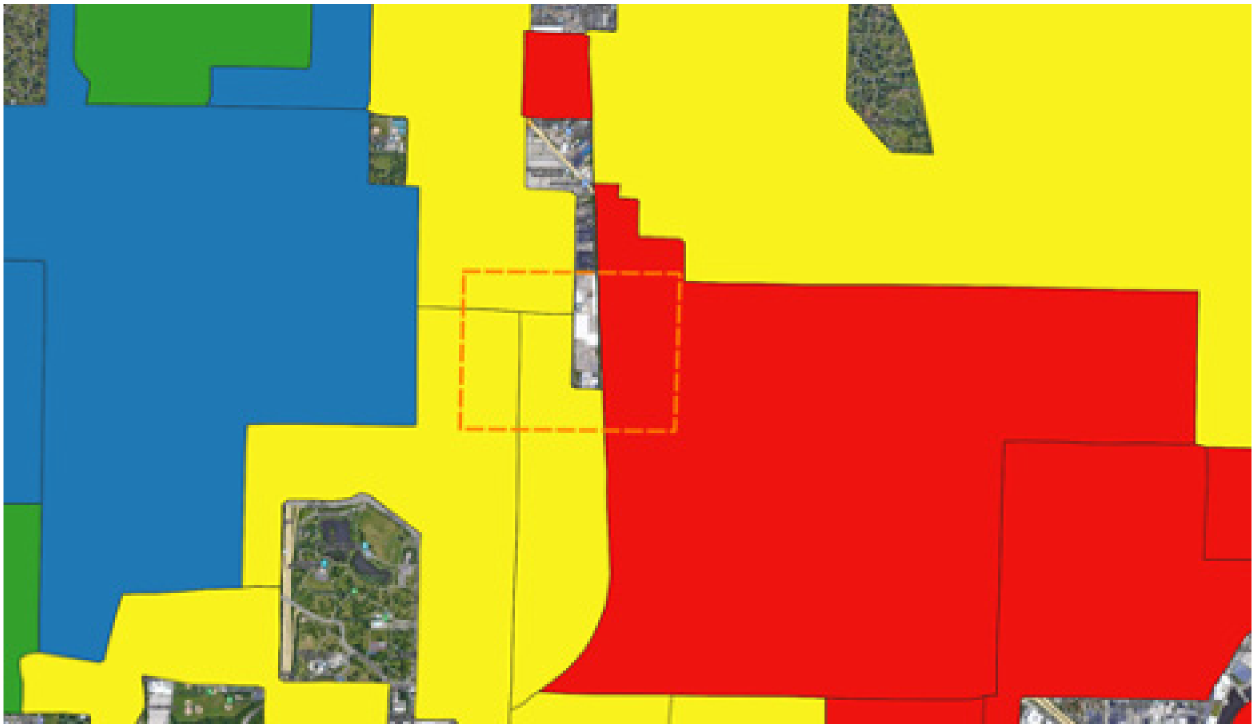

FIGURE 19: Redlining in Metcalfe Park. In red, areas that were graded with a D (the lowest possible grade). Neighborhoods graded with a D were qualified as "hazardous" based on investment risk. In these neighborhoods, banks were discouraged from considering financing mortgages. In yellow, areas that were graded with a C, the second lowest possible grade with which neighborhoods were graded. Neighborhoods graded with a C were also considered to have high investment risk, albeit lower than D. To access the data or learn more about the grading system commonly known as redlining (which usually refers to neighborhoods graded as D), you may visit the Mapping Inequality Project's website.

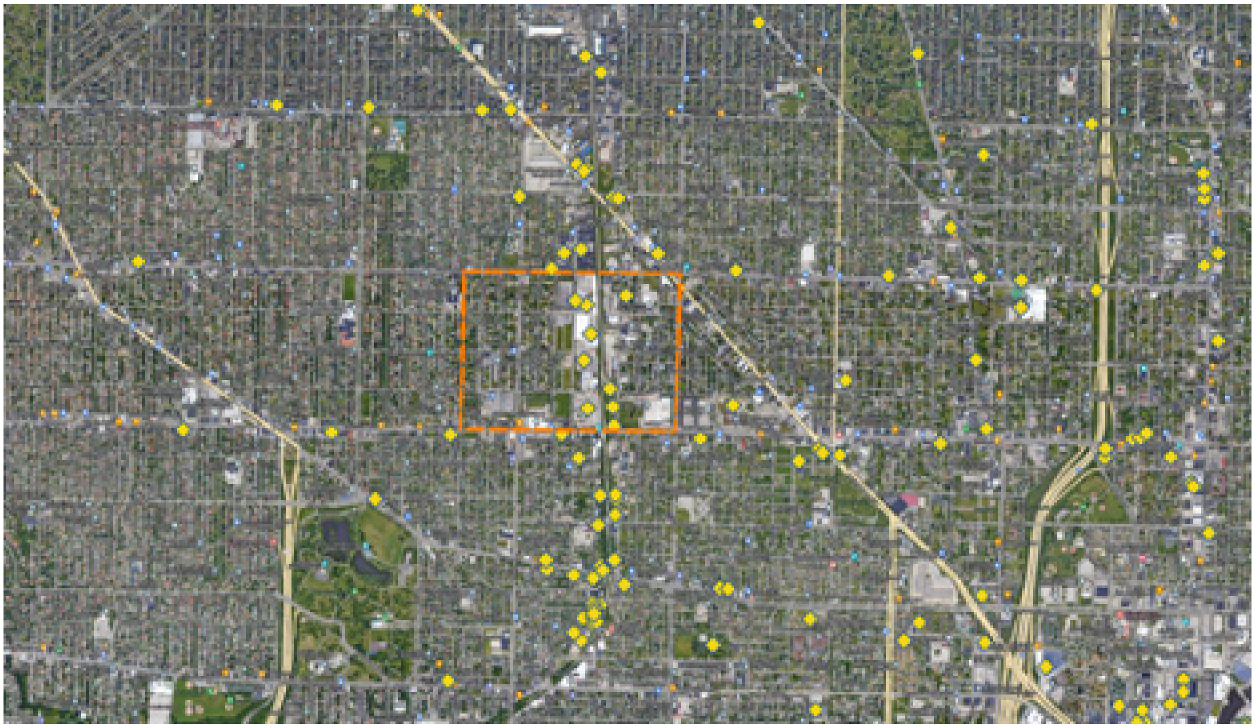

FIGURE 20: Open remediation sites in Metcalfe Park. To access the data and learn more about each site, you may visit Wisconsin's Department of Natural Resources' RR Sites Map.

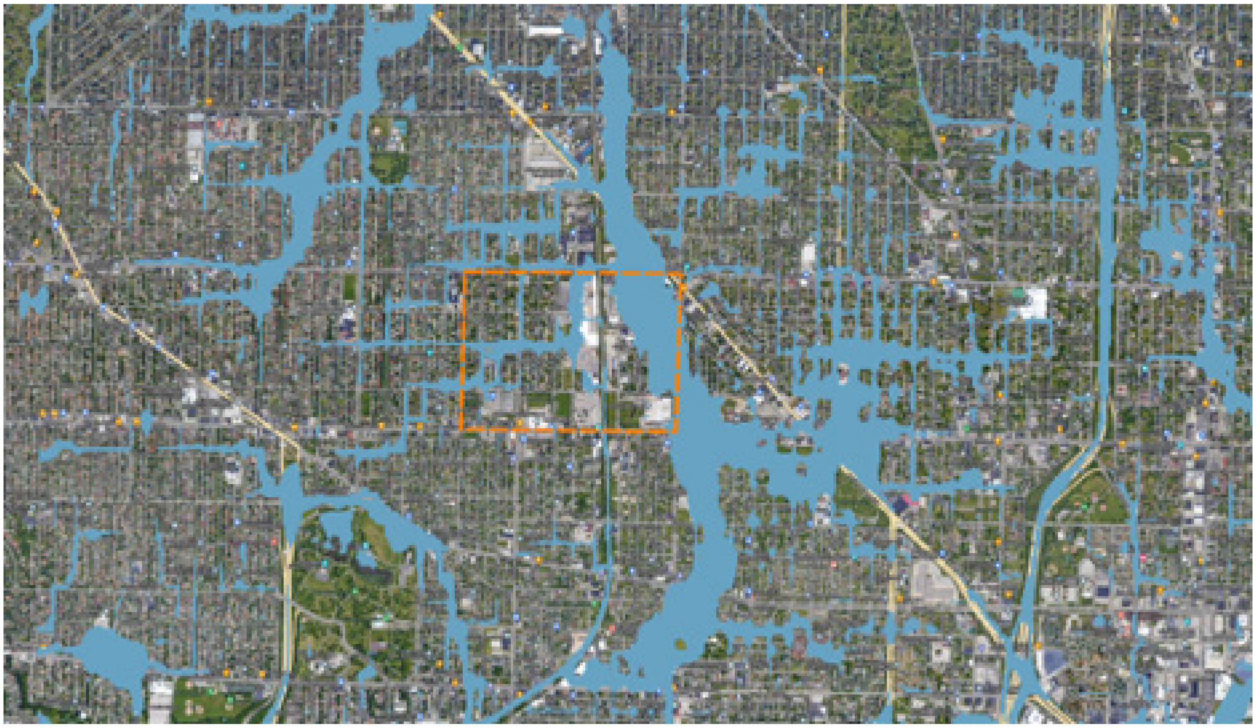

FIGURE 21: Pluvial flooding in Metcalfe Park under an extreme precipitation scenario (a 100-year, 1-hr storm). Flooding is considered when the maximum flood depth obtained during the simulation exceeds 4 inches.

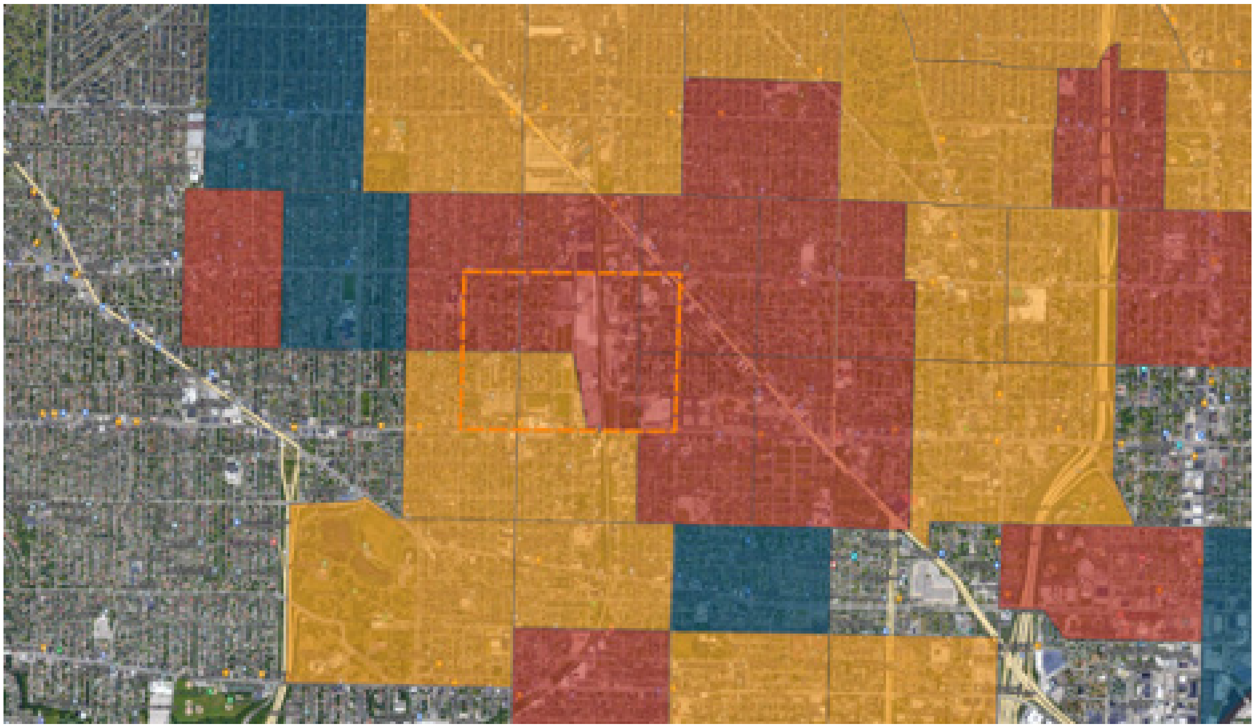

FIGURE 22: Exposure and vulnerability hotspots in Metcalfe Park. Based on the FHVA, high exposure and vulnerability indices overlap in the neighborhood. The Southwest corner of the community has not been identified as an exposure hotspot. However, the census tracts that are not identified as such show significant flooding in their areas that overlap with Metcalfe Park (as shown in Figure 14), with low or no flooding in their southern segments that do not overlap with the neighborhood. Because of this, the Southwest corner of Metcalfe Park should still be considered an area of interest for hazard mitigation strategies.

4

NEXT STEPS

Next Steps

The development of Milwaukee's Flood Health Vulnerability Assessment has generated powerful insights, data, and a methodology which is flexible and can be updated based on the feedback and intended use from local organizations, practitioners, and decision makers. The following actions are identified as key next steps:

- **Outreach**: We aim to showcase this report and other products of the FHVA to different stakeholders and request feedback to further advance and identify additional actions that may make it an effective tool, both from a decision making and an advocacy perspective. These efforts will be mainly led through Groundwork Milwaukee's Climate Safe Neighborhoods initiative, which will share the outcomes of its project facilitating engagement activities with other grassroots organizations.
- **Storymap**: A story map presenting the development process of the FHVA will be released as part of Groundwork Milwaukee's Climate Safe Neighborhoods initiative. This storymap will be the main communication tool produced during this project, presenting the information in an interactive manner that allows the user to explore the different indicators used and compare the results obtained across Milwaukee.
- **Advocacy**: Our hope is that the FHVA will provide a useful tool for local advocacy efforts and to prioritize equitable green infrastructure solutions for local communities in Milwaukee. Some organizations and agencies identified as potential targets, partners, and users of this tool are Reflo, Milwaukee Water Commons, Green and Healthy Schools, the Green Schools Consortium, Milwaukee Environmental Collaboration Office, Milwaukee's Metropolitan Sewerage District, and Wisconsin's Department of Health Services.

In addition, this project provides an opportunity to engage with the medical community by leveraging the overlap between extreme weather events and healthcare. The FHVA could support healthcare professionals to better understand the environment in which their patients live and what risks they face, subsequently improving anticipatory guidance. For instance, this project was co-developed in collaboration with the group Wisconsin Health Professionals for Climate Action, which may play a role in future dissemination efforts within healthcare providers. Public health education institutions such as the UW School of Medicine and Public Health, the UW-Milwaukee Zilber School of Public Health, and Aurora offer urban and public health education programs in which the FHVA would fit as a formative tool. Finally, the FHVA may contribute to the materials covered as part of the continuing education series held at Advocate Aurora, where a session for physicians, nursing staff, social workers, pharmacists and advanced practice clinicians will be organized to delve into the impacts of climate change on public health.

5

ASSUMPTIONS & LIMITATIONS

Assumptions & Limitations

Like any mapping approach, the development of Milwaukee's FHVA required navigating data and methodological limitations, as well as making assumptions that need to be acknowledged. These limitations do not necessarily undermine the validity of this study, but rather set its context and lay out potential pathways that may help address some of them.

First, the selection of vulnerability indicators under each category was influenced by the availability of suitable data. Several health metrics were discarded due to data gaps and needed to be replaced by other indicators. For example, the first indicator identified to represent vulnerability to respiratory illnesses was Age-Adjusted ER Rate due to Pediatric Asthma, but the indicator presented important gaps across the city of Milwaukee, prompting the selection of the indicator Age-Adjusted ER Rate due to Asthma. In addition, this indicator was available at the zip code level, and required being disaggregated. A simplistic approach was taken by using an areal-weighting process by which the ER-Rates for each census tract were calculated as a proportional average of the overlapping zip codes. This process, while straightforward, assumes a uniform distribution of the population within the areas of the zip codes and census tracts. A more realistic approach, which may be implemented in future iterations of the FHVA, would require setting up the weights of the disaggregation based on population or residential density rather than area.

Second, the indicators finally selected represent a small set of variables that are commonly used to track vulnerability to flooding and other natural hazards. However, several other variables were not considered in order to keep the indices simple and easy to interpret. Nevertheless, because flexibility was a key attribute prioritized during the development of the FHVA, the entire process that generates the different outputs of the FHVA has been scripted and is readily available to add / remove any indicators that might be deemed useful under specific circumstances (e.g. considering emergency response VS long term climate change adaptation) or that may become available with new data releases. A github repository is available upon request to examine the scripts and the technical documentation behind the FHVA, including further details on the sourced datasets. This github may also be useful for other cities and organizations interested in learning more about this process in order to replicate it in their locations.

Third, flood exposure incorporates the outcomes of a 1-hr, 100-year flooding simulation (a 3.03'' storm) carried out using the CityCAT model. This simulation, which was carried out at a ~30x30 feet resolution, considers the flow of surface runoff throughout Milwaukee while accounting for the processes of infiltration and friction caused by green areas. Drainage networks, which play a key role in the urban hydrology by assimilating and distributing stormwater, were not considered due to a lack of data and resources needed to set up and run a model of such complexity. Nevertheless, we chose to focus on a storm of such magnitude and intensity under the assumption that it can be expected that the drainage network of the city will be unable to manage such amounts of runoff, even if temporarily. This study, however, should not replace local efforts to map flood hazards considering a broader set of data and factors, nor should it be used as a stand-alone instrument to extract conclusions at the individual parcel level. To learn more about the simulations carried out during our study in Milwaukee, as well as some insights related to the distributional justice of flood risk in the city, click here. You may also learn more about some of our underlying methodological considerations in this brief report. To learn more about the CityCAT model, you may check this factsheet or this scientific publication that explains the model's functioning in detail.

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Contact us!

For inquiries about the project, you may contact Groundwork Milwaukee at young@groundworkmke.org and the Urban Systems Lab at urbansystemslab@newschool.edu.

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APPENDIX

Appendix A

TABLE 2: Data Sources for the Development of Milwaukee's Flood-Health Vulnerability Assessment

Indicator / Dataset	Resolution	Source	Comments
% Adults with Diabetes	Census Tract	Health Compass Milwaukee (datasets for 2019)	
% adults with poor mental health over last 14 days	Census Tract	Health Compass Milwaukee (datasets for 2019)	
Age-adjusted ER rate due to asthma	Zip Code	Health Compass Milwaukee (datasets for 2019)	Zip Code level data was disaggregated to census tracts using areal weighted interpolation
% Population with a Disability	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% Adults without a Health Insurance	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% Residents aged below 18 and above 65 years old	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% People with a salary below twice the federal poverty level	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% People aged above 25 years old without a high school diploma	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% of the population aged 5 and over unable to speak English	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% of residents self-identified as BIPOC	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
% Households without a car	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.

% Households composed of a single adult living alone	Census Tract	US Census Bureau, 5-year estimates for period 2015-2019	Data sourced from the American Community Survey was collected using R's package TidyCensus developed by K. Walker.
Residential units	Parcel level	Milwaukee's Master Property File 2021	
Roads		Milwaukee's Topo-Planimetric data, 2020.	
Riverine & Coastal Flooding		FEMA Map Service Center	Accessed on April 2022 via download of Wisconsin's National Flood Hazard Layer
Pluvial Flooding	30x30 feet	2-d hydrodynamic modeling	See methodology and limitations sections for an overview of the process to generate a pluvial flooding layer

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