Natural Infrastructure's Role in Mitigating Flooding Along the Upper Mississippi River

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About the Institute

The Northeast-Midwest Institute is a Washington, D.C.-based, nonprofit, nonpartisan public policy organization committed to economic vitality, environmental quality, and regional equity for the 18 states of the Northeast and Midwest. As a policy-focused institute with a 40-year track record of producing first-rate research, developing policy options, and building and supporting regional coalitions, the Institute has a unique standing in that it was founded in response to calls by the Congressional Northeast-Midwest Coalition for a stable and trusted source of regional data and research as well as policy options and analysis. It is precisely these roots and relationships on Capitol Hill which now position the Northeast-Midwest Institute to chart a future that encompasses an expanded agenda of critical regional issues and to embark on a strategy to achieve increased impact.

Introduction:

After the 2019 flooding events in the Upper Mississippi River basin, it has become clear that communities in that region need to reassess how they prepare for flooding. Traditional methods of flood management through *gray infrastructure*, such as levees or floodwalls, are helpful to the communities they protect but are being shown to exacerbate flooding in the region.[1] How then should communities prepare? An approach that is gaining recognition and support is *natural infrastructure*, otherwise known as *green infrastructure*. By utilizing natural methods of flood management, communities can protect themselves, reduce the risk of flooding for downstream neighbors, and improve environmental conditions in their area. This report will outline the threats faced by the Upper Mississippi region and the ways in which they can prepare.

Background:

Flooding impacts are on the rise around the world. In fact, 2019 was the costliest year for flood damages in U.S. history with total economic costs reaching nearly $24 billion.[2] These flooding impacts accounted for around 35% of all U.S. economic losses from natural disasters in 2019.[3] The flooding events throughout the Mississippi River basin, including the Missouri River basin, accounted for $20 billion of 2019 losses.[4] As flooding impacts get worse, due to climate change and increased population and development in flood-prone areas, communities throughout the Upper Mississippi River basin need to reevaluate their flood management strategies to prepare for this new normal. The year 2019 may be the worst year on record for flooding damages, but projections indicate that in years to come, the U.S. could face worse.[5]

The U.S. experiences five main types of flooding: riverine, coastal, storm surge, inland, and flash.[6]

- **Riverine flooding** occurs when water levels rise past the banks of the river into the surrounding floodplain.
- **Coastal flooding** is when coastal land is inundated by higher than average tides.
- **Storm surges** are large coastal inundation events caused by severe storms.
- **Inland flooding** occurs from abnormally high rates of precipitation duration or intensity.

[1] Munoz et al., "Climatic Control of Mississippi River Flood Hazard Amplified by River Engineering."
[2] "Weather, Climate & Catastrophe Insight: 2019 Annual Report."
[3] "Weather, Climate & Catastrophe Insight: 2019 Annual Report."
[4] "Weather, Climate & Catastrophe Insight: 2019 Annual Report."
[5] Mallakpour and Villarini, "The Changing Nature of Flooding across the Central United States."
[6] National Severe Storms Laboratory, "Severe Weather 101: Flood Types."

- **Flash flooding** is caused by excessive rainfall within a short period.[7]

Of these five types of flooding, the Upper Mississippi River Basin is subject to just three of the five types, specifically riverine, inland, and flash flooding. This report will focus primarily on riverine and inland flooding as these are the most common events that Upper Mississippi River basin communities face.

2019 Mississippi Basin Floods:

Communities along the Mississippi River have always had to deal with some form of seasonal flooding.[8] However, as climate change leads to increased levels of precipitation, communities along the Mississippi will be faced with more intense flooding over time.[9]

In 2019 the Mississippi River basin, including the Missouri River and Arkansas River, experienced the worst flooding events in recent history.[10] The flooding events left over 20 million acres of farmland throughout the region unusable and impacted nearly 14 million people.[11,12] By the time the waters receded in September of 2019, the flooding cost the nation an estimated $20 billion in damages and lost revenue.[13] In Iowa, Kansas, Missouri, and Nebraska, the federal government declared major disasters in 78% of counties, which makes them eligible for emergency federal aid from FEMA.[14]

In Iowa alone, flooding from the Missouri River inundated over 145,000 acres of farmland and caused roughly $2 billion in damages to the state's economy.[15] States where farming is a critical industry are significantly at risk of flooding impacts as farmland requires remediation after being flooded due to the sand and debris left behind after the waters recede.[16] This requires specialized equipment and time which delays farmers' ability to plant a new crop and increases costs.[17] Additionally, much of the damage is uninsured.

Of the $20 billion in economic losses the U.S. experienced from Mississippi River basin flooding in 2019, only $6.5 billion was insured loss.[18] This level of uninsured loss can be devastating to many communities and as such indicates both a need to expand flood

[7] National Severe Storms Laboratory.
[8] Winkler et al., "Climate Change in the Midwest A Synthesis Report for the National Climate Assessment."
[9] Winkler et al.
[10] Climate Nexus, "Mississippi River Basin Spring Flooding 2019."
[11] Ahmed, "Last Year's Historic Floods Ruined 20 Million Acres of Farmland."
[12] Almukhtar et al., "The Great Flood of 2019: A Complete Picture of a Slow-Motion Disaster."
[13] "Weather, Climate & Catastrophe Insight: 2019 Annual Report."
[14] Frank, "Army Corps Looks to Avoid Repeat of 2019 Midwest Floods."
[15] Eller, "Farm Losses Drive Iowa's Flood Damage to $2 Billion, Farm Bureau Economists Estimate."
[16] Eller.
[17] Eller.
[18] "Weather, Climate & Catastrophe Insight: 2019 Annual Report."

insurance protections but also to develop more comprehensive flood management strategies as this threat to the Upper Mississippi River states will not recede soon.

Flooding Impacts Projected to Increase:

Over the past fifty years, flooding in the Mississippi River basin has increased in both frequency and intensity.[19] The economic losses caused by flooding are also increasing.[20] Both the increase in flooding and flooding impacts are primarily the result of three major factors: climate change, population and urban growth, and ineffective flood management.

Climate Change:

Climate change is a major factor in the increased level of flooding in the Mississippi River Basin. As the climate warms, atmospheric moisture will increase as warmer temperatures produce faster rates of evaporation.[21] Throughout the past fifty years, the Upper Mississippi River Basin experienced both an increase in annual precipitation and a significant increase in spring precipitation.[22] Additionally, the magnitude of precipitation of heavy rain events has increased by 37% during the same period.[23] Combined, these factors have increased both the number of flooding events and their magnitude.[24,25,26]

While the past is not a perfect corollary of the future, climate change projections indicate that the pattern of the last fifty years will continue, bringing increases in precipitation throughout the region in winter, spring, and fall.[27] Likewise, the frequency and magnitude of heavy precipitation events are also projected to continue to increase.[28] As such, flooding will continue to become more frequent in the Upper Mississippi River basin.[29,30]

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[19] Frederick, "Precipitation Trends in the Mississippi River Watershed."
[20] University of Maryland Center for Disaster Resilience and Texas A&M University Center for Texas Beaches and Shores, "The Growing Threat of Urban Flooding: A National Challenge 2018."
[21] Winkler et al., "Climate Change in the Midwest A Synthesis Report for the National Climate Assessment."
[22] Frederick, "Precipitation Trends in the Mississippi River Watershed."
[23] Frederick.
[24] Frederick.
[25] Winkler et al., "Climate Change in the Midwest A Synthesis Report for the National Climate Assessment."
[26] Mallakpour and Villarini, "The Changing Nature of Flooding across the Central United States."
[27] Winkler et al., "Climate Change in the Midwest A Synthesis Report for the National Climate Assessment."
[28] Winkler et al.
[29] Winkler et al.
[30] "Climate Impacts Along the Mississippi River Corridor."

Population and Urban Growth:

While climate change explains some of the increase in flooding event frequency, the increase in economic losses from flooding comes more from population and urban growth. By continuing the development of flood-prone areas and moving populations into them, communities open themselves up to greater economic losses from flood events.[31] After all, a flooded riverfront business district will cost far more to remediate than a flooded park or wetland. Unfortunately, communities throughout the Upper Mississippi region continue to develop along riverfronts and in floodplains, increasing their own risk of economic loss and population displacement.[32]

Ineffective Flood Management:

A recent study has found that flooding in the Lower Mississippi River is intensified by the use of levees and other traditional infrastructure-based flood management methods.[33] While levees can be effective at protecting the community where they are located, they also have the effect of pushing floodwaters downriver, adding to the level of flooding that downriver communities will face.[34] The Mississippi River has 3,500 miles of levee systems.[35] While the US Army Corps of Engineers states that these levee systems protect "more than 4 million citizens, 1.5 million homes, 33,000 farms, and countless vital transportation routes," studies show that this extensive levee system, combined with other forms of river engineering, has led to a level of flood risk unprecedented in the last 500 years.[36] The study examined levees and other forms of river engineering such as 'revetments' – structures placed along a riverbank to reduce erosion – and 'cut-offs' – channels cut to avoid river bends and shorten travel distance – which also contributes to the flooding risk.[37] All of these methods have been shown to increase the speed of water flowing down the river, increasing the risk that flood waves will form and overtop the banks of the river or even levees protecting downriver communities.[38]

Largescale systems of levees and river engineering can exacerbate flooding risks. However, for many communities, levees can be necessary to protect areas that cannot be easily moved such as major pieces of infrastructure. For such levees to be effective, they need to be properly maintained. A recent report by the Environmental Law and Policy Center (ELPC) found that a high number of levees along the Upper Mississippi River are

[31] Opperman, "A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risks."
[32] Gowen, Sellers, and Williams, "Even as Floods Worsen, Midwest Towns Plan New Riverfront Development."
[33] Munoz et al., "Climatic Control of Mississippi River Flood Hazard Amplified by River Engineering."
[34] Opperman, "A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risks."
[35] "Levee Systems - Mississippi River and Tributaries'."
[36] Munoz et al., "Climatic Control of Mississippi River Flood Hazard Amplified by River Engineering."
[37] Munoz et al.
[38] Munoz et al.

at risk of failure.[39] Out of the levees surveyed, six were classified as having a "high-risk" of failure, twelve were classified as "moderate-risk," and an additional 60 levees were unable to be classified due to a lack of proper safety assessments.[40] The high-risk status of just those six levees puts a collective 1,854,718 people and a total of $31.18 billion worth of property in danger of flooding damages.[41] While the Army Corps of Engineers is working to repair many of these levees, almost 100 levees throughout the Midwest will remain unrepaired for up to two years.[42]

A Natural Alternative:

River systems in their natural state flood regularly. Before river engineering, rivers such as the Mississippi would disperse flood waters over large floodplains, both slowing the flow of the overloaded river and enriching the landscape.[43] River-floodplain systems are also incredibly important ecosystems.[44] However, through river engineering, river-floodplain systems have been altered in dramatic ways, changing flowrates, fragmenting ecosystems, and preventing natural cycles flooding which many species depend upon, resulting in freshwater species being endangered at greater rates than other species.[45]

While the disruption of these natural systems and cycles is detrimental to the environment, these same natural systems and cycles offer strategies to manage and mitigate the flooding risks to riverfront communities. Using such natural processes and natural features – such as vegetation and soils – is known as *natural infrastructure* or *green infrastructure*.[46,47] When applied to a larger area such as a city, this method takes the form of a series of green spaces such as parks or protected wetlands that provide benefits such as flood protection, wildlife habitats, cleaner air, and cleaner water.[48] Overall, the design philosophy of natural infrastructure is to work *with* natural processes as opposed to against them.

Natural Infrastructure for Riverine Flooding

When combatting riverine flooding, the purpose of natural infrastructure is to allow the rivers to follow their natural paths and when overloaded, spread those floodwaters into

[39] Learner and Tabet, "High Risk Levees along the Upper Mississippi River As Identified by the United States Army Corps of Engineers."
[40] Learner and Tabet.
[41] Learner and Tabet.
[42] Frank, "Dozens of Damaged Levees Won't Be Fixed by Flood Season -- Thursday, February 6, 2020 -- Www.Eenews.Net."
[43] Shader, "Making Room for Floods in the Midwest."
[44] Opperman, "A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risks."
[45] Opperman.
[46] Opperman.
[47] EPA, "Using Green Infrastructure to Mitigate Flooding in La Crosse, WI: Assessment of Climate Change Impacts and System-Wide Benefits."
[48] EPA.

floodplains and wetlands rather than into communities.[49] The Dutch, world leaders in flood mitigation, have adopted this strategy in the last decade and have coined it making "Room for the River."[50]

The Dutch have focused their efforts on a few major strategies that can serve as a great example for communities along the Mississippi River.

- Moving dikes further inland to enlarge floodplains
- Lower floodplains so that they can absorb more water
- Creating overflow areas that can be safely flooded to protect cities
- Opening side channels and tributaries that allow the river water to disperse[51]

These strategies and others have resulted in increasing the amount of water that the Rhine River can hold without flooding protection.[52]

In the U.S. similar strategies are being used. One of the most common strategies is the creation of overflow areas that are usually remediated wetlands or green spaces such as parks.[53] This is an incredibly effective strategy, as a single acre of wetland can hold up to 330,000 gallons of water.[54] Just this one acre of wetland could, therefore, protect 13 homes from thigh-high flooding.[55]

To assess this wetland/green space strategy at a larger scale, Resources for the Future examined the value of conserving the Meramec Greenway, a 9,000-acre conservation area made up of parks and forests in St. Louis County, Missouri.[56] They found that this conservation area provided the county around $13 million per year in avoided flood damages.[57] This amounts to a 38% reduction of damages when compared to a scenario without the Greenway.[58] Broken down to the acre, the team found a roughly $6,000 value per acre of green space.[59]

By removing the artificial restraints on river systems and allowing them to periodically flood into protected floodplains and green spaces, communities throughout the Mississippi River basin can protect their homes and prevent significant damages. Fortunately, decision-makers throughout the region are recognizing this value, as

[49] Shader, "Making Room for Floods in the Midwest."
[50] Cho, "Making Room for Rivers: A Different Approach to Flood Control."
[51] Cho.
[52] Cho.
[53] Blackmore, "A Better Way to Decrease Disastrous Flooding on the Mississippi River."
[54] Cho, "Making Room for Rivers: A Different Approach to Flood Control."
[55] Cho.
[56] Kousky, Walls, and Chu, "Flooding and Resilience: Valuing Conservation Investments in a World with Climate Change."
[57] Kousky, Walls, and Chu.
[58] Kousky, Walls, and Chu.
[59] Kousky, Walls, and Chu.

evidenced by a statement released by the 90 mayors of the Mississippi River Cities and Towns Initiative calling for more natural infrastructure to mitigate flooding.[60]

Natural Infrastructure for Inland Flooding

Inland flooding is primarily caused by extensive precipitation that can overwhelm a city's stormwater systems causing localized flooding events within a city.[61] As such the primary goal of natural infrastructure to mitigate inland flooding is to absorb as much of that precipitation as possible, slowing its path to stormwater systems.[62] Cities primarily use methods such as permeable pavement, rain gardens, and green roofs – roofs covered with a layer of soil and vegetation – as these methods allow precipitation to be soaked up and stored in soil and vegetation.[63]

As of 2005 more than 43,000 square miles of the U.S. were covered in pavement and other types of impervious surfaces.[64] By today that number is certainly larger as it's estimated that around a quarter of a million acres of land are paved or repaved each year.[65] This creates a massive issue as water runs off of these surfaces where previously that land had absorbed it.[66] Runoff from an acre of impervious surface can be up to 20 times greater than an acre of grass.[67] At a city scale, this can create a massive influx of water that can overwhelm stormwater systems and create flooding events in a city.

Milwaukee, WI created a program called GreenSeams to reduce sewer overflows by developing more natural infrastructure. In an analysis comparing this new natural infrastructure program to the city's traditional gray infrastructure, the Milwaukee Metropolitan Sewerage District found that the GreenSeams program areas can hold over 1.3 billion gallons of stormwater while the traditional flood management facilities could hold only 315 million gallons.[68] Not only was GreenSeams far more effective at flood management, but it was also extremely cost-effective.[69] Their analysis found that the GreenSeams program cost the city only $0.017 per gallon held, compared to the flood management facility which cost $0.31 per gallon.[70]

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[60] Blackmore, "A Better Way to Decrease Disastrous Flooding on the Mississippi River."
[61] EPA, "Using Green Infrastructure to Mitigate Flooding in La Crosse, WI: Assessment of Climate Change Impacts and System-Wide Benefits."
[62] EPA.
[63] EPA.
[64] Frazer, "Paving Paradise: The Peril of Impervious Surfaces."
[65] Frazer.
[66] Frazer.
[67] Frazer.
[68] American Rivers and Center for Neighborhood Technology, "The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits."
[69] American Rivers and Center for Neighborhood Technology.
[70] American Rivers and Center for Neighborhood Technology.

As the EPA website states, "Green infrastructure is a cost-effective and resilient approach to managing stormwater…"[71]

Davenport, IA, and Riverine Flood Management

The city of Davenport, Iowa sits directly on the Mississippi River. Unlike most cities along the river, Davenport has never built a permanent floodwall.[72] Rather Davenport uses a system of riverfront parks and wetlands to absorb floodwaters rather than rebuff them.[73] As Mayor Frank Klipsch notes, "Building a floodwall, a solid-structure floodwall, it pushes the problems downriver."[74]

Davenport has long dealt with flooding from the Mississippi River. Between 1964 and 2014, Davenport experienced almost 35 flood crests (river crests above 15 ft.).[75] The rate of flooding seems to be increasing, as between 2015 and 2019 there were 15 instances of flood crests.[76] This is an increase from an average of 0.7 flood events per year to 3 per year. As flooding rates have increased, Davenport has evolved its strategy for mitigation.

In the 1980s a plan was proposed to build a $34 million floodwall.[77] The plan was quickly defeated due to community love and pride of the city's waterfront which hosts sporting events, music festivals, and an extensive selection of local businesses. City officials such as Mayor Klipsch have made a goal of both mitigating floodings while maintaining an open riverfront.[78] This has been accomplished primarily with natural infrastructure.

A central pillar of Davenport's flood mitigation strategy is the expansion of green spaces along the river. In 1994, Davenport established its Flood Acquisition Program, intended to buy properties within the Mississippi floodplain.[79] In that year over 100 homes were removed, clearing areas to safely absorb floodwaters.[80] Since then Davenport has engaged in a series of efforts to expand green spaces through remediating and preserving the Nahant Marsh, expanding the city's riverfront parks, and even partnering with neighboring communities to collaborate on natural infrastructure efforts.[81] Through these efforts, Davenport has managed to make flooding, "more of an inconvenience than a disaster."[82] As flooding continues to increase in the region, the city

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71 EPA, "Soak Up the Rain: The Benefits of Green Infrastructure."
72 Blackmore, "A Better Way to Decrease Disastrous Flooding on the Mississippi River."
73 Blackmore.
74 Blackmore.
75 Public Works Administration, "Davenport's Historic Relationship with the Mississippi River."
76 Public Works Administration.
77 Blackmore, "A Better Way to Decrease Disastrous Flooding on the Mississippi River."
78 Blackmore.
79 Public Works Administration, "Davenport's Historic Relationship with the Mississippi River."
80 Public Works Administration.
81 Public Works Administration.
82 Public Works Administration.

plans to engage in a Mayor and Council Work Session in 2020 to discuss further flood risk reduction measures.[83]

La Crosse, WI and Inland Flood Management

La Crosse, Wisconsin has a drainage infrastructure that is very sensitive to heavy precipitation due to its flat topography and long pipe network.[84] Under heavy rain conditions, water overloads the drainage system and often backs up into low-lying areas of the city, creating small localized flooding events.[85] These floods, while not as devastating as cities that experience large-scale riverine flooding, create a constant source of property and infrastructure damage. As such the city has prioritized a series of natural infrastructure projects to increase flood resilience through its Green Complete Streets ordinance, passed in 2012.[86]

La Crosse has coined its chosen strategy of natural infrastructure *green streets*.[87] These green streets incorporate multiple interventions including permeable pavement, bioretention areas (similar to rain gardens), landscaped medians, street trees, and vegetated swales – shallow channels or ditches filled with vegetation to absorb water.[88] Generally, La Crosse designs these new streets so that on either side of the impervious pavement are either sections of permeable pavement or bioretention areas to capture all the runoff from the road, easing the stress on the drainage system.[89]

While La Crosse is still in the process of developing these green streets, the strategy is effective through an EPA evaluation. The purpose of the evaluation was to assess both the flood mitigation effectiveness and the cost-effectiveness of the various interventions, focusing on permeable pavement and bioretention areas, at various levels of implementation.[90] They find that fully implementing permeable pavement at all possible locations eliminated inland flooding from heavy rain events.[91] Bioretention areas were less effective but still able to eliminate 88% of flooding if fully implemented.[92] This shows that by just trading out impervious pavement for permeable surfaces, whether permeable pavement, rain gardens, or bioretention areas, inland flooding can be heavy if not fully remediated. La Crosse continues to expand its flood resilience efforts on an on-going basis.[93]

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[83] Public Works Administration.
[84] EPA, "Using Green Infrastructure to Mitigate Flooding in La Crosse, WI: Assessment of Climate Change Impacts and System-Wide Benefits."
[85] EPA.
[86] EPA.
[87] EPA.
[88] EPA.
[89] EPA.
[90] EPA.
[91] EPA.
[92] EPA.
[93] Lenz, "Phone Interview with La Crosse, WI Utilities Manager, Jan. 6."

Conclusion:

The Upper Mississippi River basin is experiencing greater flood risks with each passing decade. Climate change threatens to continue to increase the frequency and magnitude of flooding events. Growing population and urban development in flood-prone areas are putting more people and property at risk of flood damage. Additionally, our centuries-long attempt to engineer the Mississippi River into a mild commercial thoroughfare has instead exacerbated flooding impacts to their most extreme level in 500 years.[94] Rivers and flooding cycles are natural systems that need to be accounted for. Luckily, nature provides methods with which these risks can be managed more effectively and with less cost. Cities around the region, such as Davenport, IA, and La Crosse, WI, are already proving that natural infrastructure approaches to flood mitigation are a smarter long-term strategy than relying on traditional gray infrastructure. They are not only more effective at preventing riverine and in-land flooding, but they also provide a wealth of positive externalities including green spaces for communities to enjoy, wildlife habitats, cleaner air, and cleaner water. With such benefits in mind, it is time for the residents of the region at large to assess whether natural infrastructure is the best solution for their communities as well.

Suggestions for Further Research:

This report is meant as a synthesis of the flooding risks the Upper Mississippi Region experiences, the projections of flooding increase, and methods of flooding mitigation. While this report showcases the incredible research that has already been conducted on these issues, there are areas of interest that need further study. Below are listed a few:

- A cost/benefit analysis of the flood mitigation potential of a possible federal floodplain property buy-back program
- A study to estimate the area of protected wetlands theoretically necessary to mitigate flooding throughout the Upper Mississippi River basin as well as a mapping effort to identify potential locations for remediated wetlands
- A city-by-city analysis of flood mitigation strategies to develop a best practices roadmap for cities throughout the region to use
- Evaluation of federal programs supporting flood mitigation efforts to determine the gap between available support and state/local need

[94] Munoz et al., "Climatic Control of Mississippi River Flood Hazard Amplified by River Engineering."

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