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REIMAGINING THE UNIMAGINABLE

THE AUGUST 2018 PHEASANT BRANCH FLOODING IN MIDDLETON, WI

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Dear Reader,

The Department of Planning and Landscape Architecture at University of Wisconsin-Madison is pleased to share this report from our Spring 2019 special topics course focused on resilience and recovery planning for the Pheasant Branch corridor. This project exemplifies the department's commitment to applied, community-engaged learning and service, reflecting UW-Madison's broader commitment to the Wisconsin Idea. On behalf of our department, I hope the work completed by Dr. Sledge and these thirteen students helps the City of Middleton and its many friends and partners to move forward from the 2018 flooding disaster with a clear sense of possibilities and community vision around the Pheasant Branch corridor. We appreciate this opportunity to be part of Middleton's recovery planning, and we owe a special thanks to the many staff and community members who shared their time and perspectives with the class.

Dr. Ken Genskow, Professor and Department Chair

The Wisconsin Idea

One pillar of the University of Wisconsin is the Wisconsin Idea: that all the endeavors at the University of Wisconsin–Madison should bring a positive impact to the community, the nation, and the world. The University of Wisconsin has extension offices across the state to assist communities in a variety of ways. While the City of Middleton is significantly closer to a University of Wisconsin campus than many communities, the Wisconsin Idea encourages collaboration regardless of distance. Through service-learning opportunities, community-based research, and partnerships with local organizations, the University of Wisconsin–Madison is committed to public service.

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Executive Summary

The following report is the product of Designing for Resilience: Reimagining the Unimaginable, a graduate-level course from the University of Wisconsin–Madison Department of Planning and Landscape Architecture. This material is presented with the understanding that additional engineering and professional work will be required to verify and expand upon the findings and recommendations within this report.

On August 20th, 2018, the City of Middleton experienced a flood event as a result of a historic rainfall of 11.63 inches in a 24-hour period. The flooding of Pheasant Branch inflicted significant damage to the Pheasant Branch creek corridor and the buildings surrounding the confluence pond west of US Highway 12. The historic rainfall also caused the flooding of residential homes, Esser Pond, and Tiedeman's Pond.

This report addresses the flooding along the Pheasant Branch storm water corridor (creek corridor).

Our intent herein is to explore the nature of the Pheasant Branch watershed and how the community can recover from the August event and mitigate future events. The report is arranged into four separate but interconnected sections:

I. ***Adapting Urban Infrastructure*** identifies local ordinances and infrastructure practices that could help the City of Middleton better accommodate increased water flow and protect public health and safety. Based on flood models generated by the Federal Emergency Management Agency, the currently federally recognized floodplain in Middleton is significantly smaller than the recorded flooding from the August 20th event. To ensure that businesses and residential areas remain resilient to future flood events, we recommend establishing a Floodplain Overlay Zoning district that expands the amount of land protected by floodfringe ordinances. In addition to the new zoning, current ordinances should be updated to reflect the threats to public safety caused by the flood event. We also propose infrastructure practices for businesses, residents, and future development that are designed to ease burdens on urban stormwater management systems.

II. ***Restoring and Recovering Vegetation*** provides guidelines for replanting efforts along the Pheasant Branch storm water corridor. Shortly after the August flood event, the City of Middleton contracted with Cardno to assess the extent of the damage along the Pheasant Branch creek corridor. From the results of the Cardno erosion analysis, we recommend the corridor be replanted with vegetation from emergent marsh and sedge meadow habitats to ensure the vegetation is both successful in securing the stream bank and resilient to future flood events.

III. ***Building a Community for Resilience*** encourages the City of Middleton and the Middleton community to be more proactive in disaster readiness. The 2018-2023 Conservancy Lands Plan and demographic information for the area around the Pheasant Branch creek corridor both

indicate a need for the City of Middleton to establish more effective communication with traditionally underrepresented populations. We recommend the City of Middleton forms a community of practice for the Pheasant Branch creek corridor. We additionally recommend the City of Middleton utilize our tools to engage with Pheasant Branch stakeholders during future restoration efforts.

IV. ***Managing the Pheasant Branch Watershed*** assesses areas on the fringes of Middleton and surrounding municipalities to suggest locations for future water management opportunities. We sought to identify successful strategies of slowing peak flow rates during severe precipitation events; areas in the Pheasant Branch watershed that have water storage capacity to reduce runoff; land use plans for urbanization and agriculture in the watershed; and funding programs to assist in land acquisition and wetland restoration. We conducted Geographic Information Systems (GIS) analyses to identify potential storm water storage areas and potential storm water mitigation areas within the Pheasant Branch watershed. From these analyses, we recommend the identified land which could be acquired and repurposed into land suitable for mitigating downstream flooding.

The recommendations made herein are our own and do not necessarily reflect the views of the agencies and individuals consulted in preparation of this report.

We welcome your critical feedback and we are available for future discussion.

This report was designed to be viewed in electronic format.

Print versions may not display maps and images with sufficient resolution or clarity.

Overview of Recommendations

I. Adapting Urban Infrastructure

- Implement a Flood Overlay Zoning District in the areas around the business park, confluence pond, and Esser Pond
- Require all structures within Flood Overlay Zoning District to maintain flood insurance, emergency response plans, and business continuity plans
- Identify all potential sources of hazardous materials and perform adequate soil and water quality tests to identify risks throughout the watershed
- Apply updated floodfringe city ordinances to the Flood Overlay Zoning District
- Install curbside rain gardens and green roofs and provide incentives to encourage private property owners to construct them
- Provide information to residents about retrofitting residential buildings to increase flood resiliency
- Establish pocket green spaces in lower-lying areas of the city with good drainage
- Include impervious surfaces, subsurface water storage, floating streets, and water lanes in future road work projects

II. Restoring and Recovering Vegetation

- Adjust creek corridor vegetation based on two distinct topographical sections
- Utilize planting guide to restore native plants to the creek corridor and increase habitat resiliency
- Implement recommended action steps to recover lost habitat along the creek corridor

III. Building a Community for Resilience

- Establish a Community of Practice (CoP) to develop a long-term vision for accommodating a wide range of users of the creek corridor
- Develop a Pheasant Brach Restoration Communication Plan

IV. Managing the Pheasant Branch Watershed

- Conduct field studies and monitoring to confirm watershed analysis
- Prioritize areas for restoration and conservation in the engineering analysis
- Consider engineered water storage practices to augment existing watershed conditions
- Develop more advanced methods and models for storm water volume estimations
- Protect identified flood mitigation and water storage areas
- Include the protection of water storage and flood mitigation areas in the Intergovernmental Agreement with the Town of Springfield

Acknowledgements

This section of the report is to extend appreciation and thanks to all the individuals who set aside time to assist in developing this report. From presentations in the classroom to meetings in Middleton and abroad, the knowledge and resources provided by these individuals made this report possible.

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Introduction

A Brief History of Pheasant Branch

Historic flooding in the Pheasant Branch watershed occurred on August 20th that significantly altered the creek corridor landscape. The flooding on August 20th occurred as a result of a series of decisions that find their origin in the 1800s. Before Middleton was established, marshland and prairie dominated the area west of Lake Mendota. Pheasant Branch at that time flowed out of a glacial lake and the springs in the Pheasant Branch Conservancy. The current north and south watersheds were not part of the Pheasant Branch watershed. Settlers drained the marshland and prairies to access peat deposits and to cultivate for agriculture. By building the north and south fork channels, the settlers expanded the Pheasant Branch watershed and increased the amount of water that regularly flowed through the creek. Today, the Pheasant Branch watershed is estimated to be about 10-times larger than its original, pre-settlement size (Garn, 2017).

As Middleton grew, the community adjusted to meet changing demands. A sanitary sewage line was installed along the corridor and a nearby landfill was converted into more usable land. In the 1980s, the growing Middleton community actively sought economic growth. The City expanded westward, establishing business and industrial parks near the now-empty peat deposits. In 2012, the City built the confluence pond into Pheasant Branch with the hopes of accommodating water flowing off the large parking lots nearby.

Before the flood and still today, the corridor experienced heavy recreational use. The trail in the creek corridor connects to the trail system within the Pheasant Branch Conservancy and crosses several major roads in Middleton, making the trail easily accessible to a broad variety of users. The creek corridor is also the primary means for water within the Pheasant Branch watershed to flow into the Conservancy, which flows into Lake Mendota.

The August Flood

On August 20th, 2018, the City of Middleton experienced a flood event as a result of a changing climate that produced a historic rainfall of 11.63 inches in a 24-hour period. The rainfall amount came close to setting a record for the State of Wisconsin, and at the peak of the storm, rain was falling at 2 to 4 inches per hour (Johnson and Jones, 2018). The Pheasant Branch's north and south branches flooded their banks, as did Tiedeman's and Esser Ponds. Other areas of the city saw flooding from stormwater accumulation and from groundwater that seeped into basements. Businesses, mostly west of the Beltline (US Highway 12), accumulated over $35 million in flood damages. Residential areas experienced at least $4.7 million in damage. Public sector damage totaled over $7 million, most of which was damage to the creek corridor from erosion, sedimentation, and damage to bridges and pathways in recreational areas.

A Call to Action

Following the August flood event, Shawn Stauske, Mark Wegner, and Matt Amundson from the City of Middleton met with research scientist Jeff Sledge and professors Ken Potter, Ken Genskow, Kurt Paulsen, and John Harrington from UW-Madison. The City of Middleton expected to focus on planning and design in 2019 and then implement the plans and designs contracted through the City's Request for Proposal (RFP) process in 2020. The Department of Planning and Landscape Architecture created the course URPL 590: Designing for Resilience as an opportunity for the City of Middleton and students in the Department of Planning and Landscape Architecture to mutually benefit from the educational and research opportunities arising from the flood.

Entering A New Normal

Engineering standards codified in policy are based on a reality that no longer exists. The forces behind the August flood event are expected to continue. Weather and climate trends indicate that weather-related hazards will continue to increase both in frequency and in severity. In order to best prepare for the future, communities need to begin to adopt standards where events such as the August flood are the new normal.

Choosing to follow traditional standards of practice will place Middleton at increasing economic and social risks. Businesses that experience repeated flooding damage will likely leave the area, creating losses in both local jobs and taxes. Flooding typically affects low-income neighborhoods in more significant ways than in other neighborhoods. Repeated flood damage in residential areas prevents individuals from recovering and preparing for the future, hampering Middleton's quality of life.

To ensure that Middleton remains a sought-after place to live and also a business-friendly community, we recommend that new engineering standards and environmental practices be codified to reflect a changed environment.

Project Context

Scope of the Project

This report is restricted to the hydrologic flows coming from the north and south forks of Pheasant Branch through the Pheasant Branch stormwater corridor. Our focus was on the flood effects; analyzing potential for water storage and control through watershed management, policy, infrastructure, and vegetation; and methods of communication to better prepare Middleton for a future where extreme weather events are increasing in frequency and intensity.

Project Constraints

Time

The Designing for Resilience course began in January 2019 and concluded in May 2019. The following report is based on the request from the City of Middleton Department of Public Lands, Recreation and Forestry to assess the Pheasant Branch corridor within the timeframe of the course.

Resources

We would like to extend our thanks to organizations who generously provided their resources and time in supporting this project. The City of Middleton staff, Friends of Pheasant Branch Conservancy, staff at Cardno, Wisconsin Emergency Management, Dane County Emergency Management, and many others have been very accommodating.

I. Adapting Urban Infrastructure

This section of the report presents actions the City of Middleton can take to update its current floodplain maps, its floodplain and stormwater ordinances, and its urban infrastructure in order to live with increased water flow invariability instead of fighting a losing battle against it. We recommend the following:

- Implement a Flood Overlay Zoning District in the areas around the business park, confluence pond, and Esser Pond
- Require all structures within Flood Overlay Zoning District to maintain flood insurance, emergency response plans, and business continuity plans and link those plans to the current emergency response infrastructure
- Identify all potential sources of hazardous materials and perform adequate soil and water quality tests to identify and quantify impacts
- Apply updated floodfringe city ordinances to the Flood Overlay Zoning District
- Install curbside rain gardens and green roofs and provide incentives to encourage private property owners to construct them
- Provide information to residents about retrofitting residential buildings to increase flood resiliency
- Establish pocket green spaces in lower-lying areas of the city with good drainage
- Include impervious surfaces, subsurface water storage, floating streets, and water lanes in future road work projects

Current Urban Water Infrastructure in Middleton

The City of Middleton made significant investments in flood management infrastructure in recent years, but it did not contain this 1,000-year flood. The city currently uses water retention ponds, culverts, a limited pumping system, and the natural wetlands of Pheasant Branch Conservancy to control flooding. In the August flood event, the wetlands effectively slowed the water and allowed for infiltration and drainage. However, the confluence pond spilled into surrounding businesses, Esser Pond flooded, and Tiedeman Pond's conveyance system could not pump faster than the rainfall.

Based on historic rainfall numbers and flood maps from the Federal Emergency Management Agency (FEMA) and the Wisconsin Department of Natural Resources (DNR), the infrastructure investments made by the City of Middleton might have managed a 500-year flood, but the city was unprepared for the historic August 20th rainfall. According to the Environmental Protection Agency (EPA), average annual participation in the Midwest has increased 5-10% over the last 50 years, but the amount of rainfall on the four wettest days of the year has increased by 35% (United States Environmental Protection Agency, 2016). These trends are expected to continue.

Wisconsin should expect more extreme rainfall events and an increased risk of flooding. Middleton is likely to experience more extreme flooding events than the August 2018 event in the future. Dane County received 15 Presidential disaster declarations between 1976 and 2016, amounting to roughly one every three years (Dane County Emergency Management, 2017). The subsequent declaration after

this August event fits this trend and climate change will likely accelerate this pattern. The City should prepare its infrastructure and its population for the effects of climate change on the environment.

FEMA's Flood Insurance Rate Maps (FIRMs) are based on hydrologic and hydraulic studies of watersheds that determine ground elevations, floodwater depth, width of floodplains, amount of water carried during flood events, and obstructions to the flow of water (FEMA, 2017). FIRMs have enormous power over the development patterns of a city because these maps determine who is required to purchase flood insurance and who must follow building requirements for floodplain development. While these maps are highly technical, they have many limitations. FEMA's maps are often outdated due to the time it takes to update these maps. Almost two-thirds of communities have FEMA maps that are more than 5 years old (Keller et al, 2017). Middleton's FIRM was last updated in 2014 and if Middleton updated its FIRM to the most recent date, concerns remain regarding it reliability because the map does not account for rapid rain accumulation, climate change, building construction, or population growth. According to the Department of Homeland Security, only 42% of FEMA's maps "adequately identified the level of flood risk" for a community (Kelly, 2017).

FEMA's maps are based on historical data and do not analyze trends or make predictions about future weather events (Skibba, 2017). Therefore, cities should not rely on FIRMs as predictive planning tools in adapting infrastructure for a rapidly changing climate. FEMA hazard mapping does not consider a city's ability to drain heavy rainfall as it accumulates. Flooding from stormwater is exacerbated by development and impervious surfaces, as well as by inadequate stormwater routing and storage infrastructure. Areas of the city that flood as a result of rapid rainfall accumulation, inadequate drainage, and groundwater seepage would not be demarcated on even the most updated FEMA maps.

Figure 1: Hazus model for 35000 CFS discharge (August 2018 Event)

Figure 1 is an attempt to recreate the August flood event and Figure 2 is a modeling for a more extreme event using FEMA's hazard mapping GIS software, *Hazus*. The models still did not show the extent of flooding that actually occurred during the August flood event, indicating that much of the flooding was likely due to rapid stormwater accumulation. To accommodate for future events, Middleton needs additional drainage and storage.

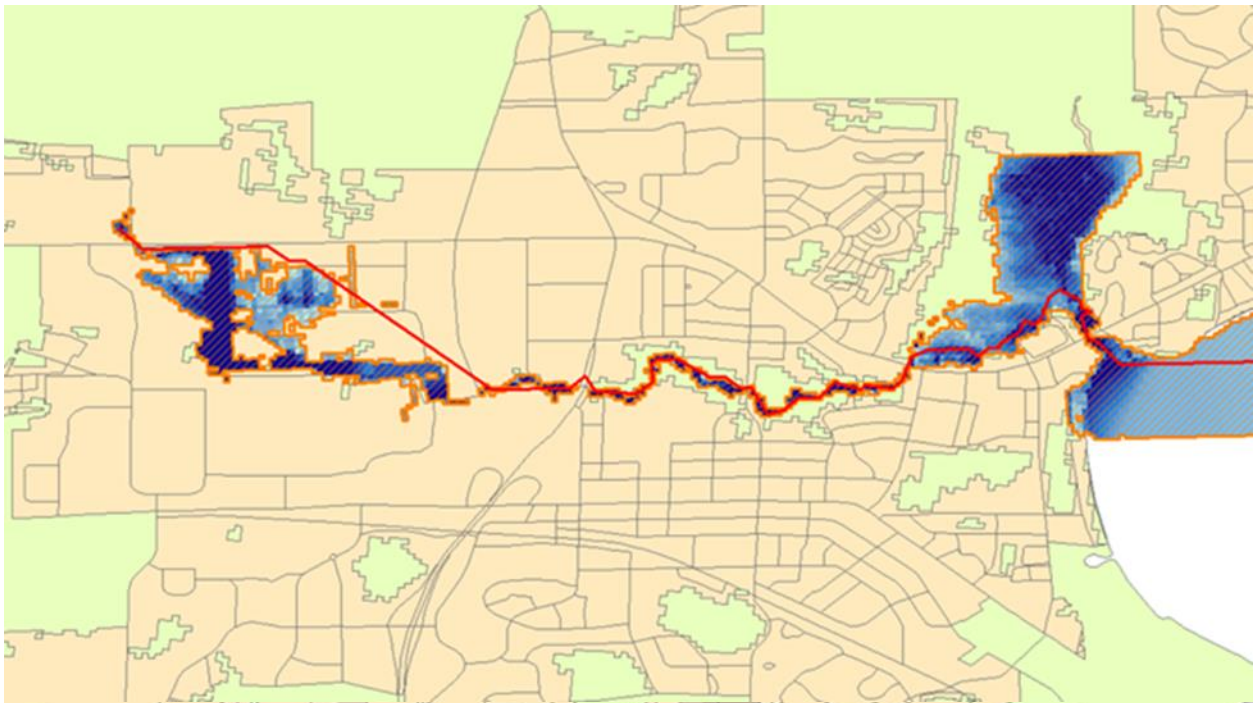

Figure 2: Hazus model for 5000 CFS discharge (1.5x larger than August 2018 event)

These models do not contain the specificity necessary for actual floodplain mapping, but they suggest of how much flooding can be mitigated by adjusting floodplain maps and ordinances according to stormwater management solutions. The figures show that flooding directly along the creek corridor, in the Pheasant Branch Conservancy, and partially around the confluence pond can be attributed to riverine flooding. However, stormwater and groundwater, which would not be addressed by an alteration to the Middleton FIRM, likely contribute to much of the flooding in residential areas and some flooding in the business park.

To ensure Middleton's urban infrastructure is resilient to future flood events, the City should consider establishing a Floodplain Overlay zoning district that encompasses key business park territory surrounding the confluence pond and Esser Pond, updating floodfringe ordinances and uniformly apply such ordinances throughout the proposed Floodplain Overlay zoning district, and integrating water management systems that slow, store, and drain stormwater.

Establishing a Floodplain Overlay Zoning District

Pursuant to section 24.02 of the City of Middleton Flood Plain Zoning Ordinance which states,

> "Other Floodplain Districts may be established under the ordinance and reflected on the Floodplain Zoning Map"

The creation of a Floodplain Overlay Zoning District encompassing key business park territory surrounding the Confluence Pond and Esser Pond just west of Highway 12 is recommended. This new proposed district would be created with the intent to protect watershed downstream of the district from contaminants and would require businesses to adopt practices aimed at increasing safety and reducing financial losses. Figure 3 indicates the boundaries of the proposed Floodplain Overlay Zoning District.

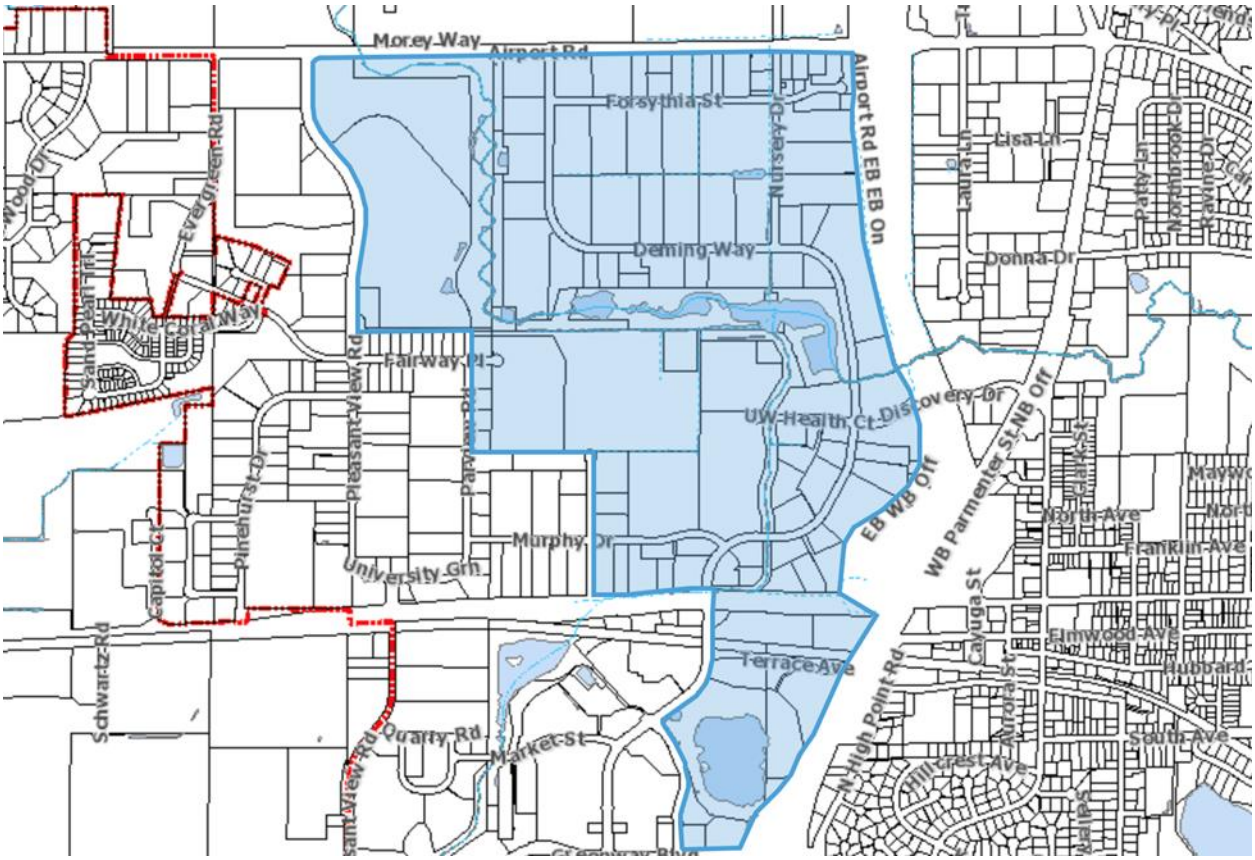

Figure 3: Boundaries of proposed Floodplain Overlay Zoning District

Overlay zoning for floodplain management encompasses only areas affected at the regional flood level. We recommend that the floodplain overlay zoning district includes areas outside the traditionally designated floodplain. The proposed district overlays existing planned development districts (both general and specific), an agricultural district, an industrial district and a conservancy lowlands district. The proposed area includes 77 structures on 102 parcels; of which, 16 parcels are owned by the City of Middleton, three by the Wisconsin Department of Transportation, and 83 are privately owned.

The regulated floodplain immediately surrounding the confluence pond and the section of creek located in this proposed district is at high risk of flooding based on its "Zone AE" designation on the City of Middleton FIRM map (Appendix A). Effective in October 2016, City of Middleton secured a Letter of Map Revision from FEMA, altering the floodplain map and effectively removing much of the developed land from Zone AE. These removed areas are also locations that experienced major flood damage in the August flood event.

A soil analysis map from the 2016 Middleton Comprehensive Plan indicates that much of the area in the proposed overlay district has "very poor" soil for construction of basement structures (Appendix B). In addition, an open space map from the same comprehensive plan indicates this area as conservancy and environmental corridor lands (Appendix C). The creation of the confluence pond in 2012 and the transformation in land use from open space to commercial benefited the city economically and protected downstream waters from sediment deposits. However, from the aftermath of the August flood to the trends for more severe storms, implementation of an overlay district may be necessary to further protect an already vulnerable area.

Risk Projections

The regional flood boundaries established by FEMA indicate a specific level of risk based on past and present conditions at the time of creation. In practice, however, floodplain constantly change due to development, rainfall patterns, stream conditions, vegetation alterations and stormwater management practices. According to the Wisconsin Initiative on Climate Change Impacts, Dane County has received a precipitation increase between 4.5 and 7 inches between 1950 and 2006 (Dane County Emergency Management, 2017), some of the largest levels in the state. Heavy precipitation events, rainfall of at least two inches in a 24-hour period, are projected to increase by roughly 25% by 2055. These heavier rainfall events and increased overall precipitation, combined with average temperature projections which anticipate a rise between 6-7° Fahrenheit by 2050, suggest the current regional flood maps and standards are likely inadequate.

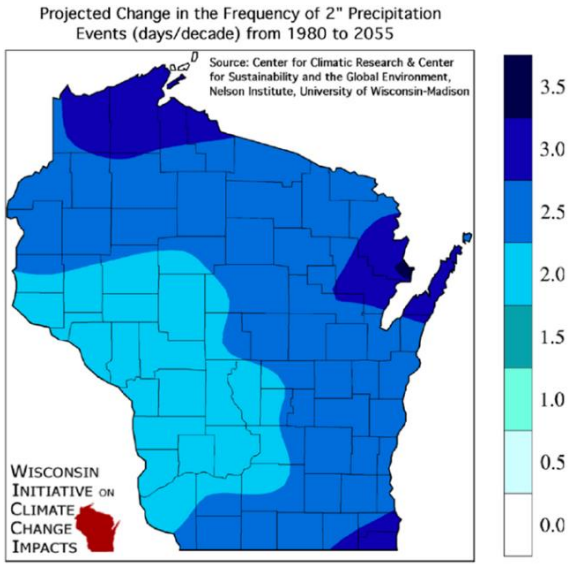

Figure 4: Projected change in Wisconsin precipitation

Urban Water Management Policies

Plan Consistency and Feasibility

The prospect of implementing overlay zoning for flood management comes with concerns over potential legal challenges and pushback from affected businesses and property owners. To preempt prevoking lawsuits under spot zoning or regulatory takings challenges, the proposed zoning must be consistent with, and further the goals and objectives of, Middleton's Comprehensive Plan (Wisc. Stat. § 66.1001 (3)(k)). In addition, clear and equally reciprocal public benefit must be demonstrated along with well-reasoned justification for implementation.

The City of Middleton's Comprehensive Plan has several goals, objectives and policies indicating strong support for floodplain management and environmental preservation. Chapter 7 of the Comprehensive Plan, which discusses dealing with agricultural, natural and cultural resources, includes the objective:

> Acquire for public use or preserve by other means lands that are environmentally sensitive, lands with access to water, and lands with historically significant areas. Environmentally sensitive lands include floodplain, wetlands, steep slopes, and wooded areas. Additional public access to Lake Mendota is desirable.

The proposed overlay zone is a method of "preserv[ing] by other means lands that are environmentally sensitive … includ[ing] floodplain…" and furthers this aspect of the comprehensive plan. Two other objectives in Chapter 7 also show the proposed zone to be consistent:

> Guide design, development and site selection of all types of development to minimize potential adverse impacts on the integrity of land and quality of ground and surface waters.

> Preserve the role of wetlands and woodlands as essential components of the hydrologic system and valuable wildlife habitat. Protect shoreland and floodplain areas accordingly.

Effectively informing and building consensus with affected businesses and impacted members of the general public is a critical component of successfully implementing the additional regulations. Great pains have been taken by the City of Middleton to attract and retain the commercial establishments consolidated in the pertinent area which have contributed to one of the most successful tax incremental financing (TIF) districts in the state. In order to avoid jeopardizing this pattern of growth, equally great pains must be taken to educate businesses and the public alike on the collective benefits of stricter flood disaster management.

Specific ordinance requirements will be discussed in the following sections, but in engaging with business and property owners in the affected area it should be noted that proposed insurance requirements, construction requirements and emergency plan requirements aim to reduce economic losses in the event of similar future flooding events. Provisions for non-conforming structures, which comprise nearly the entirety of the proposed overlay zone, and processes for securing special exemptions should also be made clear in the public engagement phase.

Floodplain Ordinance Best Practices and Recommendations

Currently, the city's floodplain zones cover a very minimal area along the Pheasant Branch creek corridor and consist primarily of Floodway District (FW) with minimal Floodfringe District (FF). Ordinances governing FW are extremely restrictive, prohibiting most forms of development and activities, and they are in line with nationally recommended best practices for floodplain zoning. The FF ordinances are significantly less restrictive. Considering there are very few, if any, structures within the FW or FF districts, these ordinances have been adequate. Given the potential for floodplain expansion in future FEMA mapping endeavors, the City of Middleton should consider a series of updates to Middleton's flood fringe ordinances. In addition, these recommended ordinances should be applied uniformly throughout the proposed flood management overlay zone.

Insurance Requirements

Businesses and residents within the floodplain overlay zoning district shall be required to hold flood insurance for the structures on their property. The City of Middleton participates in FEMA's Community Rating System, a voluntary system that incentivizes communities to implement more stringent flood management than minimum National Flood Insurance Program (NFIP) requirements and has achieved the highest community class level of 10. This rating means that Middleton residents and businesses are eligible for significantly reduced insurance premiums with discounts of up to 45% (Federal Emergency Management Agency, 2019). According to Chris Hubbuch of the Wisconsin State Journal (2018), only 2% of the $78 million in damage in Dane County was covered by insurance and commercial establishments in Middleton incurred $35 million. Of that total these significant financial losses could be substantially reduced through a more widespread adoption of flood insurance.

Emergency and Business Continuity Plan Requirements

To ensure the safety of individuals who may be present at places of business during a disaster and to facilitate effective communication between businesses and emergency assistance agencies, all commercial establishments shall be required to maintain a comprehensive emergency response and business continuity plan. According to a 2007 disaster impact report by HP and SCORE, three quarters of businesses without a continuity plan fail within a three-year period of a disaster event (Hewlett-Packard Development Company, 2007). FEMA and the Department of Homeland Security offer free resources to assist businesses in developing these plans and acknowledge their benefits to businesses, the general public and disaster response groups.

Storage of Hazardous Materials

The storage of hazardous materials and the maintaining of contaminant-free floodplain are critical components of this ordinance proposal. Currently, the city Floodfringe ordinances require that "materials that are buoyant, flammable, explosive, or injurious to property, water quality or human, animal, plant, fish or aquatic life shall be stored at or above the flood protection elevation or floodproofed" and that "adequate measures shall be taken to ensure that such materials will not enter the water body during flooding". Flood protection elevation is a standard of elevation two feet above the calculated flood level.

Floodproofing requires certification by a registered professional engineer or architect, as well as a floodproofing certificate from FEMA, and must meet the following characteristics:

- A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding
- The bottom of all openings shall be no higher than one foot above grade
- Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters (Flood Plain Zoning Ordinance, 2016.)

The ordinances lay out several requirements for sufficient floodproofing including:

- Must be designed to withstand flood pressures, depths, velocities, uplift and impact forces and other regional flood factors
- Must protect structures to the flood protection elevation
- Must anchor structures to foundations to resist flotation and lateral movement
- Must minimize or eliminate infiltration of flood waters and minimize or eliminate discharges into flood waters.

Recommendation 1: Post-Flood Contaminant Testing

It is essential to public health and safety that Middleton identify all possible sources of hazardous materials and test soil and water quality around these sources. We recommend further testing in and around the business park and confluence pond.

Several existing businesses in the proposed floodplain overlay zoning district utilize hazardous materials in manufacturing or production activities, and experienced extensive flooding damage during the August event. As an example, one business experienced nearly $600,000 of flood damage and is listed on the Federal Environmental Protection Agency's Toxics Release Inventory for its use of lead and lead components (EPA, 2019). The EPA also identifies that this facility in Middleton handles hazardous waste for that business. Standard Imaging also utilizes potentially hazardous materials and experienced extensive flood damage. These companies are currently not required to abide by any floodplain regulations around the storage of hazardous materials because their facilities are outside boundaries of current floodplain zoning.

At the time of this report, the City of Middleton has yet to conduct soil or water quality testing around the business park in areas that may have been exposed to hazardous materials like lead and waste. True North conducted the only testing since the flood event, completing two soil samples and two water samples near the old landfill dump as contracted by the City of Middleton. These tests returned negative results for volatile organic chemicals (VOC's), but this scope of testing is insufficient to determine if hazardous material exposure occurred in other areas of the watershed during the flood event.

If any hazardous materials are found to be present in soil or water, the city should pursue measures to abate the danger to public health and safety, up to and including dredging the creek bed and transporting hazardous materials to a safe landfill.

Based on the risk of hazardous material exposure around the confluence pond, we recommend additional engineering advise be sought to determine the density and depth of sampling to ensure public health and safety.

Recommendation 2: Hazardous Materials Storage Regulations in Proposed Overlay District

The City of Middleton has demonstrated a commitment to following national best practices for public health and safety. Instituting a ban of storing and processing hazardous materials within the proposed overlay district and any floodplain zones would continue to follow national best practice.

Structures like the Rockwell Automation's building should give the city pause as they consider how to proceed in preparation for future flood events. The Association of State Floodplain Managers now recommends that the following language be included in "Prohibited Uses" for all floodplain zones to protect the health and safety of residents:

> A. Storage or processing of materials that are hazardous, flammable, or explosive in the identified special flood hazard area.
>
> B. Storage of material or equipment that, in time of flooding, could become buoyant and pose an obstruction to flow in identified floodway areas.
>
> C. Storage of material or equipment not otherwise prohibited shall be firmly anchored to prevent flotation (Turner et al, 2017).

This best practice language bars the storage or processing of hazardous materials within any flood districts, which would include both any expansion of the floodplain and the proposed Flood Overlay District. This ordinance change would require companies like Rockwell Automation and Standard Imaging that use or store hazardous materials to move their storage and processing of hazardous materials off-site, which could be a major barrier to their regular business activities.

We advise the City of Middleton to engage in the often-difficult conversation on the tradeoffs between the health and safety of residents and economic development. Middleton has been extremely successful in attracting businesses to the area, and their provision of jobs and economic stability are important to maintain. The city could also consider grandfathering in existing structures or regulating them under the current FF District hazardous material storage ordinances, but these more permissive approaches may be risky should Middleton experience another massive flood event.

Recommendation 3: Landfill Cleanup and Dumping Ban

The City should also ban dumping of any kind within all floodplain zones and should clean up the existing landfill. Current landfills require a layer of impervious compacted clay overlaid by a high-density polyethylene geomembrane. This method prevents the escape of solid waste. The landfill eroded by the August flood event is not up to these modern standards and is releasing plastic, glass, old tires, and other trash into the surrounding area. The City currently plans to cap the landfill, but unless this landfill is opened and cleaned out, a chance remains that the landfill will continue to release trash in the future.

To prevent this problem from worsening, the city should ban dumping of any kind and locate on-site waste disposal systems to avoid impairment of them or contamination by them during flood events.

Recommendation 4: Gas and Liquid Storage

Another critical update is regarding gas and liquid storage tanks. While the City's ordinances currently include gas and liquid storage tanks in its definition of "structure", it is helpful to differentiate these potentially hazard structures from other structures such as bridges and culverts that do not pose the same potential hazard to health and human safety. The City of Middleton should treat gas and liquid storage separate from "structures". Adopting regulatory language similar to Maryland's model floodplain ordinances and applying uniformly in floodplain zoning and the proposed overlay district is recommended. Maryland's model floodplain ordinances phrase the regulation this way:

> Gas or Liquid Storage Tanks
>
> (A) Underground tanks in flood hazard areas shall be anchored to prevent flotation, collapse or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the base flood.
>
> (B) Above-ground tanks in flood hazard areas shall be anchored to a supporting structure and elevated to or above the base flood elevation, or shall be anchored or otherwise designed and constructed to prevent flotation, collapse, or lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, during conditions of the base flood.
>
> (C) In flood hazard areas, tank inlets, fill openings, outlets and vents shall be:
>
> (1) At or above the base flood elevation or fitted with covers designed to prevent the inflow of floodwater or outflow of the contents of the tanks during conditions of the base flood; and
>
> 2) Anchored to prevent lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, during conditions of the base flood (Turner et al, 2017).

Sanitary Sewage

During heavy rainfall events, sewer systems take on an immense amount of water. In cities with combined water and sanitary sewer systems, pipes can become overwhelmed in heavy rainfall events, causing pumping stations and treatment plants to break down and untreated sewage to seep out of manholes and into bodies of water. Some cities are investing in long-term strategies of separating water and sanitary sewer into separate systems, but even independent sanitary sewage systems like Middleton's can take on too much runoff from infiltration and inflow. These sewage backups directly threat health and safety.

Currently, the City of Middleton prohibits public or private sanitary sewage systems in the Floodway District (FW), and in the Floodfringe District (FF) requires the systems to be "designed to minimize or eliminate infiltration of flood water into the system pursuant to Section 24.09(4) of this Ordinance, to the flood protection elevation and shall meet the provisions of all City ordinances and Wis. Admin. Code

Chap. SPS 383". While this language covers requirements for safe sewer systems, it relies heavily on administrators to determine the sufficient level of floodproofing. Minnesota's Pollution Control Agency lays out very specific requirements for safe sewage systems in FF Districts. We recommended the City of Middleton adopts the language from Minnesota's administrative rules, which are replicated here:

7080.2270 FLOODPLAIN AREAS.

Subpart 1. General.

ISTS must be designed under this part if the system is proposed to be located in a floodplain. A system located in a floodplain must meet or exceed the following requirements:

A. employ flow values in parts 7080.1850 to 7080.1885;

B. meet or exceed applicable technical requirements of parts 7080.1900 to 7080.2030, 7080.2050, and 7080.2100, except as modified in this part;

C. provide flow measurement if a pump is to be employed;

D. meet or exceed the requirements of parts 7080.2210 to 7080.2230;

E. meet or exceed requirements of part 7080.2150, subparts 2 and 3, except as modified in this subpart; and

F. meet the requirements of subparts 2 to 11.

2. State and local requirements.

The allowed use of systems in floodplains must be according to state and local floodplain requirements.

Subp. 3. Location of system.

An ISTS must not be located in a floodway and, whenever possible, placement within any part of the floodplain should be avoided. If no alternative exists, a system is allowed to be placed within the flood fringe if the requirements in subparts 4 to 11 are met.

Subp. 4.Openings.

There must be no inspection pipe or other installed opening from the distribution media to the soil surface.

Subp. 5. Highest ground.

An ISTS must be located on the highest feasible area of the lot and must have location preference over all other improvements except the water supply well. If the ten-year flood data are available, the bottom of the distribution media must be at least as high as the elevation of the ten-year flood.

Subp. 6. Pump.

If a pump is used to distribute effluent to the soil treatment and dispersal system, provisions shall be made to prevent the pump from operating when inundated with floodwaters.

Subp. 7. Raising elevation.

When it is necessary to raise the elevation of the soil treatment system to meet the vertical separation distance requirements, a mound system as specified in part 7080.2220 is allowed to be used with the following additional requirements:

A. the elevation of the bottom of the mound bed absorption area must be at least one-half foot above the ten-year flood elevation if ten-year flood data are available;

B. inspection pipes must not be installed unless the top of the mound is above the 100-year flood elevation; and

C. the placement of clean sand and other fill must be done according to any community-adopted floodplain management ordinance.

Subp. 8. Inundation of top.

When the top of a sewage tank is inundated, the dwelling must cease discharging sewage into it.

Subp. 9. Backflow.
Backflow prevention of liquid into the building when the system is inundated must be provided. If a holding tank is used, the system must be designed to permit rapid diversion of sewage into the holding tank when the system is inundated.

Subp. 10.Holding tank.
If a holding tank is used to serve a dwelling, the holding tank's liquid capacity must equal 100 gallons times the number of bedrooms times the number of days between the ten-year stage on the rising limb of the 100-year flood hydrograph and the ten-year stage on the falling limb of the hydrograph, or 1,000 gallons, whichever is greater. The holding tank must be accessible for removal of tank contents under flooded conditions.

Subp. 11. Water level above top.
Whenever the water level has risen above the top of a sewage tank, the tank must be pumped to remove all solids and liquids after the flood has receded and before use of the system is resumed (Minnesota Pollution Control Agency, 2003).

Critical Facilities

Critical facilities including; schools, nursing homes, hospitals, fire, police, emergency operations, water and wastewater treatment plants, and electric power stations are necessary to protect public health, safety, and welfare during a flood event. For this reason, the Association of State Floodplain Managers has recommended building new critical facilities only outside the 500-year floodplain whenever possible (ASFPM Regulation Committee, 2011). Some exceptions could be made for existing critical facilities or for facilities that are required to be within the flood districts. These facilities should also be mandated to have dry land access.

The City of Middleton currently does not include any information about the siting of critical facilities or dry land access to these facilities within its floodplain ordinances. The city should adopt the proposed language below for the development of critical facilities:

Prohibition language:

Construction of new critical facilities shall be located outside the 500-year floodplain or the area inundated by [the highest recorded flood], whichever is larger (see also Marana's ordinance, p. 86).

Protection language:

a) Construction of new critical facilities shall be, to the extent possible, located outside the 500-year floodplain or the area inundated by [the highest recorded flood], whichever is larger.
b) Construction of new critical facilities in the area of special flood hazard shall be permissible if no feasible alternative site is available, provided:

1) Critical facilities shall have the lowest floor elevated 3 feet above the BFE or 1 foot above the 500- year flood elevation, whichever is higher. If there is no available data on the 500-year flood, the permit applicants shall develop the needed data in accordance with FEMA mapping guidelines.

> 2) Access to and from the critical facility shall be protected to 1 foot above the 500-year flood elevation or 1 foot above [the highest recorded flood elevation], whichever is higher" (ASFPM Regulation Committee, 2011).

Vegetation

Regulations around removal and alteration of vegetation or land grade can help to prevent development from encroaching on the floodplain. Middleton already uses this as an evaluative method in assessing land development for impact on stormwater runoff and erosion control. However, Middleton could add more restrictive language to the floodplain ordinances to prevent the removal of native vegetation, to maintain the integrity of the creek bed, decrease the velocity of floodwaters, and protect the natural environment. Sometimes, developers propose compensating for flood storage loss or raising flood heights by re-grading the land or removing vegetation. This practice makes hydraulic models show that the flood levels do not increase because of decreased roughness. Many cities allow developers to apply for a Letter of Map Revision from FEMA to implement these changes because the 100-year floodway will then flood through a smaller area. However, allowing the change in land grade or the removal of vegetation can cause adverse impacts to the land, including an increase in floodwater velocity, damage to habitat and vegetation, bank erosion, and an increase in floodway roughness if the area is not constantly maintained (Turner et al, 2017).

Kenosha banned filling, excavation, and removal of vegetation from their Flood Overlay District. The City of Middleton should adapt Kenosha's Flood Overlay District language to fit their needs regarding vegetation, excavation, and filling.

> Lands lying within the FPO Floodplain Overlay District shall not be obstructed in any manner, nor shall such lands be used for dumping of any material or substance (including manure) or be filled, except as authorized to permit the establishment of approved bulkhead lines or to accommodate bridge approaches. Excavation in the Floodplain area shall be prohibited, except that normal earth grading activities as defined in this ordinance to permit utilization of the lands for open space, outdoor recreation, yard, parking and similar uses are permitted.
>
> (m) Removal of Trees and Shrubs The removal of trees, shrubs and foliage from the Floodplain Overlay District shall be prohibited unless conducted in accordance with section 12.18-2 and with the further provision that such activity is conducted in a manner so as to be consistent with sound floodplain management (Overlay Districts, 2012).

General Provisions and Additional Comments

The preceding recommendations are updates or additional requirements beyond what is currently found in the City of Middleton's Floodplain Zoning Ordinances. Section 24.05(3) of said ordinances pertains to development standards for floodfringe areas and it is our recommendation that this language, along with that in section 24.08 on non-conforming uses, be adopted in the proposed flood overlay district with a few alterations. Any clauses requiring contiguous land to areas outside the floodplain shall be removed along with clauses contingent upon such requirements. In addition, the

preceding recommendations in this document shall take precedence over the less stringent requirements currently in sections 24.05(3) and 24.08.

Several provisions within sections 24.05(3) and 24.08 reference regional flood levels as a baseline for setting heights of critical structures and utilities. The City of Middleton should instead use adjacent grade levels as a substitute, following the precedent set by the City of Fort Collins, CO. Chapter 10, article 2 of the Fort Collins municipal code.

> In lieu of flood depth or mapped base flood elevation. For a location in an AO zone for which no flood depth information has been documented on the FIRM, the base flood elevation shall be deemed to be twenty-four (24) inches above the highest adjacent grade (City of Ft. Collins, 2019).

Increasing Urban Water Storage

In addition to updating floodplain maps and ordinances, the city should also implement strategies to increase stormwater storage and drainage citywide. While the best strategies for stormwater storage involve the infiltration of internally drained areas outside the urban center of Middleton, the City can pursue both short-term and long-term infrastructure adjustments to increase permeability and drainage in urban areas as well as reduce the potential for stormwater and groundwater flooding. The rapid accumulation of stormwater did not drain or store adequately during the August flood event, causing flooding in residential basements and lower floors. This lack of drainage also increased the amount of discharge from the creek and contributed to the flooding of the Pheasant Branch creek corridor. As climate rapidly changes and severe rain events become more common, urban infrastructure must change to better integrate water management systems that slow, store, and drain stormwater.

Figure 4 illustrates areas within Middleton municipal boundaries that are desirable for infrastructure interventions. In the more desirable areas, highlighted in green, the soils are extremely well-drained and in the yellow areas, they are moderately well-drained. Less desirable areas highlighted in red are less well-drained but still may provide some opportunity for infrastructure interventions.

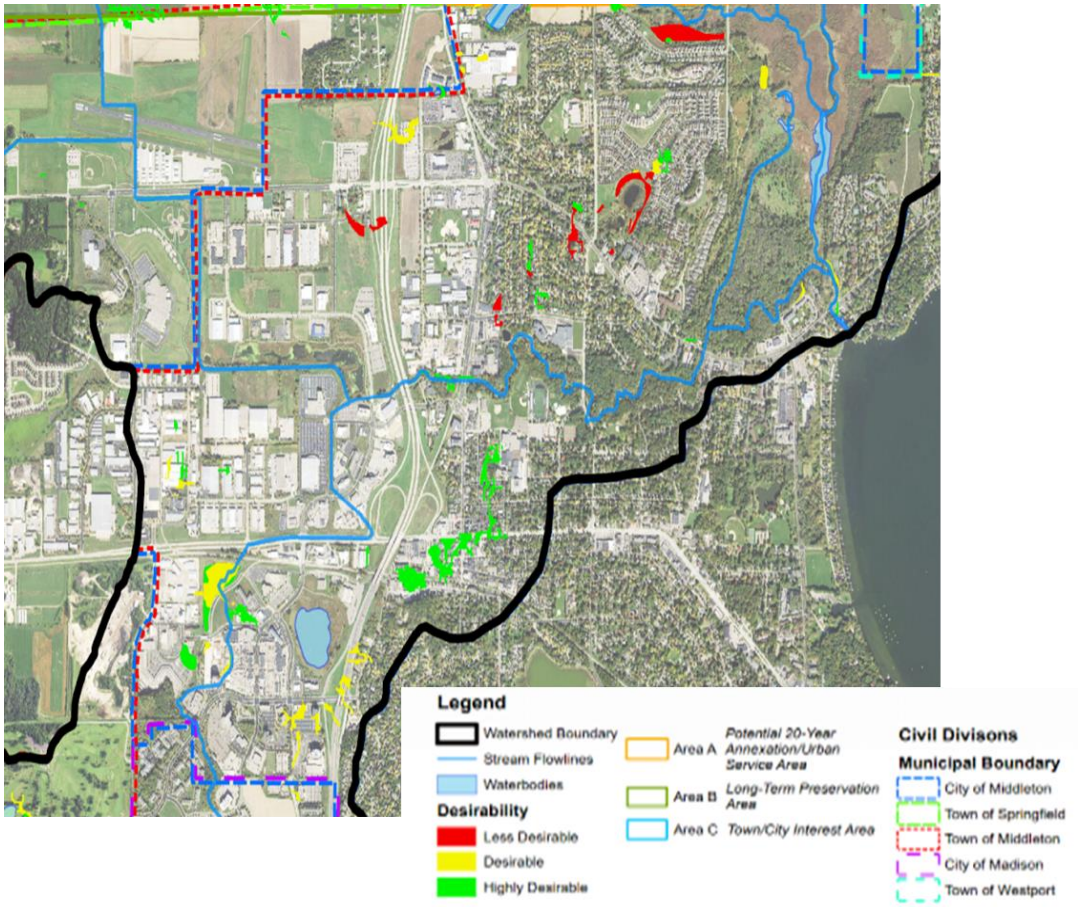

Figure 5: Urban areas desirable for water drainage

The following areas in Middleton should be considered for urban infrastructure adaptation strategies:

- Middleton Hills Park
- Median on Erdman Blvd
- Residential areas in Middleton Hills
- Open area around Schoepp Motors and Middleton Ford
- Open area behind TNT Window Tinting
- Area of Pheasant Branch Corridor between Gammex and AutoColor
- Area around FutureFoam and ACS on Parkview
- South Pond area
- Residential areas around Middleton High
- South of Esser Pond around beltline
- Around Graber Pond

Short-term Strategies for Urban Water Storage

Rain Gardens

A rain garden is a shallow excavated basin that collects and cleans storm water runoff on a small scale. Soil layers and plants in a rain garden help water infiltrate and remove pollutants. Native shrubs, perennials, flowers and grasses temporarily hold and soak in rainwater that flows off roofs, driveways, and other impervious surfaces on the average residential or commercial property. Strategic planting can also catch water that comes from gutters. Compared to a conventional lawn, rain gardens allow up to 30% more water to soak into the ground (Groundwater Foundation, 2019). Since rain gardens drain within 12-48 hours of a rainfall, they are not a breeding ground for mosquitoes. In some cities around the country, property owners receive a rebate for planting a rain garden on their property. In Washington, D.C., eligible homeowners receive $3/square foot on a first-come first-served basis until funds run out for the year. A project is eligible for a rebate if it meets the following conditions:

Figure 6: Residential rain garden; Headwaters at the Comal River in New Braunfels, Texas

- A minimum of 50 square feet of rain garden (project area) must be installed
- A minimum of 400 square feet of stormwater needs to be redirected from the roof through a downspout or from other runoff sources to the project area
- Only native plants may be planted in a rain garden (Rain Garden Rebate Program, 2018)

Other cities provide incentives including discounts on the stormwater utility fee, developer incentives for new builds, grants to property owners or community groups, and awards and recognition programs for property owners and communities that pursue excellence in water management (EPA, 2009). Residential areas in Middleton Hills near Middleton High School, where soils have highly desirable drainage, are good candidates for one of these incentive programs.

Public rights-of-way can also incorporate rain gardens by curbs and on medians to increase the potential for drainage. The city could install rain gardens in areas where rainfall caused significant damage and connect drainage pipes to existing water infrastructure. While the rain gardens would drain water to the same areas that may already be overwhelmed, they will drain more slowly and water from these curbside rain gardens would enter the system after some of the floodwater has already been effectively drained.

Figure 7: Curbside rain garden; Headwaters at the Comal River in New Braunfels, Texas

Green Roofs

Green roofs are another option for green infrastructure investment and is a system of soil media and vegetation that absorbs and stores stormwater that falls onto the roof. Green roofs lessen roof runoff, improve water quality, and reduce heat gain through evapotranspiration. Water is stored by the substrate and then taken up by water-loving plants before it evaporates or transpires back into the atmosphere. In summer months, green roofs hold 70-90% of the precipitation that falls on them, and in winter months, hold 25-40% of precipitation (Green Roofs for Healthy Cities).

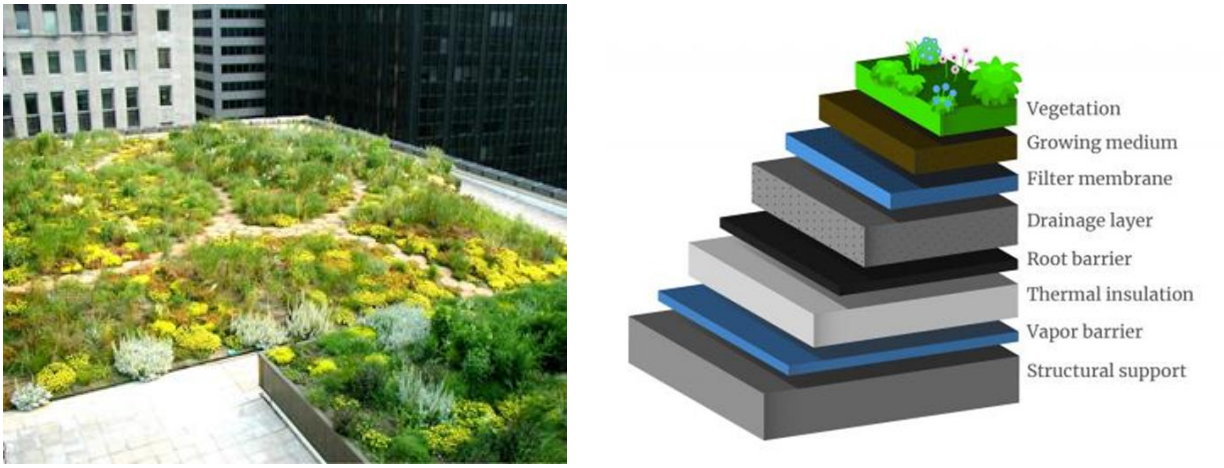

Figure 8: Green roof; Roofing Toronto (left) and Green roof materials; EPA 2019 (right)

Green roofs also filter the water and delay runoff, resulting in decreased stress on water sewer systems during peak flow. In addition, they moderate urban heat island effects, increase air quality, and increase energy efficiency. Green roofs require at a minimum, high quality waterproofing, root repellent system,

drainage system, filter cloth, a lightweight growing medium, and plants. Green roofs can be purchased as modular units already put together or each layer can be laid separately on site.

Green roofs can be installed on the roofs of public buildings, and the City could offer incentives to encourage private landowners to install them on their own property.

Retrofitting Buildings that Flooded

Many residential buildings outside of the floodplain still experienced flooding during the August event, particularly basement flooding, and property owners should be aware of retrofitting options available for their properties that protect from further flooding. If the city decides to include residential properties within the floodplain districts and sets requirements for elevation or floodproofing, these requirements are typically determined on a "substantial damage" or "substantial improvement" basis. For example, if a homeowner in the floodplain wanted to perform a renovation that would cost the equivalent of 50% of the current value of the home, they would be required to meet floodplain requirements like raising their first occupiable floor to flood protection level or floodproofing their mechanicals. Several methods exist to retrofit current residential structures to better withstand extreme rain events or flooding. When deciding how to retrofit a residential building, the structural integrity of the building and the critical systems should be accounted for, as should its use, access, parking, and neighborhood character (Weisbrod, 2014).

Raising the elevation of a structure is the most effective method for preventing residential flooding. A structure can be raised up to flood protection elevation with a new foundation constructed underneath, which significantly reduces both flooding risks and flood insurance premiums. However, raising buildings comes with challenges: it can be an expensive process; it is difficult to achieve for attached residences; it requires residents to temporarily live elsewhere during the renovation; it requires new accessibility options for those with disabilities or general mobility problems; and it can have adverse impacts on the streetscape.

Non-structural elevation strategies including filling the basement or elevating critical systems are alternatives to raising the elevation of a structure. First, filling basements reduces risks and insurance premiums and has little impact on the aesthetics of a neighborhood. However, most property owners use their basements for living or storage spaces and losing that space is not ideal. If the structure shares walls with other buildings, filling basements may cause problems with hydrostatic pressure that are expensive to mitigate. Second, raising critical systems like mechanical, plumbing, and electrical above the flood protection elevation might be the easiest form of non-structural flood prevention. This method can make the return home after a flood more affordable and carries small credits for flood insurance. However, tenants may have to temporarily relocate while elevating critical systems and this method could result in a loss of usable floor space.

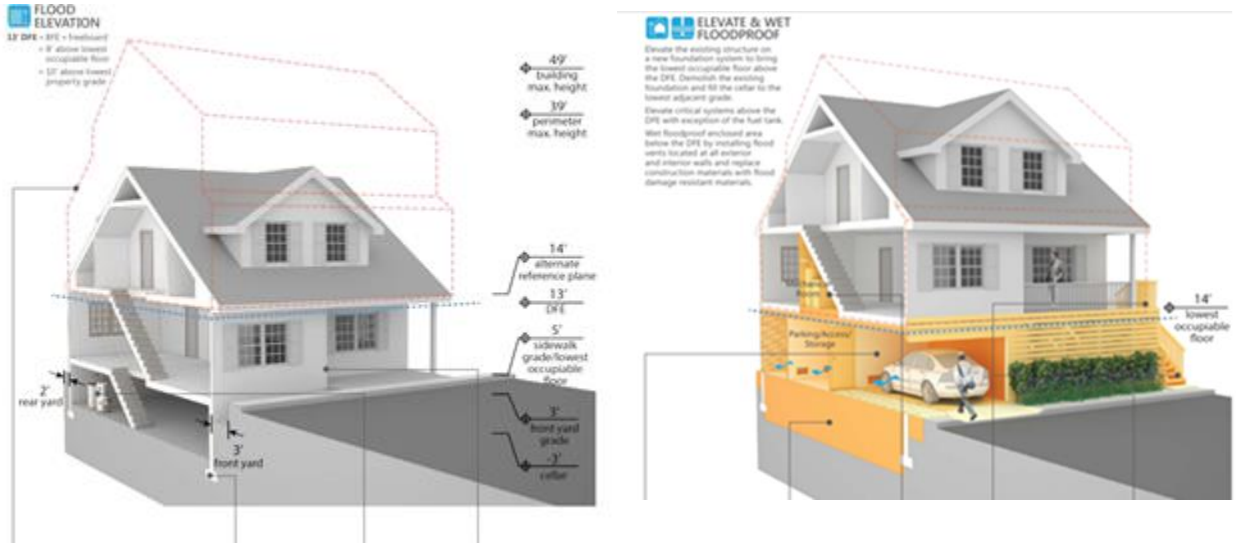

Figure 9: Building retrofit example; New York City Department of City Planning

For large residential structures where elevating might be financially infeasible, wet floodproofing is another method for flood damage prevention. Wet floodproofing allows floodwaters to pass through the building in order to equalize hydrostatic pressure, reduce the danger of buoyancy from hydrostatic uplift forces, and limit damages to the structure and finishes. In practice, wet floodproofing turns the first-floor use into parking, crawl space, and storage. The wet floodproof area requires openings for water to enter and exist as well as the use of floodproof materials.

Pocket Green Spaces

Small pocket green spaces are another simple, small way to adapt the urban infrastructure to better drain stormwater. Pocket green spaces are small, interactive spaces along sidewalks or medians that help maintain urban green space and can serve as tools for stormwater retention. In Montgomery, Pennsylvania, a pocket green space was built in the city center containing a rain garden, porous pavers, and a "subsurface infiltration basin"— a large container about five feet below the surface filled with crushed stone. The location was on low ground so that water ran toward the green space during a rainstorm (Weilbacher, 2018). The green space can be used for children's play, live music, and other public activities during dry condition; however, it can soak up several inches of water, slowly drain, and stores stormwater during storm events. If the system overloads, the green space can be connected to pipes that lead to bodies of water, but the drainage will still be slower, delaying the influx of water until after peak flow.

Figure 10: Pocket green space in Philadelphia; Carrion 2015

Long-term Strategies for Urban Water Storage

Adjustments to Materials for Streets and Sidewalks

Cities need to provide paved surfaces for transportation including streets, bike lanes, surface parking lots and sidewalks, but these transportation-related hard surfaces make up 50-60% of impervious surfaces in most cities (Beckwith et al, 2007). The more impervious surfaces that exist in a watershed, the more runoff occurs, increasing peak and total flow of floodwaters.

As the City of Middleton conducts routine roadwork and updates to sidewalks and other infrastructure, they could replace existing pavement and concrete with pervious materials that will permit water to flow through. Permeable paving is typically about 20% more expensive than traditional pavement, but in the long-term, changing to permeable pavements will save money that would be spent on repairing damaged roads and buildings from future flooding (Terhell, Cai, and Murphy, 2015).

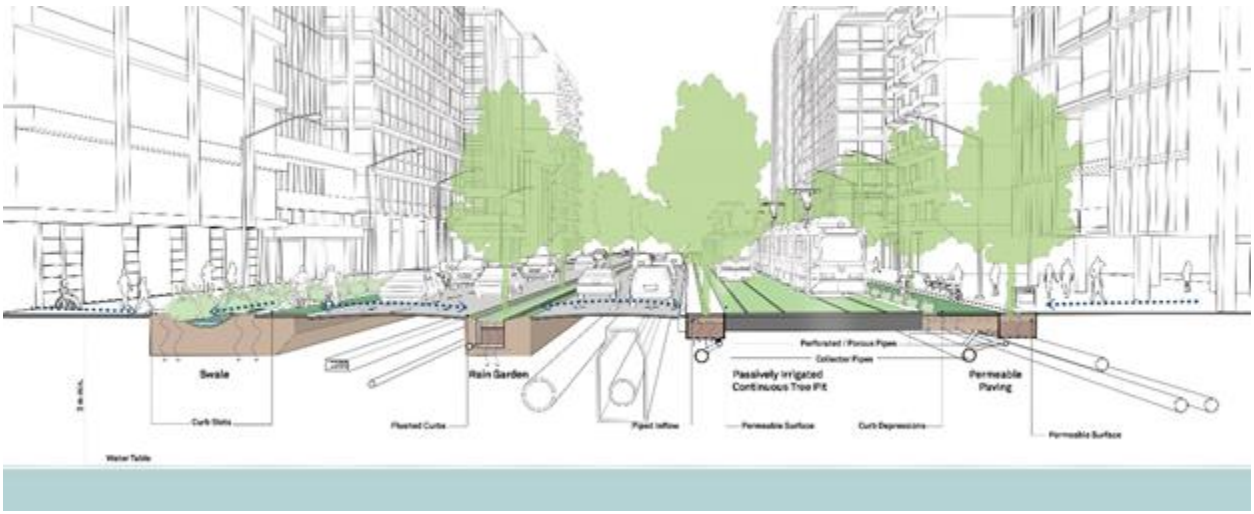

Figure 11: Permeable pavements and storage; Global Designing Cities

Figure 12: Permeable pavement with curbside rain garden and subsurface stormwater storage; Greater New Orleans Urban Water Plan 2013

Beneath pervious pavement on streets and sidewalks, it is possible to create built-in water storage. Subsurface storage is particularly effective on sloping streets so that the water is intercepted before it reaches lower areas that are prone to flooding. The storage can be designed as narrow, but deep, basins that allow room for utilities and cable to run beneath the streets (Greater New Orleans Urban Water Plan, 2013). Figure 13 compares the basic properties of major permeable pavement types and their uses.

Table 7.2. Comparative Properties of the Three Major Permeable Pavement Types

Design Factor	Porous Concrete (PC)	Porous Asphalt (PA)	Interlocking Pavers (IP)
Scale of Application	Small and large scale paving applications	Small and large scale paving applications	Micro, small and large scale paving applications
Pavement Thickness1	5 to 8 inches	3 to 4 inches	3 inches 1, 8
Bedding Layer 1, 8	None	2 inches No. 57 stone	2 inches of No. 8 stone
Reservoir Layer 2, 8	No. 57 stone	No. 2 stone	No. 2 stone 3-4 inches of No.57 stone
Construction Properties 3	Cast in place, seven day cure, must be covered	Cast in place, 24 hour cure	No cure period; manual or mechanical installation of pre-manufactured units, over 5000 sf/day per machine
Design Permeability4	10 feet/day	6 feet/day	2 feet/day
Construction Cost 5	$ 2.00 to $6.50/sq. ft.	$ 0.50 to $1.00/ sq. ft.	$ 5.00 to $ 10.00/ sq. ft.
Min. Batch Size	500 sq. ft.		NA
Longevity 6	20 to 30 years	15 to 20 years	20 to 30 years
Overflow	Drop inlet or overflow edge	Drop inlet or overflow edge	Surface, drop inlet or overflow edge
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colors/Texture	Limited range of colors and textures	Black or dark grey color	Wide range of colors, textures, and patterns
Traffic Bearing Capacity 7	Can handle all traffic loads, with appropriate bedding layer design.		
Surface Clogging	Replace paved areas or install drop inlet	Replace paved areas or install drop inlet	Replace permeable stone jointing materials

Figure 13: Permeable pavement types; University of Maryland Extension 2016

Water Lanes and Street Features

Floating streets and water lanes are two additional features that could be integrated into future road projects to increase water storage and decrease runoff. Traditional streets are "crowned", meaning they are highest in the middle and slope down either side to gutters. "Floating streets", however, are highest at one side and slope to a parking lane and bioswale that can store water (Greater New Orleans Urban Water Plan, 2013).

Figure 14: sloped permeable pavement; University of Maryland Extension 2016

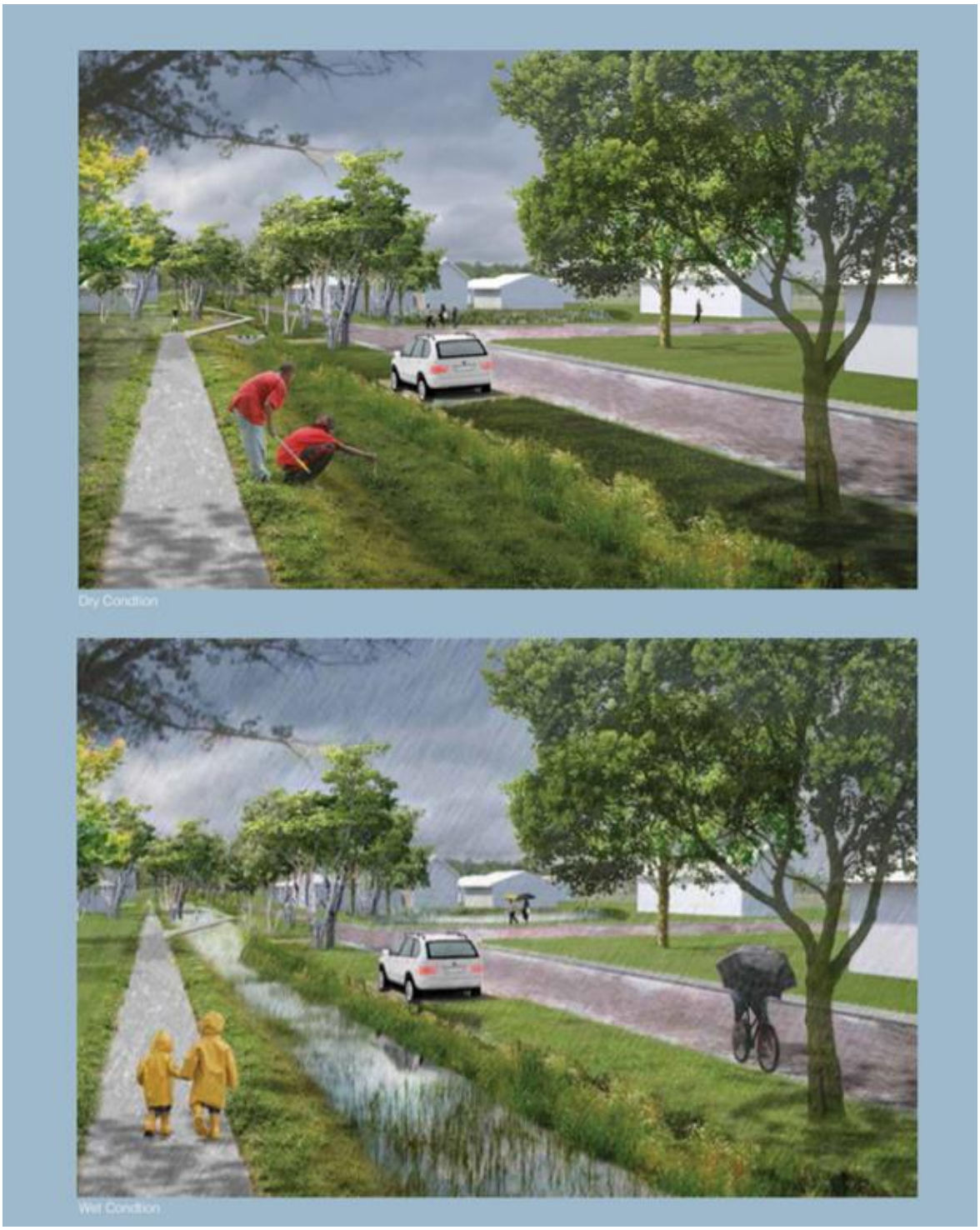

Figure 15: Floating streets and water lanes; Greater New Orleans Urban Water Plan 2013

Water lanes are lanes next to floating streets that are filled with water-loving native plants, drain significant amounts of rainwater, and deliver the rest to storage basins instead of allowing it to flood the streets. These innovations can prevent street flooding and help direct water into the ground or to designated storage areas (Greater New Orleans Urban Water Plan, 2013).

Summary of Urban Infrastructure Recommendations

The following recommendations are based on FEMA insurance data, current zoning ordinances, and urban stormwater management best practices. Stormwater management ordinances may need to be more specific in the future, especially as urban development continues, and climate change increases the frequency and severity of weather events.

1. Implement a Flood Overlay Zoning District in the areas around the business park, confluence pond, and Esser Pond.

2. Require all structures within Flood Overlay Zoning District to maintain flood insurance, emergency response plans, and business continuity plans.

3. Identify all potential sources of hazardous materials and perform adequate soil and water quality tests to identify risk.

4. Apply floodfringe city ordinances to the Flood Overlay Zoning District with updates to bring ordinances in line with nationwide best practices.

5. Install curbside rain gardens and green roofs on public rights-of way and buildings and provide incentives to encourage private property owners to construct them.

6. Provide information to residents about retrofitting residential buildings to prevent flooding.

7. Establish pocket green spaces in lower-lying areas of the city with good drainage.

8. Include impervious surfaces, subsurface water storage, floating streets, and water lanes in future road work projects.

II. Restoring and Recovering Vegetation

This section of the report presents a vegetation zoning plan to restore habitat and stabilize banks in the Pheasant Branch creek corridor using erosion risk, riparian zones, and desired habitat-types to guide replanting efforts. We recommend the following:

- Adjust creek corridor vegetation based on two distinct topographical sections
- Utilize planting guide to restore native plants to the creek corridor and increase habitat resiliency
- Implement recommended action steps to recover lost habitat along the creek corridor

The Changing Natural Environment

Pheasant Branch is comprised of habitats including wetlands, marsh, wet prairie, prairie, shrub communities, lowland forests, and oak savanna (Conservancy Lands Committee, 2010). The differences between these habitats involve the type of soil or substrate, amount of settled water, access to sunlight, bank angle and location of the vegetation in relation to the stream, and density of trees. These habitats are home to a multitude of mammals, insects and birds, some of which are under threatened or endangered conditions. According to the Birds of Pheasant Branch Conservancy Guide, over 191 bird species have been spotted along the Pheasant Branch creek corridor and in the Conservancy. The creek corridor is important for pollinators, with over 58 species of butterflies recorded in the area. Mammals are another essential part of this ecosystem and need a ranging variety of habitat.

Pheasant Branch contains most of these habitats; however, urban development has drastically reduced the amount of the native vegetation. Oak and prairie habitat acreage have been drastically reduced by agriculture and development to less than 0.1% of the original community size (Conservancy Lands Committee, 2010). Wetlands have also been destroyed, drained, and tiled for agricultural use. The wetlands can no longer fulfill their original purpose: to act as water storage and seepage grounds in the event of flooding. Invasive species and the changing landscape push out native plant species in these areas.

In the wake of the August 2018 flooding, both native and invasive species washed away from the stream corridor. Erosion led to the loss of over 2,000 pounds of sediment from the stream. The stream bank just east of Park Street eroded back nearly 75 feet from its original slope. The creek corridor lost over 200 mature trees, as well as many grasses, sedges, rushes, and shrubs helping to stabilize the bank (Mark Wegner). In some areas, the sedimentation deposit neared four feet high and was filled with trash from an old nearby landfill.

The nearly complete loss of vegetation in many areas of the creek corridor left the river banks unstable and extremely hazardous. Without the protection of land cover and root density, the stream banks are vulnerable to future floods and extreme weather events. Fortunately, the widespread deposition of sediment along the Pheasant Branch creek corridor will suffocate many invasive plant species including garlic mustard or Dame's Rocket that once infiltrated the area. Now, the corridor can be repopulated with healthy native species without fear they will be crowded out by invasive plants.

Erosion Risk Factors

Erosion significantly influences habitat, stream health, and vegetation. The Bank Erosion Hazard Index (BEHI) classifies erosion into six categories to determine stream bank erosion and potential. The BEHI is a composite score from five categories: bank height, root depth, root density, surface protection, and bank angle. The BEHI assists in developing priorities and strategies for stream restoration in cases, such as Pheasant Branch, where multiple sections require work (West Virginia Department of Environmental Protection, 2019). The metrics for these conditions include: ratio of bank height to bank-full height, ratio of root depth to bank height, root density (percent), bank angle (degrees), surface protection (percent). In accordance, each metric is given a numeric value and a score. Categories are based on total scores comprised of each metric score added together.

Table 1: Complete BEHI procedure

BEHI category	Bank height	BH score	Root depth	RDH score	Root density	RD score	Surface protection	SP score	Bank angle	BA score	Total score by category
Very low	1.0 – 1.1	**1.45**	90 - 100	**1.45**	80 - 100	**1.45**	80 - 100	**1.45**	0 - 20	**1.45**	≤ 7.25
Low	1.1 – 1.2	**2.95**	50 - 89	**2.95**	55 - 79	**2.95**	55 - 79	**2.95**	21 - 60	**2.95**	7.26 – 14.75
Moderate	1.3 – 1.5	**4.95**	30 - 49	**4.95**	30 - 54	**4.95**	30 - 54	**4.95**	61 - 80	**4.95**	14.76 – 24.75
High	1.6 – 2.0	**6.95**	15 - 29	**6.95**	15 - 29	**6.95**	15 - 29	**6.95**	81 - 90	**6.95**	24.76 – 34.75
Very high	2.1 – 2.8	**8.5**	5 - 14	**8.5**	5 - 14	**8.5**	10 - 14	**8.5**	91 - 119	**8.5**	34.76 – 42.50
Extreme	> 2.8	**10**	< 5	**10**	< 5	**10**	< 14	**10**	> 119	**10**	42.51 - 50

Figure 16: Bank Erosion Hazard Index (BEHI)

The City of Middleton contracted with Cardno to create "The Pheasant Branch 2018 Flood Damage Assessment and Five-Year Plan", which identifies five of the six BEHI categories in Pheasant Branch. The report assessed the 2018 flood damage in the Pheasant Branch creek corridor and provided some recommendations for future mediation and development. The Cardno report also used GIS to determine where the erosion occurred along the Pheasant Branch Creek Corridor. Our report uses Cardno's classification system and GIS in order to determine where extreme erosion occurred and what type of vegetation will be best suited for particular erosion levels and habitat types.

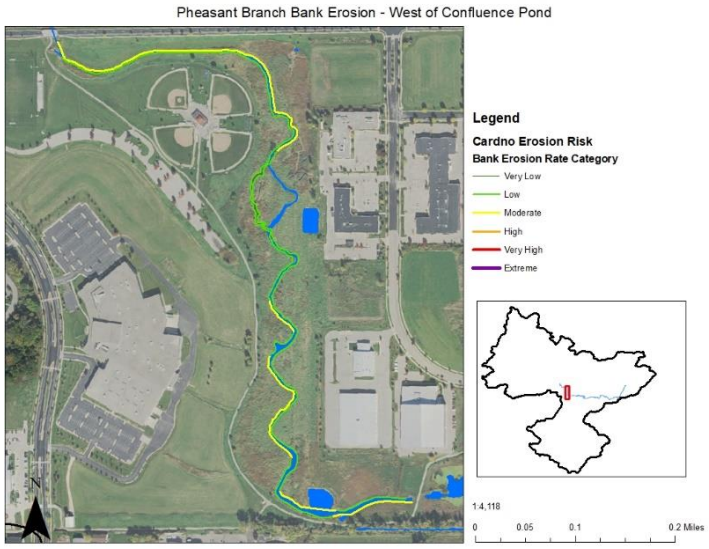

Figure 17: Pheasant Branch erosion assessment; Cardno 2018

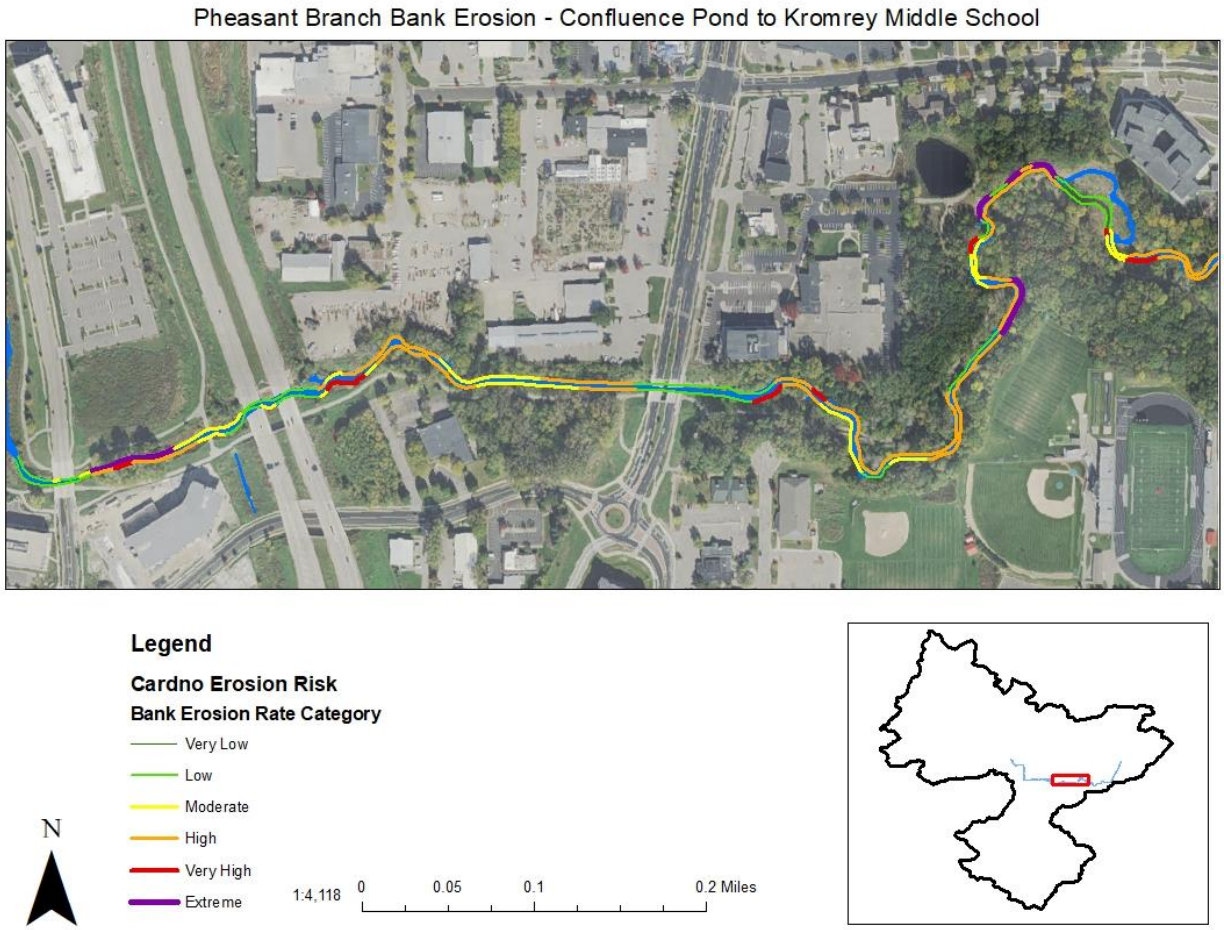

Figure 18: Pheasant Branch erosion assessment; Cardno 2018

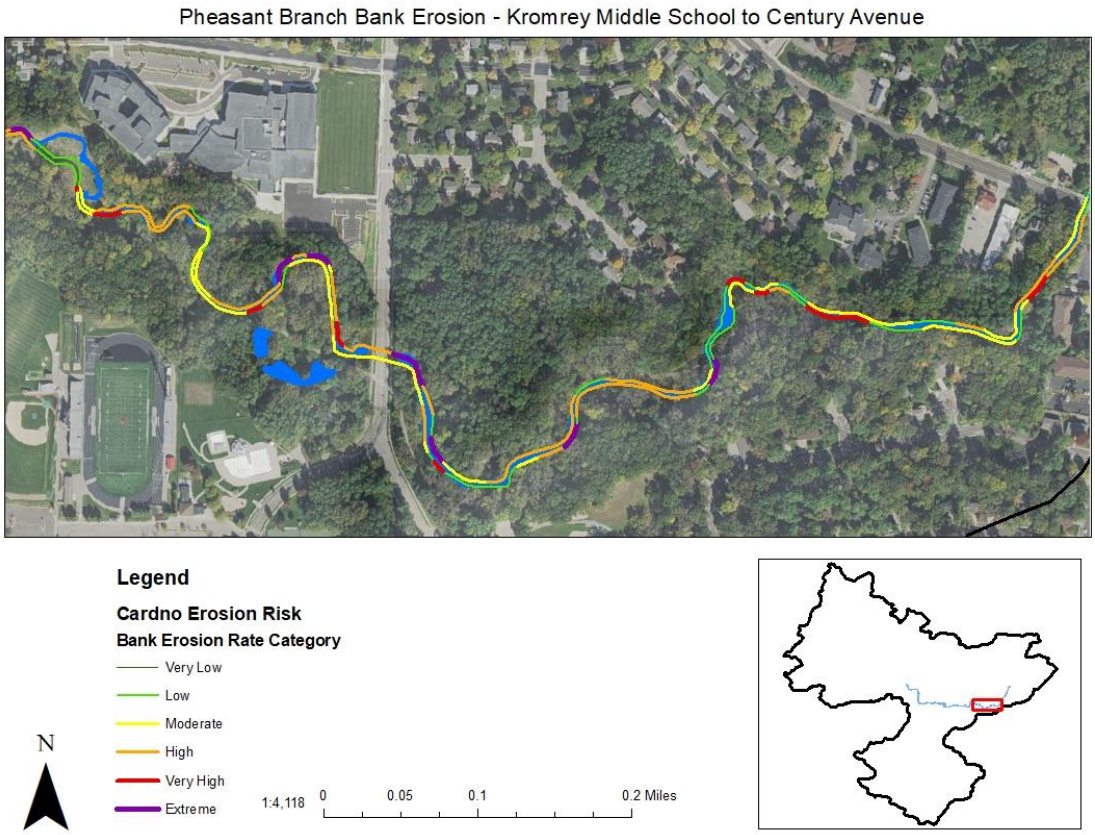

Figure 19: Pheasant Branch erosion assessment; Cardno 2018

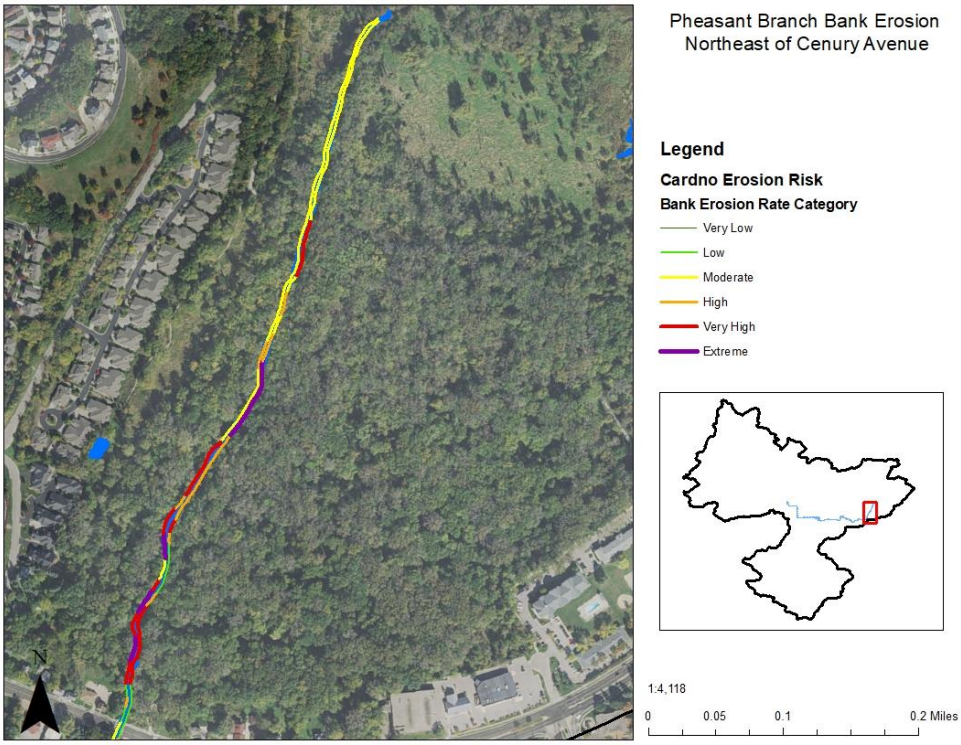

Figure 20: Pheasant Branch erosion assessment; Cardno 2018

The greatest threat to stream stabilization and erosion criteria is another flood event. Recurring floodwaters have the potential to hinder or destroy recovery efforts, especially newly-planted seedlings. Any habitat restoration must be done in conjunction with engineered solutions in order to prevent the new vegetation from washing away in a future flood event.

Previous Erosion Control Projects

Erosion is a natural, constant threat and will always be a challenge for storm management. Cardno completed multiple studies on erosion and implemented different erosion control strategies including rootwad treatments, erosion blankets, gabion baskets, forb and grass seeding, and channel relocation. In July 2008, Pheasant Branch underwent a rootwad treatment to stabilize the banks between Park Street and Century Avenue. A new channel was constructed two years later in the section between Park Street and Parmenter Street. In March 2014, the stream butting against Kromrey Middle School was moved to the south of the corridor. While some of the localized stabilization methods held during the August flood event, damage to the banks that received a higher stream flow impact is clearly visible and will be more difficult to reconstruct and stabilize. A remaining challenge is conceptualizing the corridor landscape with the expectation of similar floods occurring more often than ever before.

Riparian Zoning

Zones of varying flood risk and soil moisture extend laterally from the creek corridor. These zones need to be considered when choosing vegetative communities:

- Bank-full width: The width of the stream at the bank-full stage, which is the point just before the stream enters the floodzones.
- 100-year & 500-year floodzone: The 100-year and 500-year floodzones were determined using FEMA 1% and .2% annual floodzone maps. These floodzones are relatively flat areas that are inundated during flood events. The NOAA Atlas 14 100-year, 24-hour storm event is 5.42 - 8.17 inches and the NOAA 500-year, 24-hour storm event is 6.75 - 11.5 inches.
- Upland: The upland zone is above the 500-year floodzone, labeled as an area of ‘minimal flood risk’ area in FEMA maps. This area has drier soil and is infrequently inundated.

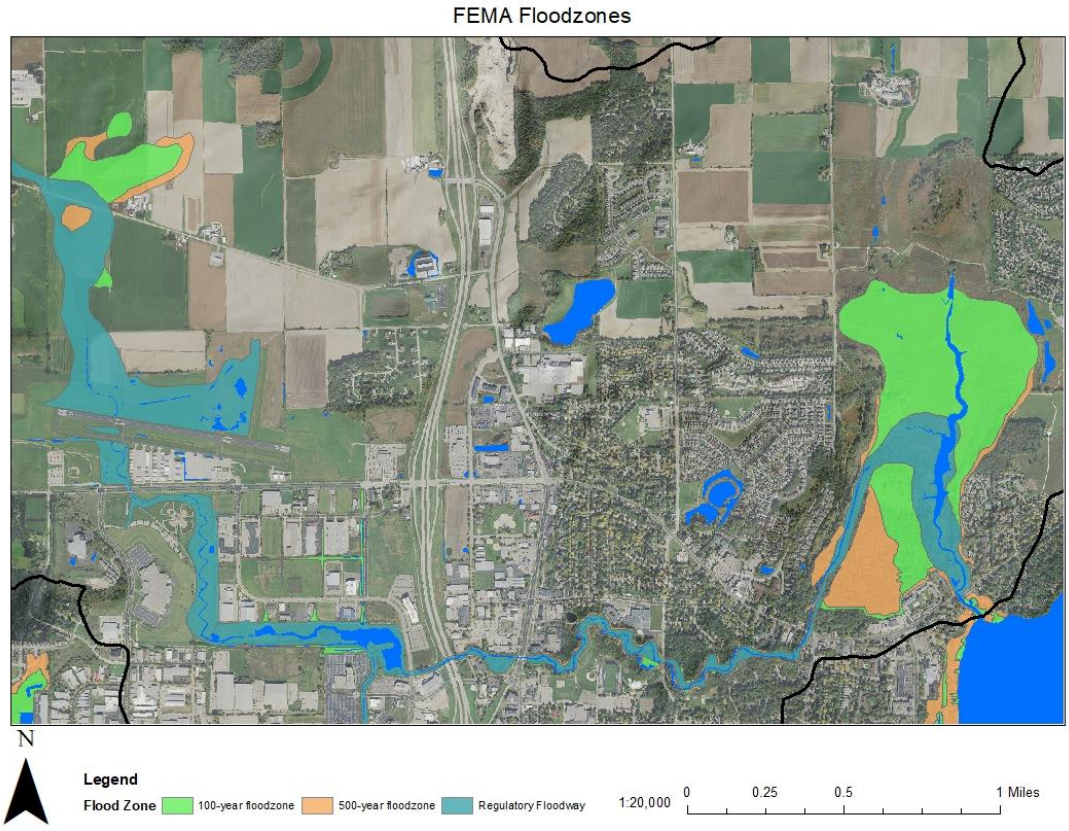

Figure 21: FEMA designated floodzones along Pheasant Branch

Habitats and Species of Pheasant Branch

Habitats along the corridor were determined using the Wiscland 2 dataset produced by Wisconsin Department of Natural Resources (2016). The primary habitats present along Pheasant Branch include emergent wetlands and wet meadows within the floodzones and wet hardwood habitats in the 500-year floodzone north of Century Avenue. The primary upland habitats include Pine and Northern Hardwoods along the steep portions of the creek, and cool-season and warm-season grasses surrounding Frederick's Hill. See Table 1 for the Wiscland 2 descriptions of each habitat type and Figure 22 for a map of land cover types in the corridor.

Table 1: Land cover descriptions

Land Cover	Wiscland 2 Land Cover Class	Description
Emergent/Wet Meadow	Cattails, Other Emergent Wet Meadow	Persistent and non-persistent herbaceous plants standing above the surface of the water or wet soul and covering 30% or more of the area. Vegetation examples include cattails, sedges, rushes, asters, goldenrods, and nettles.
Wet Hardwood	Tamarack, Silver Maple, Other Bottomland Hardwoods, Other Swamp Hardwoods	Areas with more than 50% cover from bottomland or swamp trees such as Tamarack, Silver Maple, or Black Ash.
Pine	White Pine, Red Pine	An upland area of land covered with woody perennial plants and at least 50% of the area is white or red pine predominant. The trees reaching a mature height of at least 6 feet tall with definite crown and canopy closure of at least 10%.
Northern Hardwoods	N. Pin Oak, Black Oak, Red Oak, White Oak, Burr Oak, Central Hardwoods, Other Northern Hardwoods	An upland area of land covered with woody perennial plants and at least 50% of the area is Northern or Central Hardwood such as Oak, Maple, Ash, or Birch. The trees reaching a mature height of at least 6 feet tall with definite crown and canopy closure of at least 10%.
Cool and Warm Season Grass	Cool Season Grass, Warm Season Grass	Lands covered primarily by grasses and forbs with less than 5% being shrubs or woody vegetation. Cool-season grass areas include fields planted for conservation purposes and old crop or hay fields. Warm-season grasses include upland prairie species such as Bluestem, Bush Clover, and Coneflower.

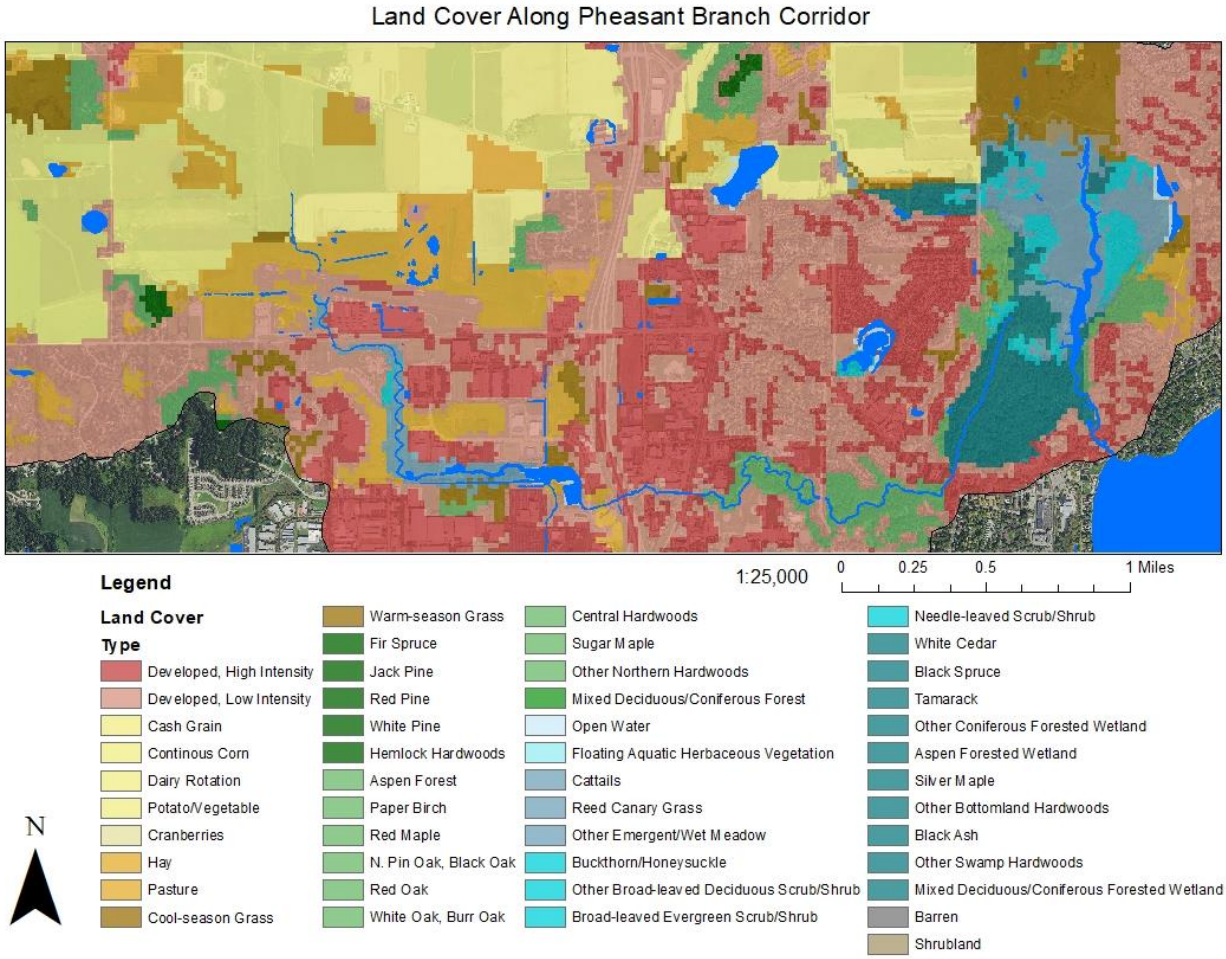

Figure 22: Land cover along Pheasant Branch

Pheasant Branch Wildlife

The Pheasant Branch creek corridor is home to a diverse array of mammals, insects, and birds that depend on the variety of habitats present along the creek. The Friends of Pheasant Branch Conservancy guides to Birds, Mammals, and Butterflies were used to match species with habitat types within the corridor (Watermolen et al, 2003; Watermolen et al 2005; Watermolen, 2005). Additional information on habitat associations of bird species was obtained from the Wisconsin Bird Conservation Initiative (Wisconsin Department of Natural Resources, 2013). The emergent wetlands and wet meadow habitats are home to a wide array of mammals including bats, coyotes, weasels, and muskrat as well as birds including waterfowl, sandpipers, and herons. Finally, the flowering plants provide habitat for dragonflies and butterflies.

Wet hardwood provides habitat for mammals including weasels, bats, beaver, grey fox, deer, and mice. Similar bird species exist in the wetlands where there is standing water, but the larger trees in a wet hardwood ecosystem provide additional habitat for woodpeckers, the Prothonatory Warbler, and wood ducks.

The large woody vegetation of northern hardwood and pine forests provide nesting habitat for Eastern Gray Squirrels and a wide variety of birds. Woodpeckers, Great-Horned Owls, Barred Owls, and Chimney

Swifts nest in large cavities of trees. Wood Thrushes and wood-warblers including Cerulean Warblers, Common Yellowthroat, and Blackburnian Warblers utilize forest habitat. Eastern Tiger Swallowtail and Spring Azure are examples of butterflies that also use woodland habitat in the corridor.

Finally, cool and warm weather grasses provide habitat to a diverse array of mammals, birds, and insects. Red Fox and Groundhog are two common mammal species to these upland areas. The melodic songs of Meadowlarks join other grassland birds including sparrows and bobolinks, while Monarch and Painted Lady butterflies take advantage of the many flowering plants present from spring until fall.

Threatened and Endangered Species

Four state-endangered and one federally-endangered species have been recorded in the township containing the Pheasant Branch creek corridor (T7N R8E) (Conservancy Lands Committee, 2010). Creating suitable habitat for these species should be considered when choosing plant species throughout the corridor. The four state-endangered species are Purple Milkweed (Asclepias purpurascens), Silphium Borer Moth (Papaipema slipii), Hairy Wild Petunia (Ruellia humilis), and Ornate Box Turtle (Terrapene ornate) (Conservancy Lands Plan). The one federally-endangered species reported in the township is the Rusty-Patched Bumble Bee (Bombus affinis). Additionally, one state-threatened species, Roundstem Foxglove (Agalinis gattingeri), has been reported in the township. A greater inventory of plant species can be found on the Pheasant Branch Conservancy website.

Community input and citizen science programs, such as *iNaturalist* and *ebird*, are valuable resources for the Middleton community to track the return of species in the Pheasant Branch creek corridor. Monitoring species returning to the area helps assess the health of the corridor and the information collected from these programs can guide continued rehabilitation practices. The prevalence of certain keystone species in the creek corridor indicates how well the corridor has recuperated. Similarly, the presence of invasive species indicates an increased need for a more suitable habitat. The ability to crowdsource a species inventory for the Pheasant Branch creek corridor will provide continuous data that assists the City of Middleton in identifying priority areas.

Typology Recommendations for the Creek Corridor

With knowledge of the current land cover and topography of the creek corridor, we crafted recommendations for riparian zone improvements with a focus on native plants and plant materials. Our goal is to return the Pheasant Branch creek corridor to a more natural state, benefiting the communities of Middleton adjacent to the Pheasant Branch creek corridor and the wildlife of the area.

Two separate creek corridor typologies were created to provide a better visual representation of the different zones of planting along the Pheasant Branch creek. These sections are simplified from the Cardno erosion studies to separate the corridor into two distinctions: Section 1 as low risk of erosion and Section 2 as high risk of erosion, based on the slope steepness in these areas.

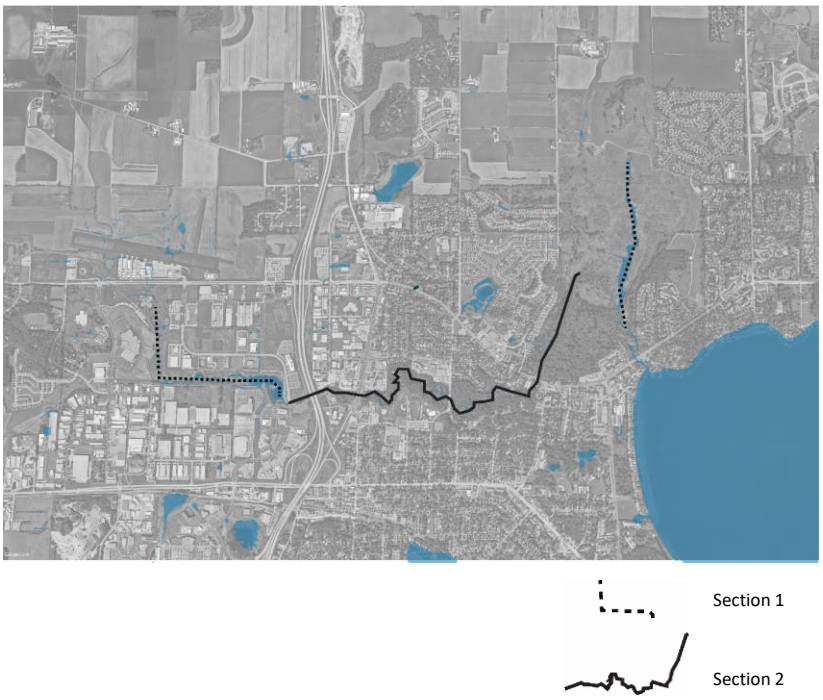

Figure 23: Two typographies in Pheasant Branch

Section 1: Creek Corridor near Confluence Pond

Figure 24: Landscape cross-section near Confluence Pond

Lower risk areas along the creek corridor tend to have gradual slopes with grasses that function as storm water staging and retention areas. Incorporating more wetland plants into these areas will facilitate storm water infiltration, while providing crucial habitat and foraging options for wildlife and pollinator species. These areas tend to slow down water movement; therefore, less consideration should be given to hardscape water management elements like riprap or gabion walls.

Section 2: Creek Corridor near Kromrey Middle School

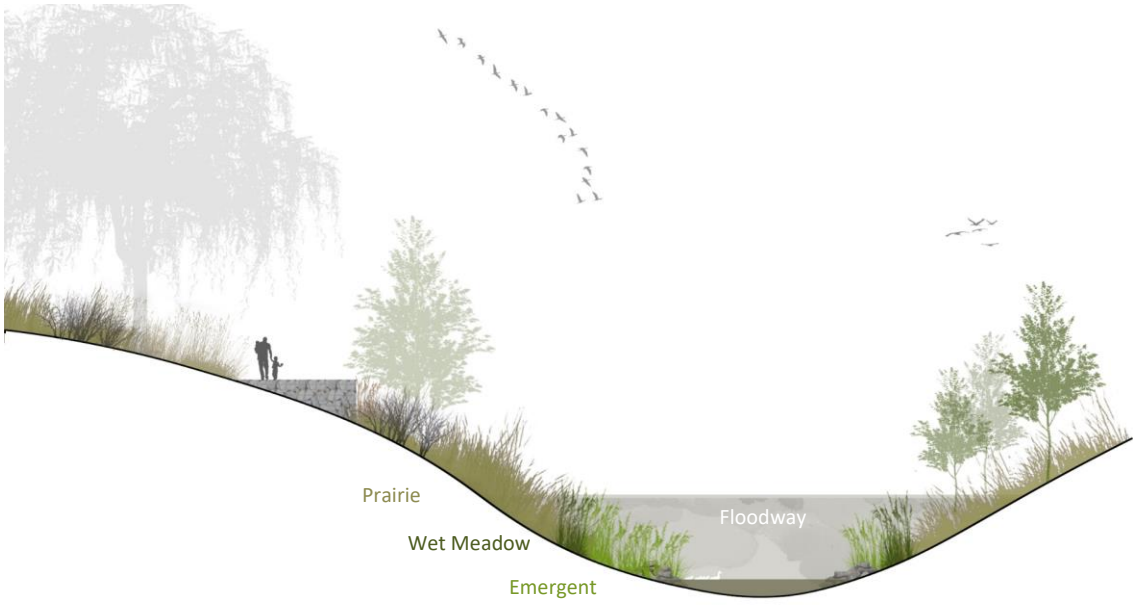

Figure 25: Landscape cross-section through creek corridor

Steep creek banks are a concern for much of the creek corridor and are more susceptible to erosion during flood events. Planting in these areas should be a supplement to rip rap and gabion walls to secure soils. Emergent and wet meadow sedges hold soils in place near the normal creek height, while native prairie vegetation line elevated parts of the stream banks. These plants also provide native habitat and foraging options for wildlife and pollinators which rely on this creek for water. Trees and shrubs in these areas will also help to stabilize soils and provide visual interest, while creating natural barriers that slow flood waters.

Pheasant Branch Planting Guide

Table 8 is a compilation of native plants for each planting area, depending on the moisture of the area. We recommend these plants based on their resilience to flood conditions as well as their root depth, native region, and habitat quality. A handful of plants that are endangered within Wisconsin are incorporated into these schematic planting plans, indicated by the “Native” column in Table 2. Flora with asterisks indicates endangered species.

Table 2: Planting guide for Pheasant Branch

Common Name	Scientific Name	Native (Y/N)	Root Depth (in.)	Mature Height	Classification	Attracts
Emergent Planting Zone						
Sweet Flag	*Acorus americanus*	N	suckering, 6-12"	2-6'	Grass	
American Lotus	*Nelumbo Lutea*	Y	12" +	2-5'	Tuber	
Bottlebrush Sedge	*Carex hystericina*	Y	12" +	2-4'	Sedge	
Fox Sedge	*Carex vulpinoidea*	Y	2' +	1-3'	Grass	
Marsh Marigold	*Caltha palustris*	Y	12"+	1-2'	Herbaceous perennial	
Wild Rice	*Zizania aquatica*	Y	6"	up to 10'	Grass	Butterflies, Birds
Wet Meadow Planting Zone						
Fox Sedge	*Carex vulpinoidea*	Y	2' +	1-3'	Grass	
Common Boneset	*Eupatorium perfoliatum*	Y	several feet	3-6'	Herbaceous perennial	Native Bees
Joe Pye Weed	*Eutrochium maculatum*	Y	several feet	5'	Herbaceous perennial	Bees, Butterflies
Red Elderberry	*Sambucus racemosa*	Y	24"	3-5'	Shrub	Birds
Indian Currant	*Symphorocarpus orbiculatus*	Y	12-24"	4-6'	Shrub	Birds
Meadow Rue	*Thalictrum rochebrunianum*	Y	12-24"	4-6'	Shrub	Birds
Common Milkweed	*Asclepias syriaca*	Y	12"	3-5' +	Herbaceous perennial	Butterflies
Prairie Planting Zone						
Sweet Grass	*Hierochloe odorata*	Y	12" +	24"	Herbaceous perennial	Birds
Switch Grass	*Panicum virgatum*	Y	12"+	3-6'	Grass	Birds
Butterfly Weed	*Asclepias tuberosa*	Y	12", deep tap root	up to 2'	Herbaceous perennial	Butterflies, Bees
Big Bluestem	*Andropogon gerardii*	Y	24"+	3-6'	Grass	Birds
Smooth Aster	*Aster laevis*	Y	12"	2-4'	Herbaceous perennial	Butterflies, Birds, Bees
Prairie Blazing Star	*Liatris pycnostachya*	Y	12"	2-5'	Herbaceous perennial	Butterflies, Birds, Bees
Purple milkweed**	*Asclepias purpurascens*	Y	12"	2-3'	Herbaceous perennial	Butterflies
Roundstem Foxglove**	*Agalinis gattingeri*	Y	6"+	1-3'	Herbaceous perennial	Butterflies, Birds, Bees
Azure Bluet**	*Houstonia caerulea*	Y	6"	1-2'	Herbaceous perennial	Butterflies, Birds, Bees
Hairy Wild Petunia**	*Ruellia humilis*	Y	6"	1-2'	Herbaceous perennial	Butterflies, Birds, Bees

Shrub Planting Zone						
'Northern Lights' Azalea	*Rhododendron 'Northern Lights'*	N	6-12"	3-5'	Shrub	Butterflies, Birds, Bees
Gray Dogwood	*Cornus racemosa*	Y	16"+	6-10'	Shrub	Butterflies, Birds, Bees
Redtwig Dogwood	*Cornus sericea*	Y	16"+	6-12'	Shrub	Butterflies, Birds, Bees
False Indigo	*Amorpha fruiticosa*	Y	24"	6-10'	Shrub	Nectar- bees, Butterflies, Insects
Prairie Willow	*Salix humilis*	Y	10"+	up to 10'	Shrub	
Arrow-wood	*Viburnum dentatum*	Y	12"+	6-10'	Shrub	
New Jersey Tea	*Ceoanthus americanus*	Y	6"	up to 3'	Shrub	Butterflies, Birds, Bees
Red Elderberry	*Sambucus racemosa*	Y	24"	3-5'	Shrub	Birds
Tree Planting Zone						
Swamp White Oak	Quercus bicolor	Y	varies	50-60'	Tree	
Red Oak	Quercus rubra	Y	varies	50-70'	Tree	
Burr Oak	Quercus macrocapra	Y	varies	up to 100'	Tree	
Willow	Salix spp.	Y	varies	30-50'	Tree	
Yellow Birch	Betula alleghaniensis	Y	varies	50-70'	Tree	
River Birch	Betula nigra	Y	varies	50-70'	Tree	
Ironwood	Ostraya virginiana	Y	varies	25-40'	Tree	
Eastern cotton-wood	Populus deltoides	Y	varies	65-130'	Tree	

Summary of Vegetation Recovery Recommendations

The following recommendations are based on erosion assessment data, current habitats in the Pheasant Branch watershed, and creek corridor water management best practices. Vegetation along the creek corridor must be different from its pre-flood vegetation because effective stream bank erosion control measures require resilient vegetation.

1. Identify priority areas that require the most restoration work such as undercut areas and areas with the greatest loss of existing vegetation.

2. Where possible, grade eroded slopes to an acceptable slope and stabilize banks with groundcover, erosion mats, or engineered solution such as gabion baskets and root wads.

3. Restore or establish emergent wetlands and sedge meadows in the floodplain areas throughout the corridor. This habitat is meant to withstand occasional flooding and can slow and store water during future storm events. Additionally, this will provide habitat for several species already present throughout the corridor.

4. After establishment and restoration of floodplain habitats, habitat restoration should continue upland from the creek to forested and grassland habitats buffering the creek from surrounding development.

5. Utilize community input and citizen science programs, such as iNaturalist and ebird, to track where wildlife is returning in the corridor. This information can be used to establish priority areas for habitat restoration based on areas that are not seeing wildlife returning. Since wildlife is an indicator for habitat quality, missing wildlife will be a driving factor in the habitat that needs to be restored.

III. Building a Community for Resilience

This section of the report addresses gaps in engagement and communication between the Middleton community and the City of Middleton as the restoration of the Pheasant Branch creek corridor begins and to prepare for any future hazardous events. We recommend the following:

- Establish a Community of Practice (CoP) to develop a long-term vision for accommodating a wide range of users of the creek corridor
- Utilize provided templates to develop a Pheasant Brach Restoration Communication Plan

Demographics, Preparedness, and Communication in Middleton

Visitors and residents deeply value Middleton's public lands, particularly the Pheasant Branch Conservancy and creek corridor. The 2018-2023 Conservancy Lands Plan included several components of public outreach: a review of past citizen surveys; a new online survey; engagement with two stakeholder groups (Friends of Kettle Ponds and Friends of Pheasant Branch Conservancy); and a public meeting for further citizen input. The conservancy and trails system were rated very highly in surveys. Public engagement sessions revealed high use of the public areas and concern for future conservation of natural areas. The 2018-2023 Conservancy Lands Plan included specific recommendations for expanding outreach to young people (under 18 and 18-29) in addition to an online portal on the city website to collect comments and input from the public.

Natural disasters reveal weaknesses in both physical infrastructure and social systems. Natural disasters also have a greater impact on what the NAACP calls frontline communities: "neighborhoods or populations of people who are directly affected by climate change and inequity in society at higher rates than people who have power in society". The August flood event brought the community together in solidarity and revealed gaps in communication. Racial and socioeconomic inequities exist in Middleton. Census data shows that while the city is generally economically healthy, factors correlated with stability including race, income, education, and home ownership, are unevenly distributed throughout city (Steichney et al., 2018).

Demographics Along the Pheasant Branch Corridor

The primary study area for the following two recommendations is the 3-mile section of the Pheasant Branch creek corridor that runs from Parmenter Street to Century Avenue. This section of the creek is entirely contained within census tract 111.01 in Dane County.

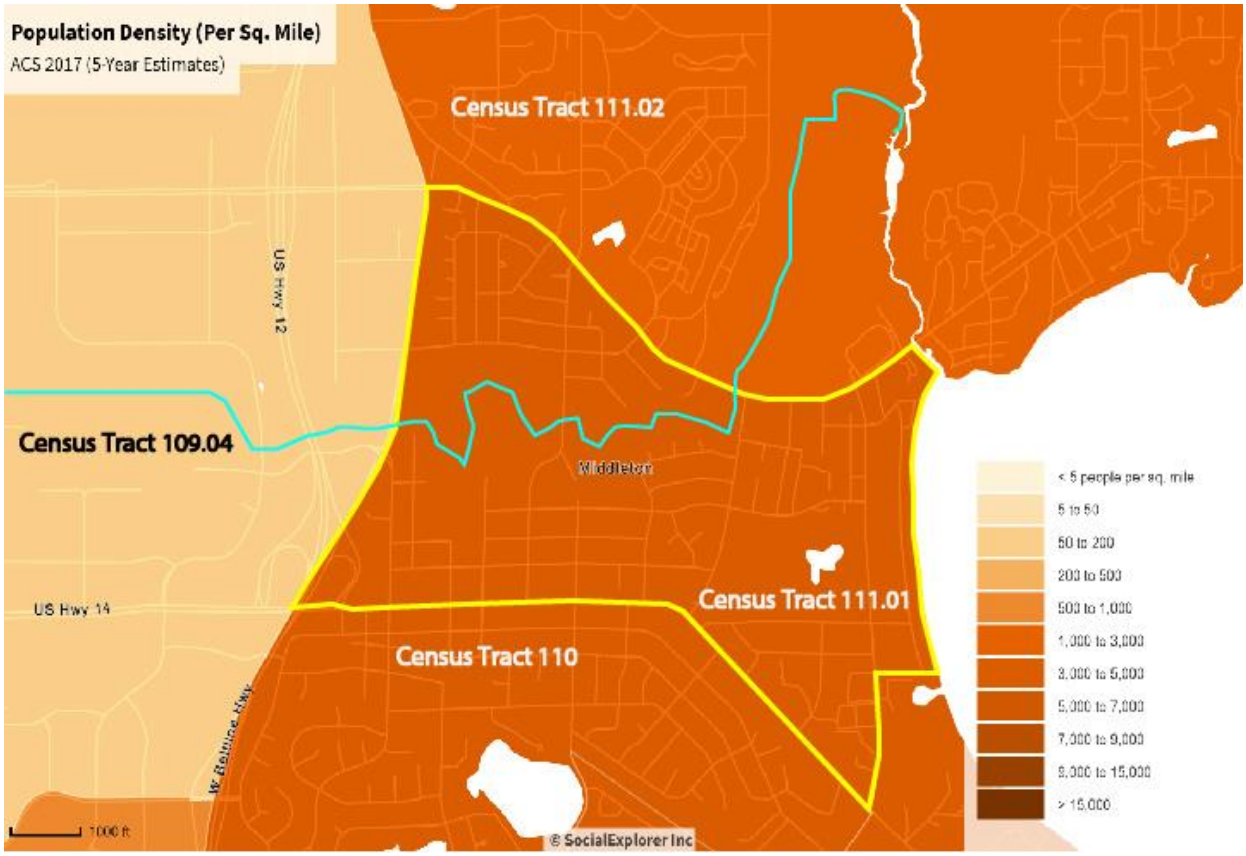

Figure 26: 5-year population estimates; American Community Survey 2017

Table 3: Key demographic information in Dane County; American Community Survey 2017

Data Category	Tract 111.01	Tract 111.02	Tract 109.04	Tract 110
Relation to creek corridor	**(central)**	**(north)**	**(west)**	**(south)**
Total Population	4,805	8,809	8,810	4,274
Density (people per square mile)	4,046.5	1,124.8	1,98.7	4,061.7
Race				
White	80.8%	84.3%	91.7%	84.3%
African-American/Black	12.9%	3.7%	0.4%	7.4%
Asian	2.4%	6.1%	6.3%	3.3%
Hispanic or Latinx	7.8%	4.5%	1.5%	1.6%
Education				
Completed HS or equivalent	96.5%	98.5%	97.7%	97.9%
Completed Bachelor's degree	43.5%	66%	61.9%	60.9%
Completed graduate degree	17.3%	29.7%	24.2%	28.9%
Completed professional school	7.3%	13.2%	11.9%	13.8%

Employment and Income				
Males age 16+ and employed	77.9%	72.2%	74.9%	69.7%
Females age 16+ and employed	76.2%	68.3%	69.1%	62.1%
Median household income	$50,117	$78,374	$120,967	$81,683
Housing and Transportation				
Renter-occupied homes	55.7%	36.2%	12.2%	40.6%
Use of public transport to work	12%	7%	0.7%	2.4%
Bike to work	0.5%	2.5%	0.4%	1.6%
Family Structure				
Age 15+ and married	41.5%	58.6%	73.2%	53.9%
Married with children	12%	20.8%	33.1%	18.3%
Single parent households	15.9%	8.8%	4.7%	10.2%

While users of the trail system and creek corridor come from all over Middleton and beyond, the demographic makeup of the area directly surrounding the corridor is unique. While the city overall is white and affluent, demographic data indicate people living in the area directly adjacent to the creek corridor are more likely to belong to a racial minority, more likely to live in rented homes, more likely to be single parents of children under the age of 18, less likely to have completed higher education, and more likely to have a lower annual income compared to the rest of Middleton. Residents in the creek corridor area are more vulnerable to disaster threats associated with flooding both because of their proximity to the creek and marginalizing factors such as income and race.

During the process of developing plans to restore and rebuild the Pheasant Branch creek corridor, the City of Middleton will need to address gaps in engagement and communication with the Middleton community. Public meetings to gather feedback and inform constituents about progress on infrastructure repairs to the corridor are an important part of the public engagement process, especially in the near future as the city moves forward with repairing bridges and trails. However, public meetings should be part of a larger strategy for engaging stakeholders and building public support for long-term restoration plans. Public buy-in is critical for ensuring success.

Current Emergency Management and Public Preparedness in Middleton

According to the U.S. Department of Homeland Security, disaster resilience is having the capability to adapt to changing conditions and prepare for, withstand, and quickly recover from disruption (USDHS, 2011). Establishing a Middleton Community of Practice with disaster preparedness and public awareness as its goals means cultivating, and drawing strength from, a community culture of resilience. In disaster events, official rescue teams may be unable to access sites and initiate operations for up to 72 hours following event onset (O'Leary, 2004). A community that shifts its expectations from relying on government workers and emergency response teams to relying on their own knowledge, skills and self-sufficiency during disasters is one that will minimize loss of life and property damage.

As a “home-rule” state, Wisconsin delegates its emergency management responsibilities to the lowest local level of governance. Currently, the responsibility to maintain the emergency mitigation and response plans resides with Dane County. Dane County maintains coordination efforts with its municipalities, including City of Middleton, and employs a network of public notification systems in the event of a disaster. However, a gap between the City and the community exists in public education and awareness facilitation caused by a lack of information integration at local levels. Disaster preparedness is most effective at the community level and the City of Middleton does not currently have a method to disseminate preparedness information from Dane County and other state and national emergency resources.

In addition to Dane County’s management services, Volunteer Organizations Active in Disaster (VOADs) coordinate membership at a state level and spring into action when disaster response is necessary. The American Red Cross is a prominent VOAD member in the Dane County area. They host training and certification classes that are well-structured but less accessible due to their fee-based enrollment. The group public-level engagement and training component through the Red Cross is limited. ReadyWisconsin, a statewide emergency management organization, provides education programs in public schools free of charge upon request. A coordinating body at a local level in Middleton is needed to promote and promulgate the disaster preparedness education that already exists.

Establishing a Community of Practice

We recommend that the City of Middleton Department of Public Lands, Recreation and Forestry intentionally build a Community of Practice (CoP) to develop a long-term vision for accommodating a wide range of users of the creek corridor. User accessibility includes considerations of the physical, engineered space (such as trails and bridges) as well as recreational opportunities and programming. Forming a CoP around user accessibility of the Pheasant Branch creek corridor and conservancy will serve three purposes:

- Increase accessibility and opportunities for different user groups of the creek corridor and conservancy areas
- Strengthen communication and understanding between stakeholder groups
- Build community resilience in the face of future natural disasters

The Pheasant Branch Conservancy and creek corridor are publicly-owned and therefore open and available to the entire Middleton community. “Middleton community” is intentionally a broad designation that is inclusive of all residents and frequent visitors to the city. Public open space that is situated in the middle of a city should accommodate a wide range of accessibility needs.

We acknowledge that there is already an active CoP in the long-standing relationship between the City of Middleton Department of Public Lands and the Friends of Pheasant Branch Conservancy (FoPBC) organization. FoPBC is a trusted organization in the community, and its members include experts in many fields, such as education, ecology, water resource management and local history. After the August 2018 flood event, donations to the FoPBC for restoration efforts significantly increased, and the

organization continues as a key partner to the city in communicating information about flood damage and restoration plans to the community at large.

Building a CoP would not replace the existing relationships between the City of Middleton and stakeholder groups. Rather, the CoP would expand and build on those relationships while providing a framework for a wide range of stakeholder groups to voice their needs and opinions as the City of Middleton develops a detailed restoration and recovery plan for the creek corridor.

Below is a definition for Communities of Practice from the UW-Madison Human Resources department website. The website has a wealth of in-depth and practical information about forming CoPs.

> "Communities of practice" are groups of people who share a concern or a passion for something they do and seek to learn how to do it better through regular interaction. They share three common elements:
>
> Domain: Communities of practice are identified by a shared area of interest or need. Membership implies a commitment to the domain and a shared competence that distinguishes members from other people. At UW–Madison, for example, a domain might be information technology, a specific HR function, an implementation response to emerging HR laws and regulations, or facilitating effective group processes, teaching and learning.
>
> Community: Communities of practice are comprised of people who share a sense of belonging. In pursuing an interest in a specific domain, members engage in joint activities and discussions, share information, and provide support to one another. They build relationships that enable them to learn from each other and care about their standing with one other. They may also experience conflicts whose resolution is supported by the community's sense of trust and respect.
>
> Practice: Members of a community of practice are practitioners. They develop a shared repertoire of resources: experiences, stories, tools, and ways of addressing recurring problems. At UW–Madison, they may share common functions (such as financial analysts or HR Managers) or skills and interests (such as leadership skills) which they seek to develop further. The practice model allows for the time and sustained interaction necessary to this development (UW-Madison Human Resources department).

The UW Human Resources website CoP worksheet notes five phases of development:

- Define your CoP
- Design your CoP
- Grow your CoP
- Let your CoP Perform
- Transform your CoP

Access to the worksheet templates from the UW Human Resources department website can be found in the *References* section of this report.

Our recommendations focus on the first two phases of development. The Community of Practice is intended to blossom in its own beneficial way, which is outside the scope of our report.

While it is up to a CoP to define itself, its members, and its goals, the following should be considered as guidelines:

Defining Goals

The CoP will define specific goals for itself. Broadly, however, their responsibilities will include:

- Ensuring accessibility for a wide range of user groups, interests, and abilities in the Pheasant Branch Creek corridor and Conservancy

  As public spaces, the conservancy and creek corridor serve a wide range of user groups. There are times the needs and interests of these groups come into conflict. While some see conflict as negative, the presence of conflict is an indication of how important the conservancy and creek corridor are to the community. If community members are invested in preserving and protecting public spaces, they may be more likely to be involved in reaching consensus on a plan for accessibility. By communicating and collaborating on a plan for user accessibility, the likelihood will increase that most or all needs are satisfactory and stakeholder concerns are addressed.

- Fostering educational and volunteer opportunities related to the Pheasant Branch Conservancy and creek corridor

  The Middleton community should strive to be educated caretakers of their public spaces and natural resources. Existing programs and partnerships with public schools, in particular Kromrey Middle School and Middleton High School, are an excellent starting point. In the past, students from Middleton High School have engaged in cross-curricular projects, from data collection to creative writing and photography, in the conservancy. The proximity of Kromrey Middle School to the creek corridor should make it ideal for hands-on science learning opportunities. Community education is another important component of the restoration and recovery process. As the city develops plans for urban and rural water storage, plantings in the corridor and so on, it is vital that the community be informed and involved. This will increase the volunteer base and build support and awareness of restoration plans. Additionally, individual property owners may be encouraged to implement best practices for flood resilience on their own properties.

- Codifying plans for communication, resource distribution and short and long-term recovery

  In the inevitable event of future natural disasters, ensuring that disaster response and recovery efforts are equitable and inclusive of all communities in Middleton regardless of race and income should be a priority. The template for a communication plan later in this section is a tool to aid in this process. The plan is designed specifically for restoration of the creek corridor and can be easily adapted for future needs.

Designing the Community of Practice

The following stakeholder groups could be considered for forming the CoP. This is not an exhaustive list, nor do we recommend that each group join the CoP right away. Rather, this list is intended to be a starting point for consideration of different stakeholders.

1. Local and county planning and government

The following stakeholders are responsible for managing public lands in and around Middleton. Additionally, City of Middleton departments and governing bodies have decision-making authority for planning and budget decisions related to the creek corridor.

- City of Middleton Department of Public Lands, Recreation and Forestry
- City of Middleton Conservancy Lands Commission
- City of Middleton Department of Planning and Zoning
- City of Middleton Plan Commission
- Middleton Common Council
- Dane County Parks and Recreation

2. Local conservancy and recreation groups

Local volunteer organizations are crucial for supporting public programs. They represent a variety of recreational interests and are a trusted source of information for their members. The Friends of Pheasant Branch Conservancy organization also includes committees that intersect with other user groups such as public-school students and the elderly community.

- Friends of Pheasant Branch
- Friends of Kettle Ponds
- Friends of Dog Parks
- Madison Audubon Society
- Capital Off Road Pathfinders (cycling group)
- Trail runners (organized through Berkeley Running Company in Madison)

3. Education and equity

Equitable access to outdoor learning and programming opportunities is critical to preparing young people for a future with climate change. The Pheasant Branch Conservancy and creek corridor provide invaluable outdoor learning opportunities for public school students in and around Middleton. Involving representatives from the public education sector in the CoP will help address institutional and physical barriers that prevent more student access to the conservancy and creek corridor. Additionally, larger urban-oriented organizations headquartered in Madison, such as the Urban League and Boys and Girls Club, have some interaction with groups of young people in Middleton and could provide program

opportunities in the creek corridor or conservancy. At the same time, equitable opportunities must exist for senior adults and those with limited mobility, dementia, and/or hearing and vision impairments. The 2018-2023 Conservancy Lands Plan includes a report by John Daly, the Vice President of the Friends of Pheasant Branch Conservancy Board of Directors, on the use of a $20,000 grant by the Friends of Pheasant Branch to develop programming in the conservancy for seniors with limited mobility and cognitive challenges (Daly, 2018). The outreach programming was developed in partnership with several groups such as the UW-Madison school of Nursing, the Alzheimer's and Dementia Alliance and local senior care centers.

- Middleton-Cross Plains school district
- UW-Madison School of Nursing
- Local senior care centers
- Alzheimer's and Dementia Alliance
- YMCA
- Boys and Girls club of Madison
- Urban League of Greater Madison

4. Disaster and Emergency Services

The following agencies need easy access to the creek corridor to respond to emergencies. The primary role of disaster and emergency services in this CoP should be to ensure that plans for the trail system include access for emergency and repair vehicles.

- Middleton Police Department
- Middleton Fire District
- Middleton EMS
- Dane County Emergency Management
- Madison & Dane County Public Health Department

Best Practices for Emergency Preparedness Education

The year following a disaster event is a window of opportunity for organizations looking to implement public education programs (FEMA, 2013). Community and political support for investing in emergency preparedness is often its highest within the year following the event. In planning for public engagement, the most effective public emergency preparedness education programs are consistent, long-term strategies that are built into existing community services and organizations. Engagement and training are best oriented toward four primary audiences: individuals, schools, government and businesses (Plough et al., 2013). The following best practices constitute a framework for beginning such programs. A Community of Practice in the City of Middleton should use these as guidelines to develop a custom plan specifically suited to community needs.

Identify Advocates and Establish a Public Education Committee

Building upon the relationships and skill-sets of stakeholders within the Community of Practice, the first step in creating a foundation for preparedness education programs is to identify potential advocates for community resilience (FEMA, 2013). The City of Middleton already staffs an Emergency Preparedness Commission and this group may be vital for emergency preparedness advocacy. Traditionally, advocates for emergency preparedness education are those who possess formal training or background in emergency preparedness, have time to devote to program building and have a natural enthusiasm for the subject. Advocates will fill the role of enlisting support from local officials and informal community leaders and will facilitate program coordination and planning.

Identify and Solicit Potential Partners

Maximizing program impact and long-term sustainability requires strong collaboration with organizations outside the public sector. Successful partnerships in disaster awareness public education programs include healthcare organizations, area nonprofits, and local businesses (Plough et al., 2013).

Both UW Health and UnityPoint-Meriter have clinic presences in the city of Middleton, are well-resourced organizations, and have a history of public education programs. UW Health also operates an emergency education center which provides training for emergency response. These organizations would be excellent partners in educational programming.

Well-established nonprofit organizations are an excellent bridge to the general public. Effective potential nonprofit partners show longevity in the community, a purpose/mission related to disaster preparedness, and a history of successful public engagement programs. Friends of Pheasant Branch Conservancy and the Clean Lakes Alliance are examples of two area nonprofits that fit this model.

Local businesses can be critical components in the long-term sustainability of public education programs. Sponsorship and promotion are two methods in which a firm in the private sector can assist emergency preparedness education. In addition to the qualities found in nonprofit partners, a firm with incentives to mitigate disasters and a history of supporting community efforts are key indicators of an effective potential partner. Businesses in the construction industry, insurance industry, environment or outdoor industries, and real estate industry may have a more vested interest in emergency management education than other industries due to the nature of their work.

Initiate Community Dialogue and Solicit Public Input

Once a public education committee is formed, public input should be sought early in the program development process. Understanding the concerns, fears and current knowledgebase of the community is essential in crafting a program tailored to its users. This is best accomplished through a public meeting where the committee presents the general concept of a preparedness education program and holds a genuine conversation with those present. While members of the community might not have technical expertise, they can help point out community assets, areas that might present problems and provide a narrative for disaster history in the area (FEMA, 2013).

Identify Existing Educational Resources

Fortunately, there is already an extensive body of disaster preparedness literature which has been developed into educational training and informational documents. The challenge has been trying to find

local groups to support the dissemination of this information to the public effectively. Local fire and police departments may offer safety programs to be delivered at schools. Dane County Emergency Management department maintains a website which includes a household emergency plan template, emergency contact information, notification systems information and more. Wisconsin Emergency Management Services offers preparedness training upon formal request. ReadyWisconsin.gov is full of excellent resources and has a school program called Student Tools for Emergency Planning (STEP) that they implement upon request. Consolidating these resources into a coherent educational program is a primary goal of the education committee.

Prioritize Equity and Identify Vulnerable Populations

Within every community, there are populations that are more susceptible to greater damage from natural disasters. As "The Good Neighbor City", Middleton should strive to encourage a cohesive community and that buildings resilience across all demographics. More vulnerable groups of people include the elderly, disabled, non-English speaking and low-income populations (Plough et al., 2013). Creating a program that is accessible and applicable to every citizen equally requires careful consideration and periodic evaluation to make sure messages are being communicated adequately.

Remember Businesses

Businesses in Middleton sustained a great deal of damage from the flood in August 2018. Most of the flooding occurred when commercial establishments were closed but some individuals report being forced to stay overnight due to the conditions outside. A key component of this education program should involve training for businesses on what actions to take if an event like this were to occur during business hours. The education committee should facilitate with existing educational resources. The Wisconsin Business Emergency Operations Center is in place to share resources between state agencies and the private sector during disasters and offers various trainings in preparedness. The Middleton Chamber of Commerce would be a good resource to connect Middleton businesses to training opportunities.

Pheasant Branch Corridor Restoration Communication Plan

The purpose of this communication plan is to inform and engage stakeholders of the Pheasant Branch Creek Corridor during the restoration process. This plan can also serve as a template for stakeholder communication in future projects throughout Middleton. Additionally, a robust communication plan will help ensure that the City of Middleton is connecting with members of the population that are traditionally more difficult to reach or less likely to have their voices heard, such as young people and historically marginalized groups. The 2018-2023 Conservancy Lands Plan indicated the need to reach community members under the age of 30 and utilization of social media is vital for the City to reach these traditionally underrepresented people in addition to other marginalized communities.

The outcomes of the Pheasant Branch creek corridor restoration and recovery process will have a significant impact on the corridor stakeholders. The historically strong voices among various stakeholder groups indicates the creek corridor is valued. In order to provide transparency and honor the stakeholders' commitment to Pheasant Branch, the community should have the opportunity to be involved in decision-making and be highly informed throughout the process.

The following Restoration Communication Plan includes three sections:

- Stakeholder Management Plan: Defines the stakeholders that should be kept updated through frequent and consistent dissemination of information
- Types of Communication: Identifies how certain types of information should be distributed to the community
- Staff Member Responsibilities Plan: Assigns staff members to various communication assignments; however, it is recommended that one staff member be responsible for all aspects of communication and serve as the main point of contact for that specific project

Pheasant Branch Corridor Restoration Communication Plan

Objective: To inform, educate, and involve the various stakeholders with the ongoing creek corridor restoration process

Communication Goals:

- Keep the stakeholders informed of project timeline, budget, and project needs
- Keep the public informed about potential safety hazards (such as structural damage or chemical contamination)
- Provide clear insight into any decisions, needs, or project roadblocks
- Provide structured opportunities for feedback from stakeholders
- Improve outreach to young people
- Improve outreach to marginalized groups

Scope of Plan: This plan is made specifically for Pheasant Branch Creek Corridor but is also meant to serve as a template for stakeholder communication in future projects.

Stakeholder Management Plan

The stakeholder management plan provides a systematic way of ensuring all user groups have access to information about the restoration process.

Table 4: Example of stakeholder identification sheet

Stakeholder	Contact Person	Points of Interests & Areas of Concern	Notes
Madison Audubon Society	Name: Email: Phone: Address:	*-natural habitat* *-minimal noise*	
Friends of Pheasant Branch Conservancy	Name: Email: Phone: Address:	*-restoration* *-conservation* *-education*	
Middleton Area School District	Name: Email: Phone: Address:	*-opportunities for involvement*	

Wheelchair/stroller users	Name: Email: Phone: Address:	*-paved trails* *-accessible bridges*	
Cyclists	Name: Email: Phone: Address:	*-accessible bridges* *-structured trails*	
Runners/walkers	Name: Email: Phone: Address:	*-preferences vary, but some enjoy rugged trails*	
Dog walkers	Name: Email: Phone: Address:	*-leash-free areas* *-varied trails*	
Other users	Name: Email: Phone: Address:		

The stakeholders listed are examples of user groups that could be included in decision-making processes. It is not an exhaustive list of user groups.

Types of Communication

City Website

Continue to use the City of Middleton website as a hub for all information, including updates, deliverables, and upcoming events.

Biweekly Newsletters

A biweekly newsletter sent out by email or mail that will include the following:

- Timeline and budget updates
- Completed projects
- Projects in progress
- Any roadblocks encountered
- Links to any deliverables

Weekly Newspaper Update

A short update on the restoration plan will be included in the Sunday paper of each week.

Progress Report Meetings

Meetings to be held when there are major updates or decisions that need to be made. The meetings will include one to two representatives from each stakeholder group and will allow for open discussion.

- Before meeting
    - Send out meeting agenda to stakeholder groups point contact
- Meeting format
    - Go through updates and decisions that need to be made
    - Allow for open discussion amongst stakeholders
- After Meeting
    - Email meeting notes to stakeholder groups point contact

Social Media

Utilization of the various social media platforms to disseminate everyday information on the restoration process.

- Facebook
    - Create an open group page for “Pheasant Branch Creek Corridor Restoration”
    - Post any upcoming events that are in relation to the restoration process
    - Post pictures of the corridor to show the progress being made and challenges being encountered
    - Check comments on page daily
- Twitter
    - Post the same information that is being posted to Facebook
    - Check replies daily
- Instagram
    - Focus on pictures of the corridor with information about the picture in the description
    - Check comments daily

Staff Member Responsibilities

For the sake of consistency and streamlining, a single staff member should oversee delivering and disseminating information to stakeholder groups. The template below shows the elements of communication divided into several tasks. In circumstances where the primary staff member responsible for communication is unavailable, a secondary individual should be assigned the role. This person could be another city staff member or an individual in the community that is highly knowledgeable of and connected to the specific project.

Table 5: Staff communication assignment sheet

Assignment	Staff Member Responsible	Frequency
Write and deliver newsletter	If unavailable, responsibility falls to:	Every two weeks
Write newsletter article	If unavailable, responsibility falls to:	Every two weeks
Prepare and deliver pre-meeting information	If unavailable, responsibility falls to:	As needed
Lead meeting	If unavailable, responsibility falls to:	As needed
Prepare and deliver meeting notes	If unavailable, responsibility falls to:	As needed
Post to social media	If unavailable, responsibility falls to:	Daily
Read and respond to social media comments and questions	If unavailable, responsibility falls to:	Daily
Keep website updated	If unavailable, responsibility falls to:	As needed

The Pheasant Branch Conservancy and creek corridor are treasured public spaces in Middleton. Experts in planning, engineering, and water resource management are responsible for codifying plans for rebuilding the creek corridor to be physically resilient to future flood events; however, community resilience is equally important for ensuring that Pheasant Branch remains a vibrant community asset for the foreseeable future. Building this resiliency requires effective collaboration and communication before disaster strikes again. Disaster preparation and recovery plans are far more robust, active, and well-received if they are developed within and by the communities who will benefit from them. Ensuring effective communication with stakeholders and community members is especially important when there are potential health hazards to the public that are associated with the creek corridor, such as structural damage to bridges, falling trees, and possible heavy metal and chemical contaminants from the flood. Strong communication and coordination about the creek corridor with the community is especially important; the census data indicates that the community around the creek corridor is more vulnerable than Middleton communities further from the creek (American Community Survey, 2017). These recommendations should provide the Middleton community with the tools needed to strengthen community resilience.

Summary of Community Resilience Recommendations

The following recommendations are based on demographic data and emergency preparedness best practices. Collaboration among Pheasant Branch creek corridor stakeholders needs to be solidified, especially as the City's population grows and climate change preparedness requires city-wide resiliency. These recommendations build on existing relationships between the city and volunteer conservancy organizations and expand on current public outreach efforts.

1. Establish Community of Practice (CoP) to develop a long-term vision for accommodating a wide range of users of the creek corridor. User accessibility includes considerations of the physical, engineered space (such as trails and bridges) as well as recreational opportunities and programming.

2. Utilize provided templates to develop a Pheasant Branch Restoration Communication Plan.

IV. Managing the Pheasant Branch Watershed

This section offers recommendations for reducing water volume throughout the watershed during future rain events. We recommend the following:

- Conduct field studies and monitoring to confirm our watershed analysis
- Prioritize areas in the Pheasant Branch watershed for restoration and conservation based on the engineering analysis
- Consider engineered water storage practices to augment existing watershed conditions
- Develop more advanced methods and models for volume estimations
- Protect identified flood mitigation and water storage areas
- Include the protection of water storage and flood mitigation areas in the Intergovernmental Agreement with the Town of Springfield

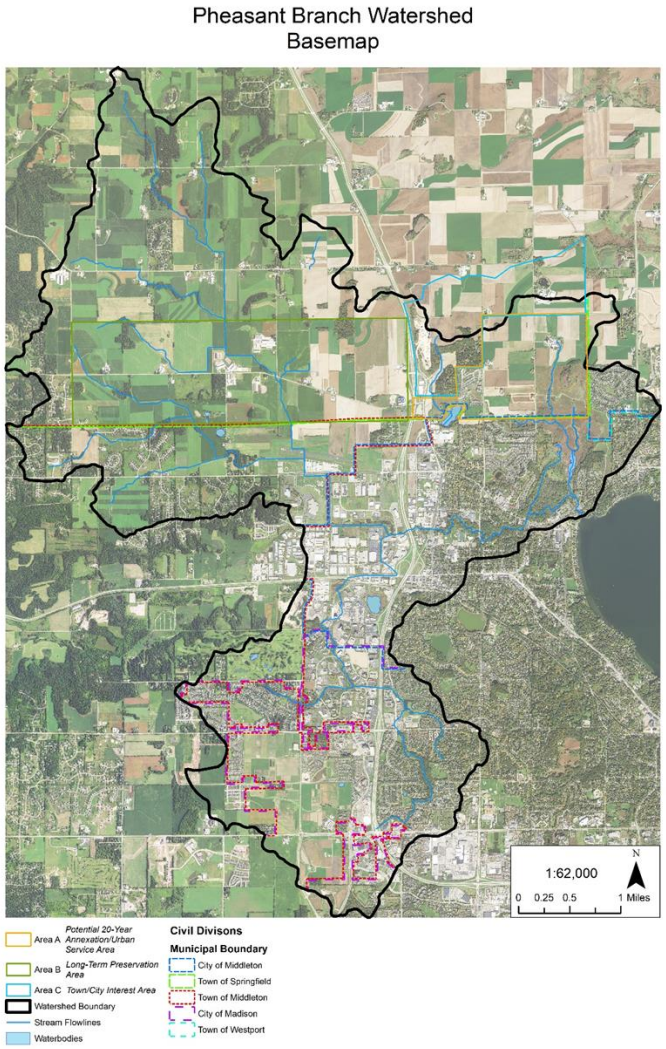

Figure 27: GIS map of Pheasant Branch Watershed

Understanding the Pheasant Branch Watershed

The Pheasant Branch watershed covers approximately 24 square miles within four different municipalities: the Town of Springfield, Town of Middleton, City of Madison, and City of Middleton. Historically, much of the Pheasant Branch watershed contained scattered wetlands in glacial depressions, and rainwater drained to a large wetland system that previously existed at the current site of the Middleton Municipal Airport. In the 1800's, early settlers altered the landscape to make it more suitable for farming by draining these wetlands and channelizing the stream to create what is now the North Fork of Pheasant Branch. This channel allowed the settlers to harvest peat from the glacial lake bed. The combination of modern urbanization, agricultural tiling, and the engineered channels greatly altered Pheasant Branch hydrology. Today, the drainage network is larger due to channelization and the connection of internally drained areas to the watershed. The watershed lost significant filtration and water storage, which increased stormwater runoff and increased the risk of downstream erosion and flooding (Friends of Pheasant Branch Conservancy).

West of the main creek corridor, where the majority of the damage occurred, the watershed is divided into two portions: The North Fork and South Fork sub-watersheds. Land use in the North Fork sub-watershed is largely agricultural with an extensive network of drainage ditches that empty towards the North Fork channel. Farmland in this portion of the watershed is among the best and most productive in the world. Land use in the South Fork sub-watershed is almost entirely urban and suburban. The South Fork channel acts largely as a stormwater drainage ditch, with little baseflow but flashy peak discharge during storm events. The North and South Fork channels converge just west of US Highway 12 into a man-made confluence pond, from which water drains eastward through the Pheasant Branch Creek main corridor towards Lake Mendota (Pheasant Branch Watershed Committee, 1999).

This section of the report focuses on the North Fork sub-watershed because of its primarily agricultural land use, where restoration of historic wetlands and the disconnection of internally drained areas from the watershed may be more economically feasible. Given the high degree of development in the South Fork sub-watershed, space for effective stormwater retrofits that could mitigate runoff and increase storage is limited. In the following section, you will find recommendations for residents and municipal officials in the Pheasant Branch watershed to both slow flows and create greater water storage during intense rainfall events. We performed Geographic Information Systems (GIS) analyses to identify potential water storage areas based on topography and potential flood mitigation areas including riparian and floodplain sites that are suitable for wetland restoration. Additionally, we identified areas for future annexation and development from the Town of Springfield to the City of Middleton.

Wetland Restoration in Practice

Wetlands can aid in flood mitigation and reduce downstream peak flows because they are able to act as natural sponges on the landscape. Wetland vegetation and soils trap water and release it slowly, while also distributing a given volume of water over a larger area. This absorption and dispersion reduces the total volume and speed of runoff during storm events (American Rivers, 2016).

An internally drained area (IDA) is a topographic depression on the landscape that forms a closed basin disconnected from the watershed. Rainwater that falls in an IDA cannot flow towards a surface water body due to the topography acting as a natural barrier. IDAs do not naturally contribute runoff during storm events because that water must infiltrate into the soils or evaporate. However, IDAs can be

artificially connected to the watershed via earth moving or subsurface tiling, which quickly drains IDAs and discharges the water to a drainage ditch.

Restoring historic wetlands that have been drained for agricultural purposes, or disconnecting IDAs that have been connected to the watershed can both be effective strategies for reducing runoff and increasing stormwater storage to mitigate downstream flooding and erosion, as happened within the Pheasant Branch creek corridor. Historically, the City of Middleton has focused their stormwater management efforts on implementing water quality and erosion control structures along and near the primary Pheasant Branch corridor. In the past 40 years, the City implemented over 100 stormwater management best practices including the confluence pond, detention basins, and gabions. These structures are successful in reducing suspended sediment and erosion during most rain events (Gerbert et al, 2012). The August 2018 event indicates a need for upland land management practices to reduce the volume and velocity of flow entering the corridor during large rainfall events. The addition of water storage basins and wetlands are meant to serve as long-term mitigation against recurring extreme flooding.

Flood Mitigation Case Studies

We identified two similar circumstances where significant post-event mitigation took place. We believe these cases are instructive due to their similarity to the Middleton flood event.

Middlebury, Vermont

In 2011, Tropical Storm Irene caused Otter Creek to overflow its banks, destroying 1,600 homes and washing out hundreds of bridges, culverts, and miles of roadway. In the community of Rutland, Otter Creek's peak discharge was 15,700 cubic feet per second (CFS) and flooding lasted for four days. However, the nearby community of Middlebury, just 30 miles downstream, did not suffer from flooding because wetland restoration and conservation has greatly benefitted and protected the community of Middlebury, VT during historic rain events. Here, the peak discharge was only 6,180 CFS (NRCSolutions, 2017b).

Upstream of Middlebury, wetlands were restored and protected to historic conditions using conservation easements. Through the Natural Resources Conservation Service's Agricultural Conservation Easement Program, Middlebury identified agricultural land that was suitable for functioning as floodplain wetlands, as well as land that could be used to connect existing wetlands. Willing landowners could sell conservation easements, protecting the land as wetlands in perpetuity and retiring it from agricultural protection. In exchange, land owners received financial and technical assistance. Thus far, the program has purchased 23 conservation easements along Otter Creek and protected 2,148 acres of wetlands. The majority of these are small sites, though the largest is a 500-acre wetland complex (NRCSolutions, 2017b).

These wetlands reduced flood damages in Middlebury during Tropical Storm Irene by 84-95%, and in a study of 10 different large storm events, they reduced damages on average by 54-78%. The cost savings for Middlebury are estimated to be $126,000-$450,000 per year (Watson et al, 2016).

Portland, Oregon

In Portland, OR, the Johnson Creek floodplain was historically forested, but much was lost to development. Due to clearing and development on the floodplain, the Foster Road area adjacent to Johnson Creek suffered almost-yearly flooding. Dozens of attempts to mitigate flooding since the 1930's, including channelizing a section of the river, have not been successful.

In 1997, Portland City Council implemented its Flood and Landslide Hazard Mitigation Plan to restore the floodplain and recapture its natural flood mitigation properties. After buying out and clearing 70 structures from the floodplain, Portland began wetland restoration activities. First, 50,000 cubic yards of soil were removed from the floodplain that had been deposited during flood events over the years. Then, 63 acres of wetlands and natural habitat were restored through native plantings, stream bank stabilization, and restoring sinuosity to the channelized portion of the stream (NRCSolutions, 2017a).

The Johnson Creek floodplain restoration project was funded largely by federal grants, with $2.7 million from FEMA and more from HUD Community Development Block Grants. Some of the funding came locally from City of Portland stormwater utility funding (NRCSolutions, 2017a).

Overall, the project was a success. In 2012, Johnson Creek rose to two feet above its historic flood stage, but the wetlands and natural habitat along the floodplain absorbed the flood water and prevented it from spilling over onto roads or in to residential areas. Over the course of 30 years, the project's benefits are estimated to be worth over $30 million because of avoided flood damage, utility damage, and the habitat and open space benefits it provides (NRCSolutions, 2017a).

Funding Wetland Restoration Work

Funding sources across different levels of government connected to wetland restoration and conservation can be used for mitigation efforts. Several of the provided wetland programs relate to improved water quality and wildlife habitat, which would be expected secondary outcomes as land transitions to wetlands in the Pheasant Branch watershed.

Federal Programs

Hazard Mitigation Grant Program (HMGP)

The August 2018 flooding was declared a major disaster by the President; therefore, the City is eligible for HMGP funding to implement plans of long-term flood mitigation. The HMGP would provide funds up to 75% of the flood mitigation plans.

Farmable Wetlands Program (FWP)

The FWP supports farmers in transitioning cropland into wetlands to improve downstream flooding, which directly relates to outlined water storage efforts in this report. Farmers can apply to the FWP and receive annual rental payments, with contracts lasting 10-15 years. FWP is administered by the United States Department of Agriculture (USDA).

Conservation Reserve Program (CRP)

The CRP helps farmers take agriculture land out of production and plant wetland species in exchange for annual rental payments, with contracts lasting 10-15 years. This USDA-administered program aims to manage soil erosion, wildlife habitat, and water quality.

Watershed Protection and Flood Prevention Program

This Program promotes land conservation in watersheds to prevent floodwater damage. For the Pheasant Branch watershed to be eligible for funding under the Program, at least 20% of all benefits stemming from the project plan must directly benefit agriculture and rural communities. The project must have public sponsorship to secure funding.

Wetland Reserve Easements

The Agricultural Conservation Easement Program offers multiple funding opportunities that fully or partially fund wetland restoration and easements. Under different easement options, the Natural Resources Conservation Service (NRCS) pays a percentage of the easement purchase, as well as a percentage of the restoration costs. Both permanent and term easements are available.

State Programs

Wisconsin Department of Natural Resources (WDNR)

The WDNR provides technical and financial assistance for landowners engaging in wetland restoration efforts. Additionally, it supports landowners who currently have wetlands on their property in ongoing management and enhancement efforts (Thompson & Luthin, 2010).

Wisconsin Wetland Conservation Trust

Through the WDNR, project funds are available by service area (the Pheasant Branch is in Rock area) through an in-lieu fee mitigation program that provides grants for wetland restoration and enhancement projects. One of the main goals of the program is to restore lost historical wetlands. Specifics regarding the current available funds and how to apply, as well as grant guidance, can be found on the WDNR website.

County Programs

Dane County Land Conservation

Through the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) grant funds are available for adopting conservation practices and implementing water diversion management.

Dane County Annual Budget

Dane County Executive Joe Parisi set aside 2019 funds to mitigate future flood impacts. A portion of this funding specifically supports the transition of agricultural land into conservation with goals pertaining to reducing stormwater runoff. This program is modeled after the Conservation Reserve Program.

Additional Project and Funding Considerations for the Watershed

An MSA Report conducted for the City of Middleton Water Resources Management Commission in August 2018 estimates the cost of land per agricultural acre in the Town of Springfield is $12,000 (Felland & Thompson, 2018).

The total cost of wetland restoration, of breaking/modifying artificial drainage to restore natural hydrology, and of on-going maintenance expenses to manage the wetlands and water basins should be considered in final project and funding plans.

Dane County supports several Yahara watershed programs (Yahara WINs, Yahara CLEAN) to reduce phosphorus runoff and improve water quality. While the restoration of wetlands and increased water storage capacity on the agricultural farms is expected to enhance water quality, this report and associated funding only considers the primary goal of water storage.

A portion of the City of Middleton Stormwater Utility funds could be used to purchase conservation easements in the Town of Springfield.

Similarly, The Friends of Pheasant Branch Conservancy could contribute collected donations to fund conservation easements and water storage projects outlined in the report.

Current Water Storage Agreements and Codes

The 2004 Intergovernmental Agreement between the Town of Springfield and the City of Middleton focuses on future development areas and transitioning land from agricultural to residential to serve the growing population and housing demand (City of Middleton, 2004). Patterns and timing of future development are outlined in the Agreement, addressing shared goals of providing seamless services and utilities to residents, not out-pricing agricultural land, and promoting the economic benefit of land use for both communities. The Agreement also establishes “joint planning and cooperation in the management and control of stormwater” (Section 4.04) and reviews shared stormwater responsibility within the Pheasant Branch watershed (Section 12). The Town of Middleton and City of Middleton have committed to work with the United States Geological Survey (USGS) and the Water Resource Management Commission in identifying areas that would improve water quality through infiltration management.

While action can be taken outside the city, the City of Middleton can also adjust water storage in the city. The City of Middleton’s stormwater ordinances focus on stormwater storage on new development and redevelopment sites but do not mention any initiatives to retroactively add stormwater storage capacity to current parcels. Pre- and post-development stormwater runoff estimates that guide the city’s ordinances are based on historical precipitation events from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 guidance. This standard does not consider prospective climate change expectations of higher frequency and severity of precipitation events. Existing drained areas are unregulated by Dane County stormwater ordinances; addressing these areas would be the most comprehensive approach to reduce downstream inflow and flood damage.

Methods of Analysis

We collected GIS data from the sources detailed in Table 6 and imported them into ESRI ArcGIS software. We created a scorecard to rank soils based on their drainage capability, quality of farmland, and other factors. The ranking system was then applied to the GIS data.

Data Acquisition

Table 6: Publicly available geospatial data gathered for use in this GIS based analysis and its source

Data Type	Source	Year	Specific layer information
Aerial Imagery	US Department of Agriculture (USDA)	2015	Dane County National Agriculture Imagery Program (NAIP) orthophoto
Boundaries	US Census Bureau	2017	Civil Divisions
Elevation	Dane County	2017	Dane County Digital Elevation Model (DEM)
Hydrology	Wisconsin Department of Natural Resources (WDNR)	2017	24K Hydrology Database (flow paths, junctions, waterbodies, watersheds)
Land Cover	WDNR	2016	Wiscland 2.0 level 4 (most detailed)
Parcels	Dane County	2016	Dane County Parcels
Soils	USDA, Natural Resources Conservation Service (NRCS)	2014	NRCS Wisconsin Soils
Wetlands	WDNR	2016	Potentially Restorable Wetlands
Wetlands	WDNR	2019	Wisconsin Wetland Inventory
Wetlands	Capital Area Regional Planning Comission (CARPC)	2019	Internally Drained Areas (IDAs)

Data Processing

All geospatial data were imported to ArcMap 10.6 and placed into a projected coordinate system (NAD_1983_HARN_Wisconsin_TM) with linear units of meters. Data were then clipped to the Pheasant Branch watershed using the HUC 12 watershed layer. This method greatly reduced the size of many of

the large datasets to ensure shorter processing times as well as making sure all data layers were in the same coordinate system for analysis. The other major data processing step was creating contours and hill shade from the Wisconsin Digital Elevation Model (DEM) layer for analysis of slope and terrain within the Pheasant Branch watershed.

Data Analysis

Potential Flood Mitigation Areas and Potential Water Storage Areas

The analysis for this assessment of potential water storage and flood mitigation areas in the Pheasant Branch watershed is soils-based. The Natural Resources Conservation Service (NRCS) soils data includes ratings for a soils' drainage, its hydrologic soil group, and its farmland class. Drainage is measured by the NRCS on a scale from excessively drained to very poorly drained. The hydrologic soils groups range from 'A' through 'D' with 'A' being soils with high infiltration and low runoff potential and 'D' being soils with low infiltration and high runoff potential. Farmland class is rated from prime farmland to not prime farmland with distinctions of farmland that has been drained and is currently protected from flooding. In our analysis these classifications were ranked as either highly desirable, desirable, less desirable, or restricted (Table 7).

Table 7: Soils-based ranking scorecard

Soils-Based Storage Analysis				
Desirability	Highly Desirable	Desirable	Less Desirable	Restricted
Score	3	2	1	0
Soil Drainage Class	Excessively drained, somewhat excessively drained, well drained	Moderately well drained	Somewhat poorly drained	Poorly drained, very poorly drained
Farmland Class	Not prime farmland	Farmland of statewide importance, prime farmland if drained and either protected from flooding or not frequently flooded during the growing season	Prime farmland if drained, prime farmland if protected from flooding or not frequently flooded during the growing season	All areas are prime farmland
Hydrologic Soils Group	A	B	C	D, A/D, B/D, C/D
Soil Analysis Value	Average of three soil classification scores			

We calculated the average of these desirability rankings to determine a final score based on soil characteristics per soil type in the analysis. We then mapped these scores onto the WDNR layers for internally drained areas (IDAs), potentially restorable wetlands (PRWs), and existing wetlands in order to visualize the most and least desirable water storage and flood mitigation areas.

With soil desirability scored, we then overlaid Potential Flood Mitigation Areas (PFMAs) and Potential Water Storage Areas (PWSAs) with Dane County parcel data to identify landowners who own land contained in these identified areas. This parcel overlay was completed to facilitate future contact by the City or Town of Middleton for potential sites.

Volume Estimation of Potential Water Storage Areas

Volume estimation of PWSAs is based on the soil properties of the identified areas and excludes land that is designated as farmland.

Prior to volume estimation, the Pheasant Branch watershed DEM layer was first divided and clipped into seven smaller zones, where PWSAs were identified.

To estimate volume, 1-foot topographic contour lines were first generated from the clipped DEM layer. Appropriate contour lines were then chosen by visual examination to represent the boundaries of PWSAs in the area of interest. This process was necessary because our analysis only considered soil properties for holding water thereby leaving out topography. By identifying proper contour lines, we located specific places that we expect will hold water under existing conditions (i.e. without engineering structures) within previously identified areas. Volume below the elevation of the selected contour line was calculated based on the extracted DEM. Parcel data (e.g. parcel ID, landowners, site coordinates and site address if available) for parcels located within the boundaries of PWSAs were identified to facilitate future contact regarding these potential sites (Appendix L).

Results of GIS Analysis

PFMA and PWSA Identification Results

We conducted two analyses based on soil drainage class and soil hydrology data identifying potential water storage and flood mitigation areas.

The first analysis considers farmland class (land use) in the desirability score (**Analysis 1**). This analysis restricted prime farmland as potential sites by giving it a score of zero. This analysis identified approximately 195 acres of PFMAs and PWSAs in the Pheasant Branch watershed (Table 8). Both detailed and simplistic land cover classifications were identified for the 195 acres (Tables 9 & 10).

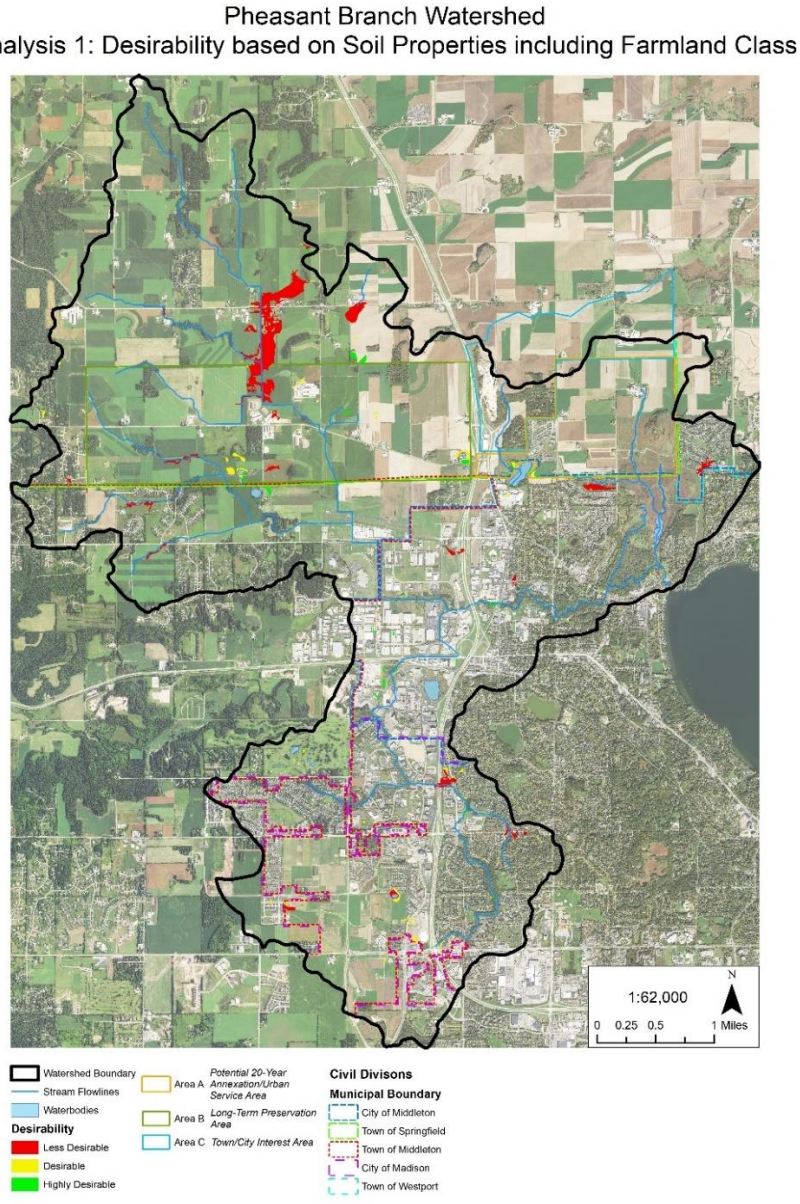

Figure 28: GIS representation of Analysis 1

The second analysis removed the farmland classification to identify the limitations this variable introduced when identifying water storage in the watershed (**Analysis 2**). This non-land-use-restricting analysis identified approximately 738 acres of PFMAs and PWSAs in the Pheasant Branch watershed (Table 8). Both detailed and simplistic land cover classifications were identified for the 738 acres (Tables 9 & 10).

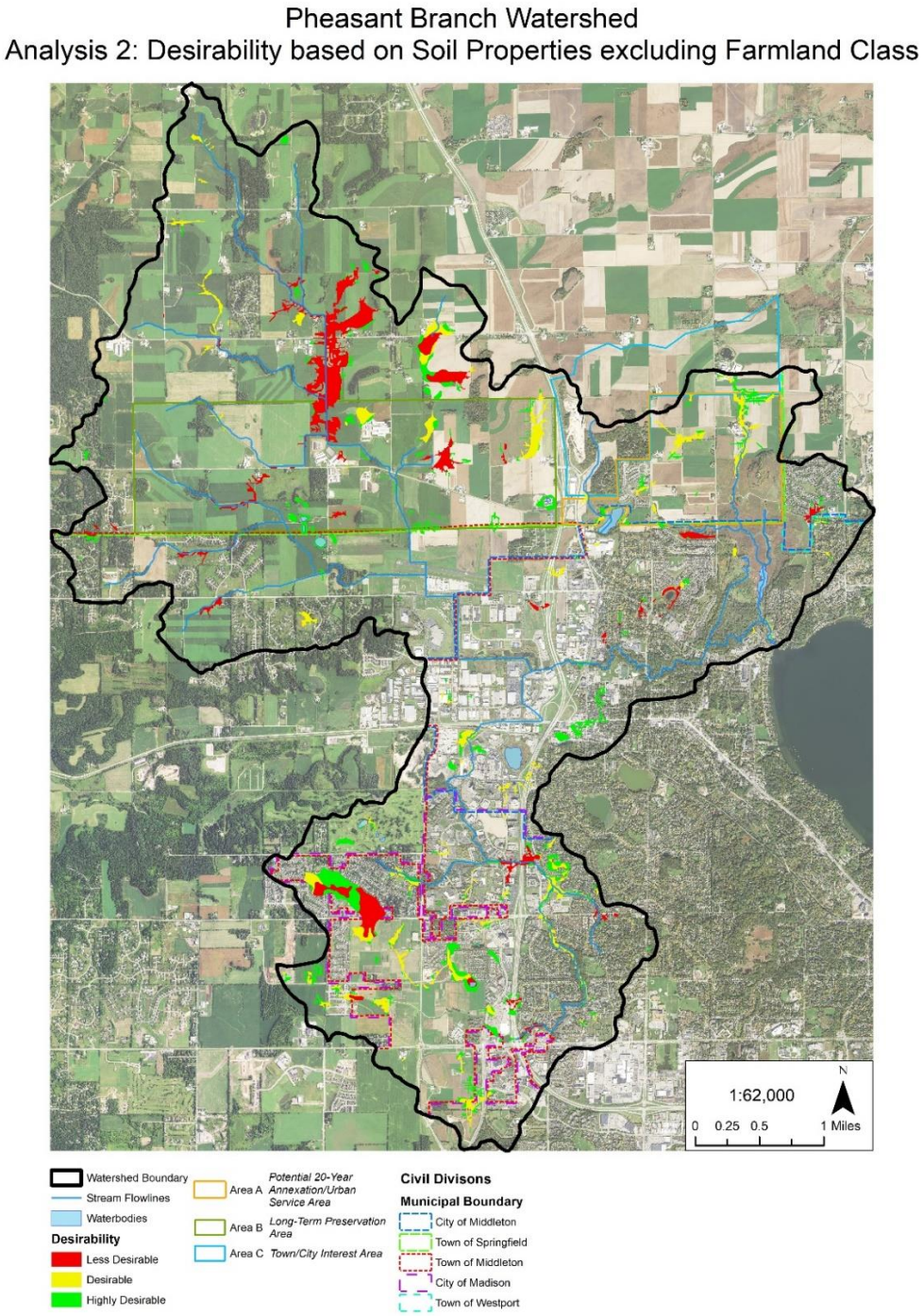

Figure 29: GIS representation of Analysis 2

Table 8: Potential PFMA and PWSA sites

Soils Analysis Results		
Analysis 1: including Farmland Class		
Desirability	**Count of PFMAs and PWSAs**	**Total Area (acres)**
Less Desirable	52	153.73
Desirable	97	25.84
Highly Desirable	63	15.30
Totals	**212**	**194.87**
Analysis 2: excluding Farmland Class		
Less Desirable	102	283.73
Desirable	160	217.64
Highly Desirable	540	237.09
Totals	**802**	**738.47**

Table 9: Land coverage of potential PFMA and PWSA sites

Detailed Land Cover Classifications in Soils-Based Analysis		
Analysis 1: including farmland class		
Detailed Land Cover	**Count of PFMAs and PWSAs**	**Total Area (acres)**
Cash Grain	8	11.01
Central Hardwoods	9	0.23
Continuous Corn	23	43.80
Cool-season Grass	6	3.11
Dairy Rotation	65	78.22
Developed, High Intensity	59	14.42
Developed, Low Intensity	86	19.26
Hay	18	14.78
Open Water	8	1.56
Other Bottomland Hardwoods	11	4.35
Other Broad-leaved Deciduous Scrub/Shrub	2	0.02
Other Swamp Hardwoods	5	1.36

Pasture	3	0.15
Warm-season Grass	14	2.50
White Oak, Burr Oak	2	0.11
Totals	**319**	**194.87**
Analysis 2: excluding farmland class		
Buckthorn/Honeysuckle	3	0.08
Cash Grain	62	63.80
Central Hardwoods	27	10.61
Continuous Corn	83	145.71
Cool-season Grass	13	4.78
Dairy Rotation	228	203.71
Developed, High Intensity	259	108.22
Developed, Low Intensity	314	109.68
Hay	53	36.11
Open Water	34	19.90
Other Bottomland Hardwoods	13	5.36
Other Broad-leaved Deciduous Scrub/Shrub	3	0.03
Other Emergent/Wet Meadow	5	0.26
Other Northern Hardwoods	6	0.92
Other Swamp Hardwoods	5	1.36
Pasture	51	18.42
Red Oak	4	0.37
Reed Canary Grass	5	2.98
Shrubland	2	0.09
Warm-season Grass	34	5.96
White Oak, Burr Oak	2	0.11
Totals	**1206**	**738.47**

Table 10: Simplified land coverage of PFMA and PWSA sites

Simple Land Cover Classification in Soils-Based Analysis		
Analysis 1: including farmland class		
Simple Land Cover	**Count of PFMAs and PWSAs**	**Total Area (acres)**
Agriculture	7	133.03
Forest	7	0.34
Grassland	20	20.54
Open Water	3	1.56
Urban/Developed	10	33.67
Wetland	1	5.74
Totals	**48**	**194.87**
Analysis 2: excluding farmland class		
Agriculture	13	413.22
Forest	10	12.01
Grassland	55	65.27
Open Water	12	19.90
Shrubland	2	0.09
Urban/Developed	20	217.78
Wetland	6	10.08
Totals	**118**	**738.35**

Volume Analysis Results

Our PWSA volume analysis within the Pheasant Branch watershed (**Analysis 3**), identified approximately 1700 acre-feet of available water storage (Table 11). These identified PWSAs have a total surface area of 182.1 acres. We identified seven zones that include PWSAs that are either in the North Fork or South Fork of Pheasant Branch and all are outside the municipal boundary of the City of Middleton (Figure 30).

The seven identified PWSA zones have varying soil desirability with storage capacity trade-offs that are linked by PWSA surface areas. For example, the PWSA in zone 4 almost entirely sits on highly desirable soils, yet it could only store a moderate amount of water due to its moderate acreage. PWSA in zone 2 provides similar storage capacity but with less desirable underlying soils. Both PWSAs in zone 1 and 5 are composed of soils ranging from the less desirable to highly desirable category. Their storage volume, however, are the two greatest because of their large surface areas. PWSAs in zone 3, 6, and 7 have minimal storage capacity even though they may be located on desirable or highly desirable soils simply because of small surface areas.

Pheasant Branch Watershed
Analysis 3: Potential Water Storage Areas based on Soil Properties excluding Farmland Class

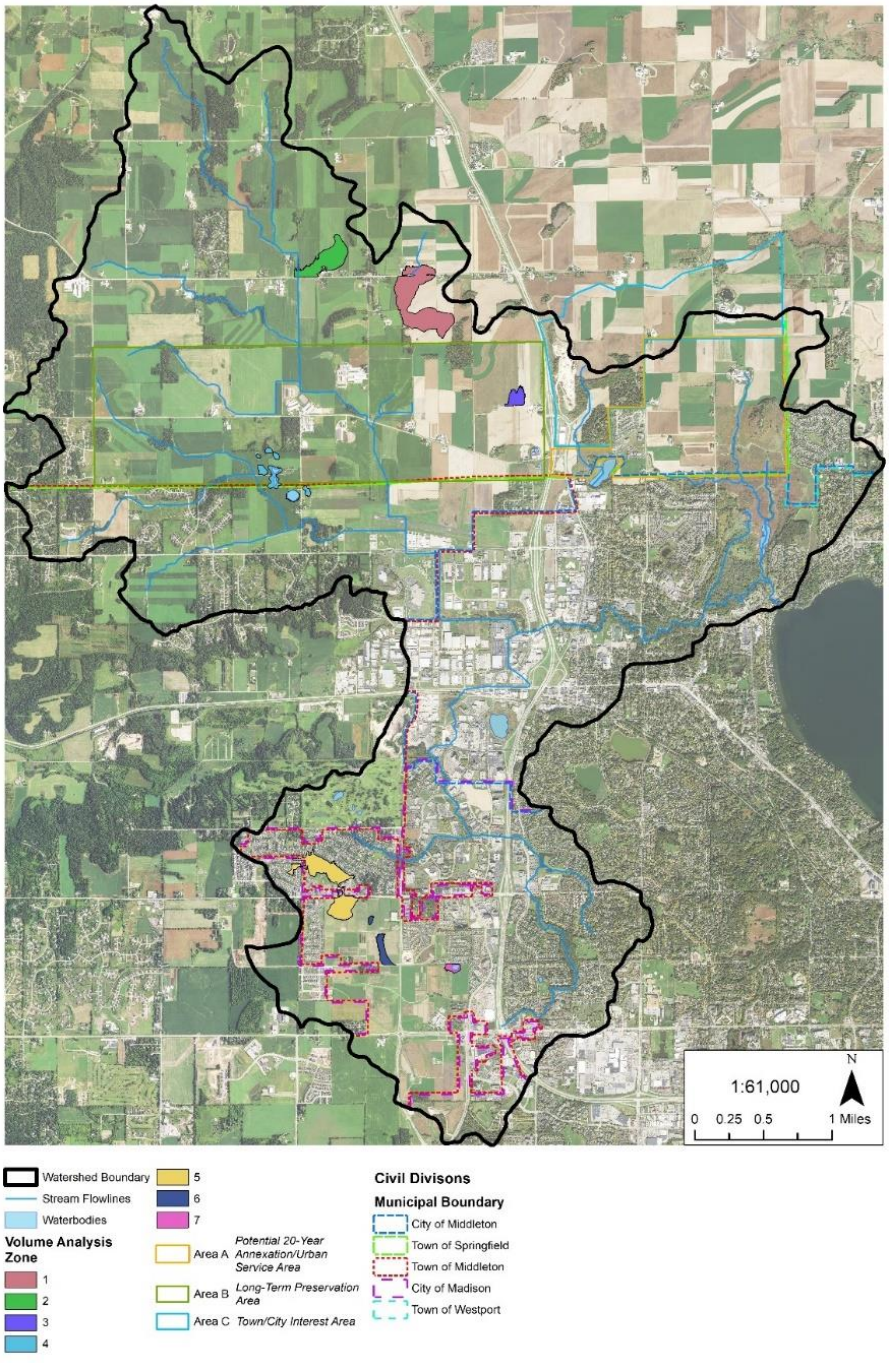

Figure 30: GIS representation of Analysis 3

Table 11: Potential water storage volume of identified PWSA sites

Analysis 3: PWSAs Volume Analysis		
Zone	**Area (acre)**	**Volume (acre-ft)**
1	66.8	778
2	31.4	136
3	8.4	16
4	17.5	170*
5	45.4	548
6	8.8	24
7	3.8	2
Total	**182.1**	**1675**

Limitations in Analysis

The purpose of conducting Analysis 3 was to build on the soil drainage assessment completed in Analysis 2. Analysis 3 was not conducted on small parcels identified in Analysis 2 because we assumed they will not provide a significant volume of storage; although, we acknowledge storage volume could be large when a small surface area is profoundly depressed. Infiltration was also not accounted for in estimating storage volume in Analysis 3. All estimations assume water ponds on impervious surfaces. However, if PWSAs lie on highly drained soils, storage volume could potentially be higher than our estimations because a portion might be able to drain through the soil.

Based on soil drainage only, Analysis 2 might identify urban areas as potential PWSAs or PFMAs. However, urban environments such as residential areas have distinct contour patterns that destroy their ability to serve as water storage areas (PWSAs). Our analysis did not estimate how much water could have been stored in pre-development conditions for current urbanized areas. For example, Analysis 2 identified PWSAs with large areas of suitable soils in Zone 7. Yet this Zone's surrounding urban land use restricts where a pond could locate and limits its extent. Therefore, only a PWSA with a surface area as small as 3.8 acres was identified in the south part of Zone 7, where it is currently farmland. Realizing that some identified PWSAs would be eliminated if Analysis 3 was based on Analysis 1 (including farmland class) instead of Analysis 2 (excluding farmland class), we based Analysis 3 on the assumption it would be possible to convert farmland into wetlands or other flood mitigation infrastructure if we know that considerable benefits exist.

In Analysis 3, one or more contours may have been chosen to overcome the highly irregular shape of the identified area. In some cases, the best contour line selected may extend beyond boundaries of areas that were previously identified, and therefore storage volume may be overestimated in these areas. As outlined in our Recommendations, we intend for additional investigation and engineered modeling to be performed to validate our results.

Discussion of Results

GIS Analysis

Our GIS based analysis of the Pheasant Branch watershed sought to identify areas that may be suitable as PFMAs or PWSAs. To reiterate, PFMAs are those which will act to slow precipitation runoff velocities and may provide some amount of infiltration based on soil properties while PWSAs will act to store water based on the topography of the land while also providing some degree of infiltration based on soil properties.

The Pheasant Branch watershed has an approximate area of 14,400 acres. Analysis 2 identified approximately 5% (738.35 acres) of this watershed area to be suitable as PFMAs or PWSAs. The restriction of farmland classification in Analysis 1 identified approximately 1% of the watershed area (194.87 acres) to be suitable for either PFMAs or PWSAs. Despite the fact that only 1-5% of available land in the watershed would be suitable for water management, our case studies show that locating wetland restoration and conservation in strategic areas has a significant impact on flood mitigation.

The inclusion of farmland class is the primary reason for the disparity in the total area identified in Analysis 1 and 2. Farmland class is determined by soil type and characteristics not land use. Therefore, many of the areas that were identified in Analysis 2 were considered as having some degree of potential for agriculture even if they have been urbanized. Clearly, these urban areas that were classified as having appropriate soils for agriculture will not be able to accommodate agricultural land uses but they may be able to be used as a PFMA or PWSA in some instances. In Analysis 1 the majority of PFMAs and PWSAs were deemed less than desirable due to the inherent excellence of soils in the watershed in terms of agricultural production. The soils in this region of Wisconsin are some of the most agriculturally productive in the world. Therefore, based on the ranking system used in Analysis 1 it is unsurprising that many of our identified areas were less desirable when we take this into account. However, we removed this classification when calculating Analysis 2 for several reasons.

Based on the original motivation for this project, the historic flooding in August 2018, the City of Middleton has a clear need to mitigate the impact of what is likely to be a more common event in the future. Restoring some of the existing farmland back to pre-settlement land uses should be considered a viable option for mitigating downstream impacts of large precipitation events. PFMAs and PWSAs can be part of the solution and need to be under consideration. Additionally, we wanted to understand the current state of PFMAs and PWSAs without considering farmland class because of the anticipated and planned land use changes in the watershed. Many of the identified PFMAs and PWSAs are located where increasing pressure for residential and commercial development exists, especially in some of the areas north of the City of Middleton.

In terms of land cover classifications of the identified PFMAs and PWSAs and the total area (acres) each land cover classification occupied, we noticed some trends in Analysis 1 and 2. The majority of agriculture land in the watershed is used for dairy rotation and cornfields. The next largest increases in area came from the high- and low-intensity developed land cover classes. To reinforce what was previous mentioned, much of the developed area in the watershed suitable for potential PFMAs and PWSAs is urbanized and has soils classified as suitable for agriculture. Clearly there are many tradeoffs to consider when making decisions about watershed stormwater management when coupled with inevitable land use change.

Development of PFMAs and PWSAs weaken their ability to mitigate floods and store water. The City of Middleton should consider effectively managing the identified areas when planning for expansion north of the city. The results of Analysis 2 are much more evenly distributed among the desirability rankings than Analysis 1. Analysis 2 desirability rankings for PFMAs and PWSAs should be considered the standard as land use in this watershed continues its transition from agricultural to urban land use.

Any amount of slowing or storing flows will have a positive mitigating impact in the Pheasant Branch watershed and even though some of these potential areas may seem small or less than desirable, every drop of water that is either slowed or stored may reduce the overall watershed response to a precipitation event.

Potential Water Storage Areas

Compared to the approximately 738 acres identified in Analysis 2, only 182 of those acres were deemed suitable for any water storage without engineering infrastructure. Of the 182 acres of identified PWSAs, we observed variability in their water storage capacities. Some store as little as two acre-feet of water, but two of the PWSAs provide a significant amount of storage. The first of which is the PWSA we identified in Zone 1 in the North Fork of Pheasant Branch. With a surface area of 66.8 acres, it can potentially store the greatest amount of water (778 acre-feet) when compared to the capacities of the other PWSAs. The second large capacity zone, the City of Madison's Blackhawk Park identified as Zone 5, has a potential storage volume of 548 acre-feet. A large portion of this PWSA is surrounded by residential housing, making it the only one of all seven PWSAs that sits in an urban environment.

Although Zone 1 aligns well with the area identified in Analysis 2, it is not a good match to what is identified in Analysis 1. According to Analysis 1, the potential area is merely a small portion of the result of Analysis 2 and of the PWSA basin. This mismatch is a common issue for several of the identified PWSAs including PWSAs in Zones 2, 4, and 7. However, other areas from the results of Analysis 1 and 2 are well overlaid, demonstrating feasible areas for potential water storage and peak flow mitigation. These areas may not be included in Analysis 3.

Though PWSAs are only a small portion of what was previously identified as suitable for water storage, we speculate PFMAs could play an important role in mitigating flood hazards. For example, both Analysis 1 and 2 have identified a large area along the stream channel of the North Fork of Pheasant Branch. Given this large surface area, peak flows could be effectively slowed.

Priority Storage Areas

When considering all three of our analyses together, PFMAs and PWSAs may be prioritized in the Pheasant Branch watershed. However, determining how or where to utilize a PFMA or PWSA requires some considerations.

If the goal is to prevent water from entering the watershed a PWSA like those we identified should be considered. PWSAs should be prioritized primarily by storage capacity (volume) then by drainage capacity followed by restoration feasibility and overall cost. Storage capacity is most important because the larger the volume that can be stored the larger potential reduction in peak flow. Drainage is also very important because once a PWSA is full only infiltration or evaporation can resupply the capacity of the PWSA to store water. Feasibility of appropriate wetland vegetation restoration is slightly less important for PWSAs because if the PWSA in question has the appropriate topography and drainage it

will be able to store water; wetland vegetation is an added co-benefit for water quality and habitat improvement. Of course, cost must also be evaluated but the aforementioned items determine if a PWSA should even be considered for cost estimates.

If the goal is to reduce peak flow by slowing runoff, PFMAs may be more appropriate. PFMAs should be primarily prioritized by size (surface area) and restoration feasibility. We consider surface area to be the most important factor in PFMAs because the longer the distance between the stream channel and the edge of the PFMA, the greater the opportunity for reducing peak flow by slowing runoff velocity, infiltration and evaporation. Without appropriate vegetation in a PFMA, it will be ineffective at slowing runoff velocity, thus making sure vegetative restoration is feasible is an important first step. Finally, after considering the size and physical feasibility of a PFMA, cost estimates should be considered.

The opportunity to effectively apply both mitigation practices exists in the North Fork of the Pheasant Branch.

Engineering Considerations

Future studies should estimate storage volume for engineered water retaining infrastructure, as possibilities exist in constructing impoundments to retain water in existing areas with suitable hydrology. Efforts should first investigate PWSAs identified in this study (Appendix K).

We recommend the City review its current Wetland Zoning Ordinance to have increased oversight and management of constructed drainage (29.03(3)(b)) and update the limits and location sites of the 'safe capacity of the downstream receiving systems' in the Stormwater Runoff Control Ordinance (26.06(2)(b)5). Additional oversight and implementation requirements for internally drained areas would mitigate the pressure on downstream stormwater structures, such as the culverts and detention ponds that failed during the August 2018 flood event.

Changes to Intergovernmental Agreement

Current water storage ordinances only contain guidelines for future development and redevelopment sites. We recommend the Town of Springfield and City of Middleton commit to commissioning studies of water storage capacities and work together to transition the land into water storage, similar to how water quality is outlined in the current agreement. The Town of Springfield's Comprehensive Plan outlines support for the watershed and environmental sustainability, stating the Town's role in protecting and managing wetlands and other interconnected water resources (Town of Springfield, 2016). Shared values and goals exist between both the Town and the City and should be reflected in the future land use outline contained in the Intergovernmental Agreement.

Not only are values aligned, but intentionally increasing water storage is an economic matter. According to the American Farm Bureau, the number of Midwest farms filing bankruptcy increased 19% in 2018 (Smith et al, 2019). Farmers need protection against destroyed cropland just as cities need protection against flooded homes and businesses. Taking land out of agricultural production should be done strategically and methodologically.

Land Use Considerations

Land use trade-offs will continuously be a driving factor in stormwater management decisions. For instance, the City would achieve higher tax income through alternative, non-conservation land uses such as agricultural, commercial or residential, but an increased revenue stream may not offset the damage of flood events. Impervious surfaces and additional drainage would be expected to increase the flow rate and water runoff volume of precipitation events.

We recognize the economic benefits from food and fiber production on current agricultural lands in the Pheasant Branch watershed. Proposed wetland restoration projects depend on the buy-in and support of identified Town of Springfield landowners, which may result in transitioning cropland out of production. We urge stakeholders to made decisions collaboratively and to take a long-term view when weighing tradeoffs.

Summary of Watershed Management Recommendations

The following recommendations are based on publicly available data regarding land use and soil conditions. A more robust model considering site information, climate, current land use, and socio-economic factors should be developed to support decision-making. Collaboration between municipalities in the Pheasant Branch watershed will be critical. Stormwater management practices may need to be intensified and regulations may need to be reinforced in the future.

1. Conduct field studies and monitoring to confirm soil types and characteristics, internally drained area dynamics, and current land use identified in this report, prior to any action.

2. Complete hydrologic modeling to quantify watershed impacts and feasibility of implementing identified PFMAs and PWSAs using field data.

3. Utilize advanced hydrologic modeling to enhance water storage volume estimates identified in this report.

4. Prioritize restoration and conservation practices utilizing field data and hydrologic modeling results as well as socio-economic and environmental factors.

5. Conduct engineering analyses considering possible stormwater impoundments in areas identified in this report as having suitable hydrology and appropriate soils.

6. Leverage Dane County and WDNR funding for implementing water storage and flood mitigation practices identified in this report.

7. Protect flood mitigation and water storage areas identified in this report through planning and zoning, ordinance revisions, and development rights purchasing.

8. Update intergovernmental agreements to explicitly protect water storage and flood mitigation areas identified in this report.

Conclusion

Middleton's flooding problem is straightforward; we need to limit the amount of water flowing into the corridor and slow the water down when it flows through the corridor. However, the solution is not as simple as the problem. The Pheasant Branch watershed and creek corridor need to undergo significant changes to increase their water storage capabilities, requiring a process that needs thoughtful, evidence-based plans, significant investment, and time. We believe our recommendations provide the City of Middleton with workable options for flood recovery and the mitigation of future events, but this report is only the beginning of a long process. Much more work will need to be done to ensure the Pheasant Branch watershed is prepared for the changing climate.

As the City of Middleton moves toward recovery and mitigation, residents must continue to have a conversation about equitable solutions. Natural disasters impact low-income communities and communities of color more than other communities, and Middleton is not an exception. We implore the City of Middleton to apply our recommendations in a method that is equitable and just.

We acknowledge the complexity of the issues addressed in this report and there may be viable recommendations not included in this report. We also understand competing views and perspectives exist regarding the future of Pheasant Branch and welcome a discussion about our findings and recommendations.

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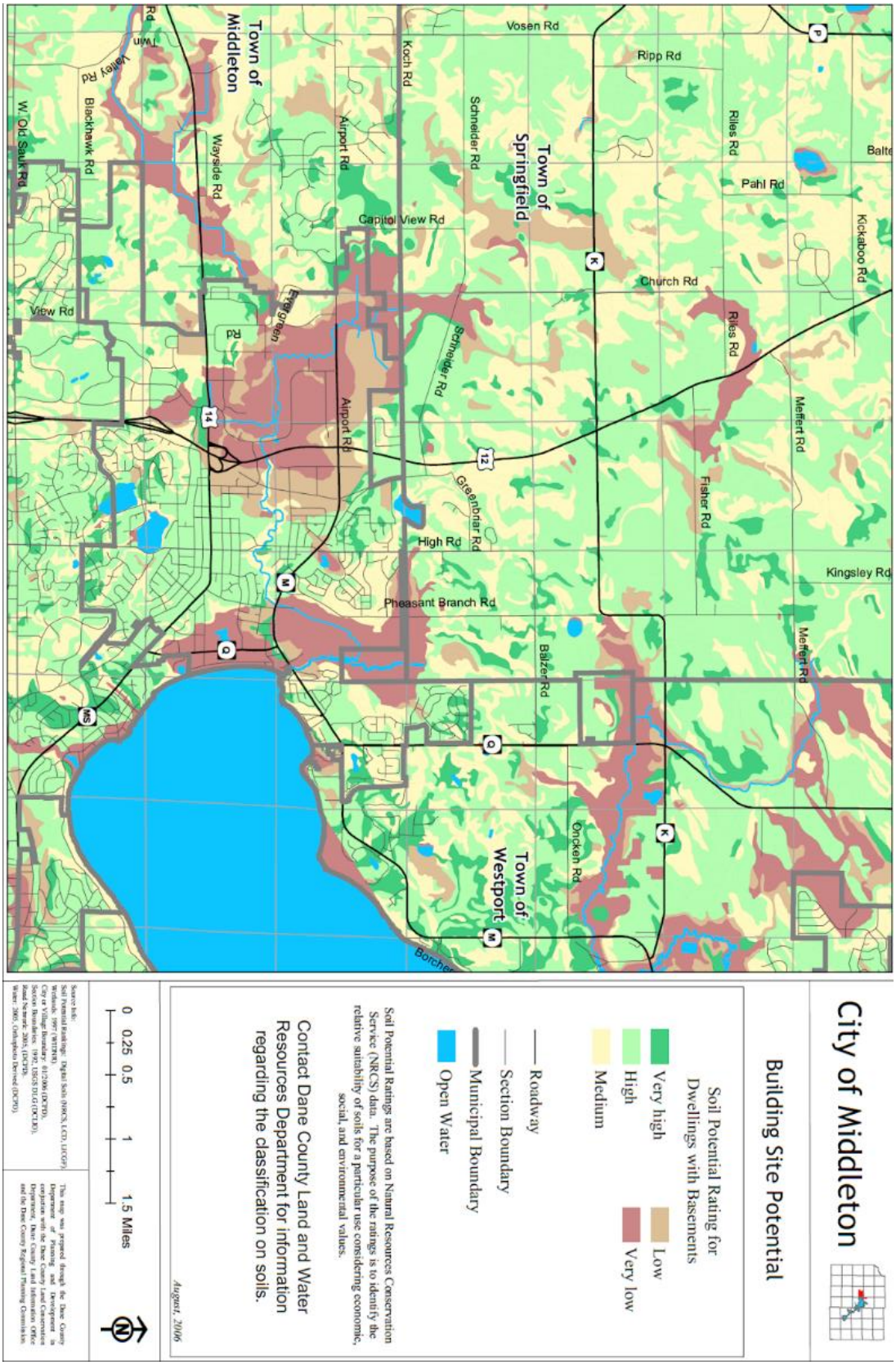
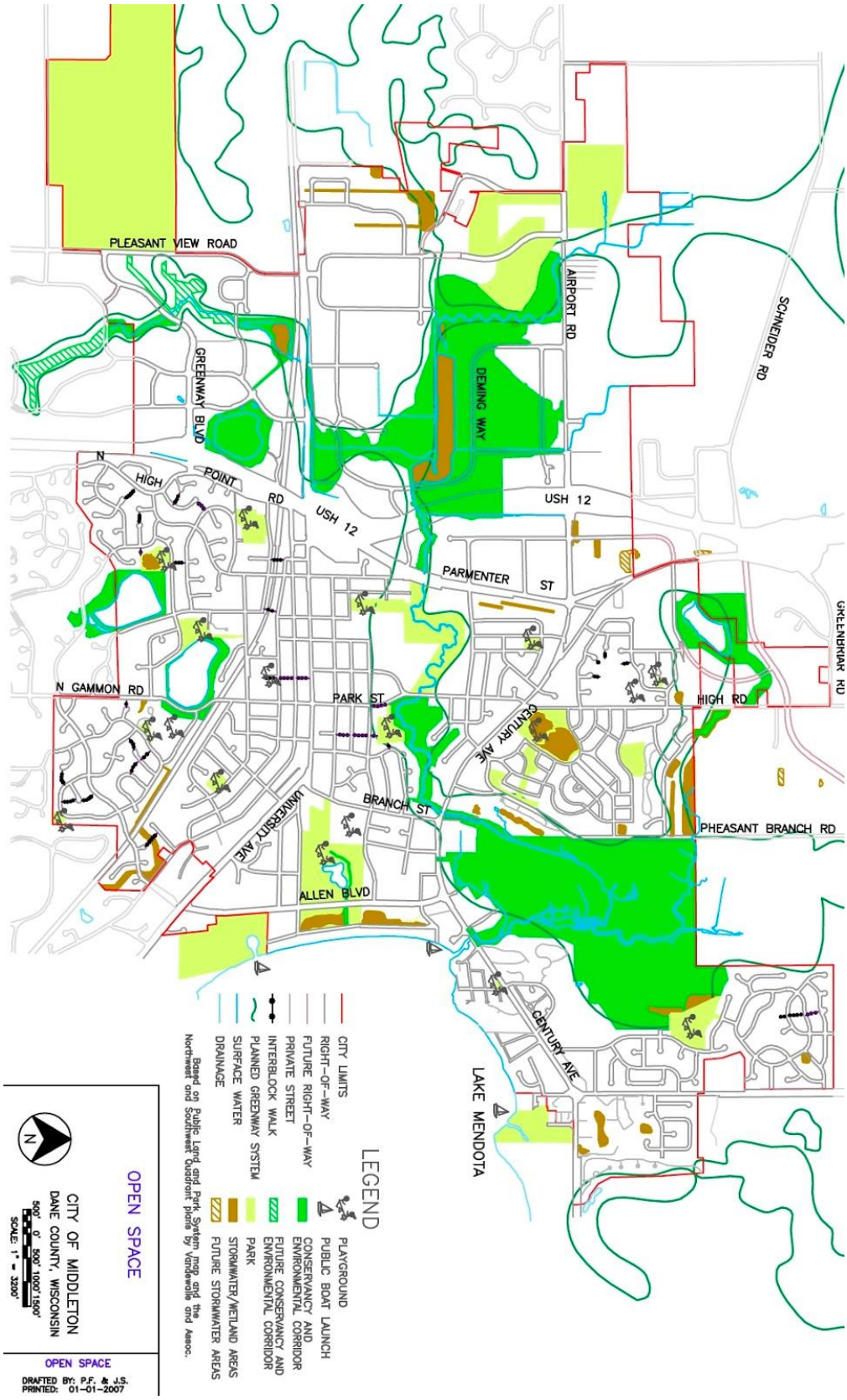
Appendices

Appendix A: FEMA Flood Insurance Rate Map (FIRM) of Pheasant Branch area

Appendix B: Soil Analysis map for structural integrity; Middleton Comprehensive Plan, adopted 2006



Appendix C: Open Space Map; Middleton Comprehensive Plan, adopted 2006



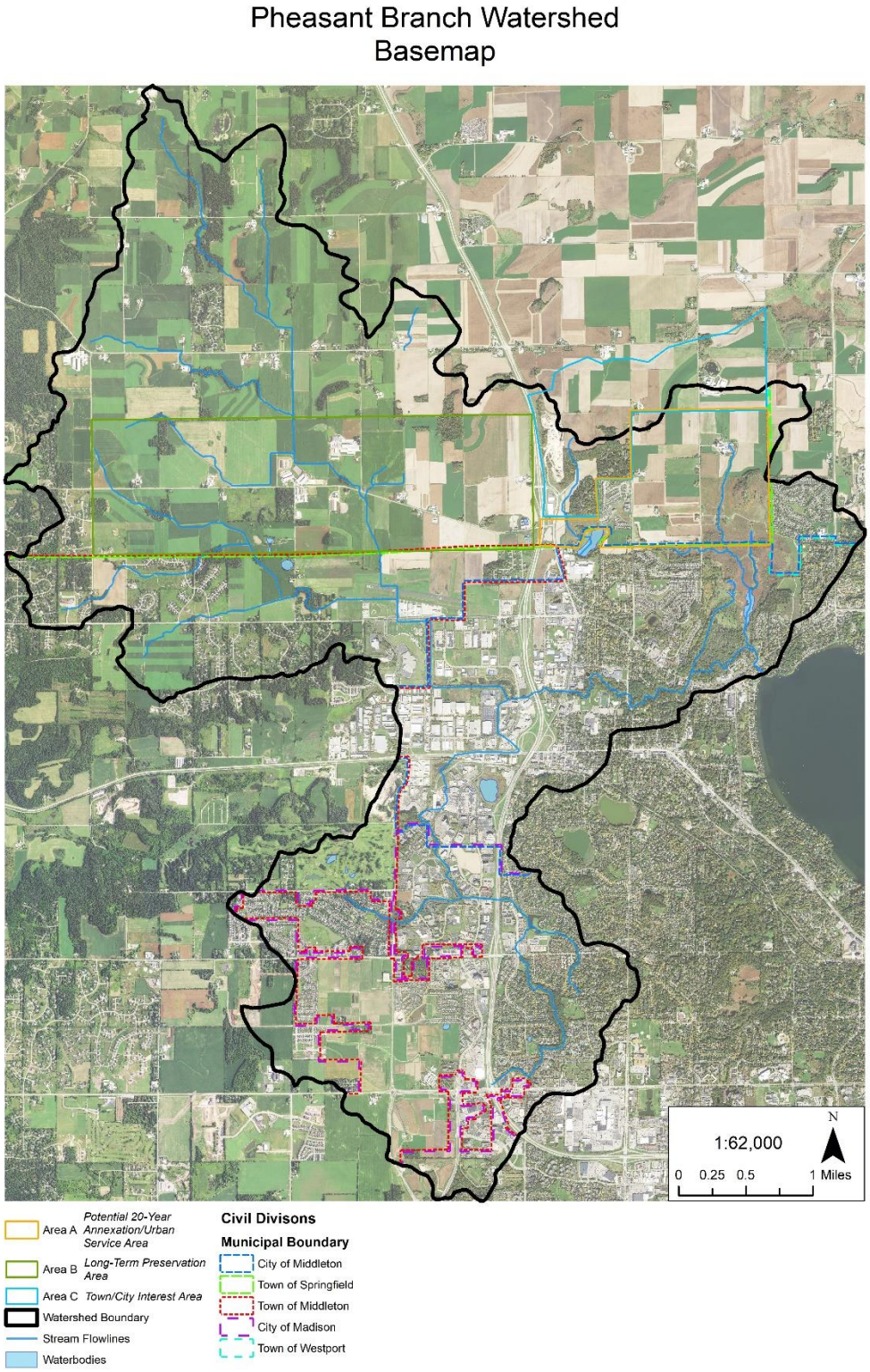
Appendix D: Stakeholder Identification Sheet

Stakeholder	Contact Person	Points of Interests & Areas of Concern	Notes
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		
	Name: Email: Phone: Address:		

Appendix E: Staff Communications Assignment Sheet

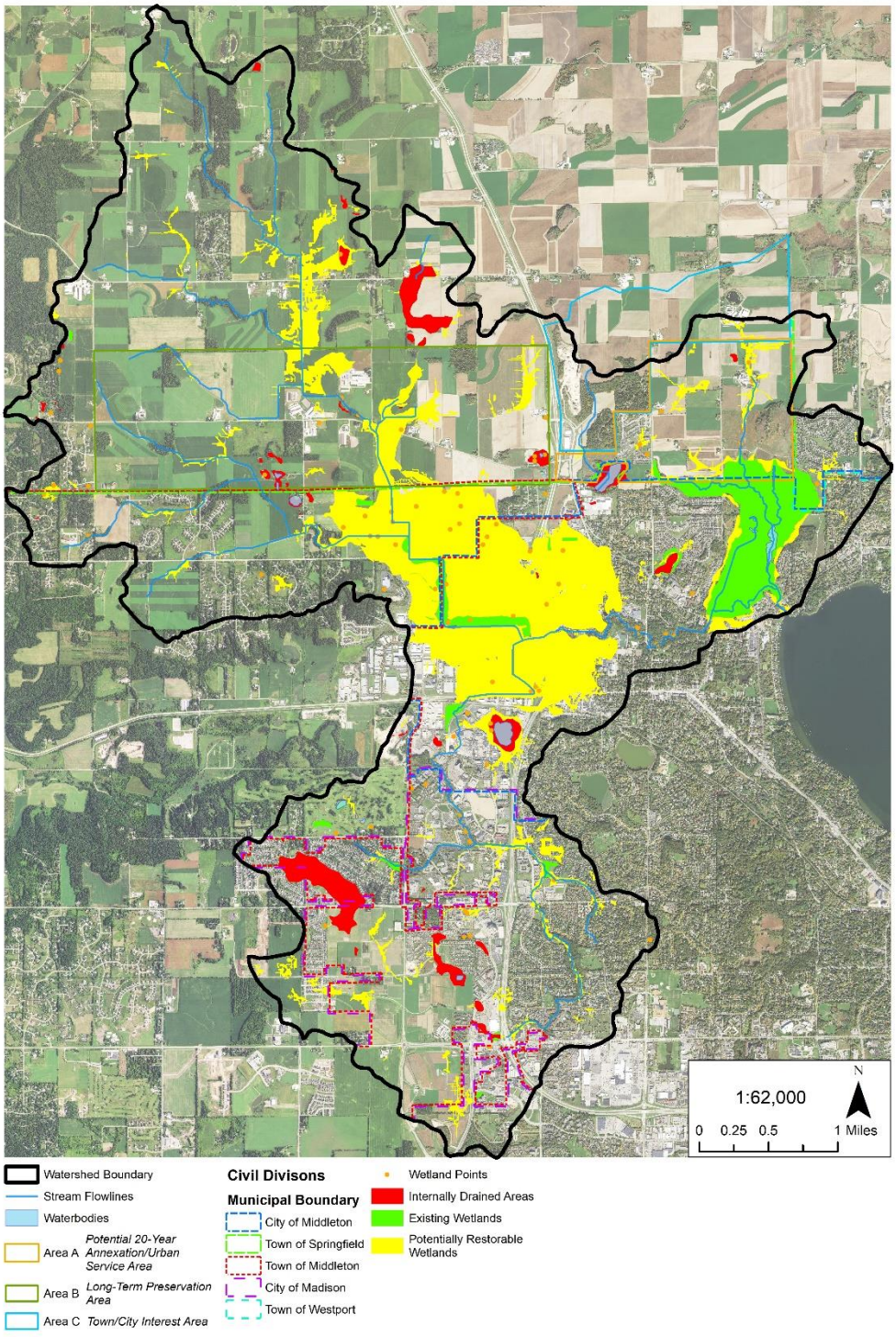
Assignment	Staff Member Responsible	Frequency
Write and deliver newsletter	If unavailable, responsibility falls to:	Every two weeks
Write newsletter article	If unavailable, responsibility falls to:	Every two weeks
Prepare and deliver pre-meeting information	If unavailable, responsibility falls to:	As needed
Lead meeting	If unavailable, responsibility falls to:	As needed
Prepare and deliver meeting notes	If unavailable, responsibility falls to:	As needed
Post to social media	If unavailable, responsibility falls to:	Daily
Read and respond to social media comments and questions	If unavailable, responsibility falls to:	Daily
Keep website updated	If unavailable, responsibility falls to:	As needed

Appendix F: Basemap for GIS Analysis of Pheasant Branch Watershed



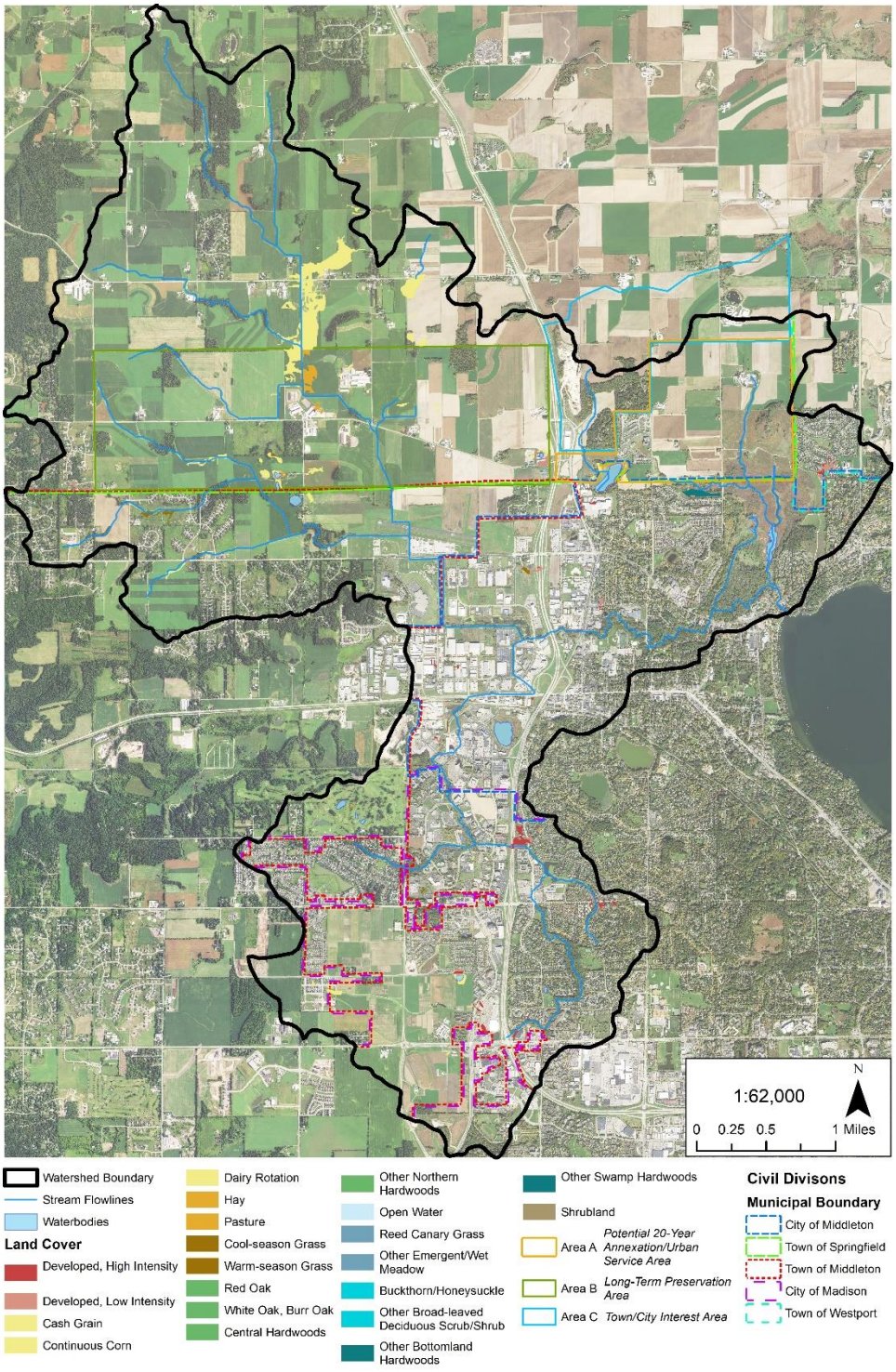
Appendix G: Pre-Analysis Storage Areas

Pheasant Branch Watershed
Wetlands, Potentially Restorable Wetlands, and Internally Drained Areas



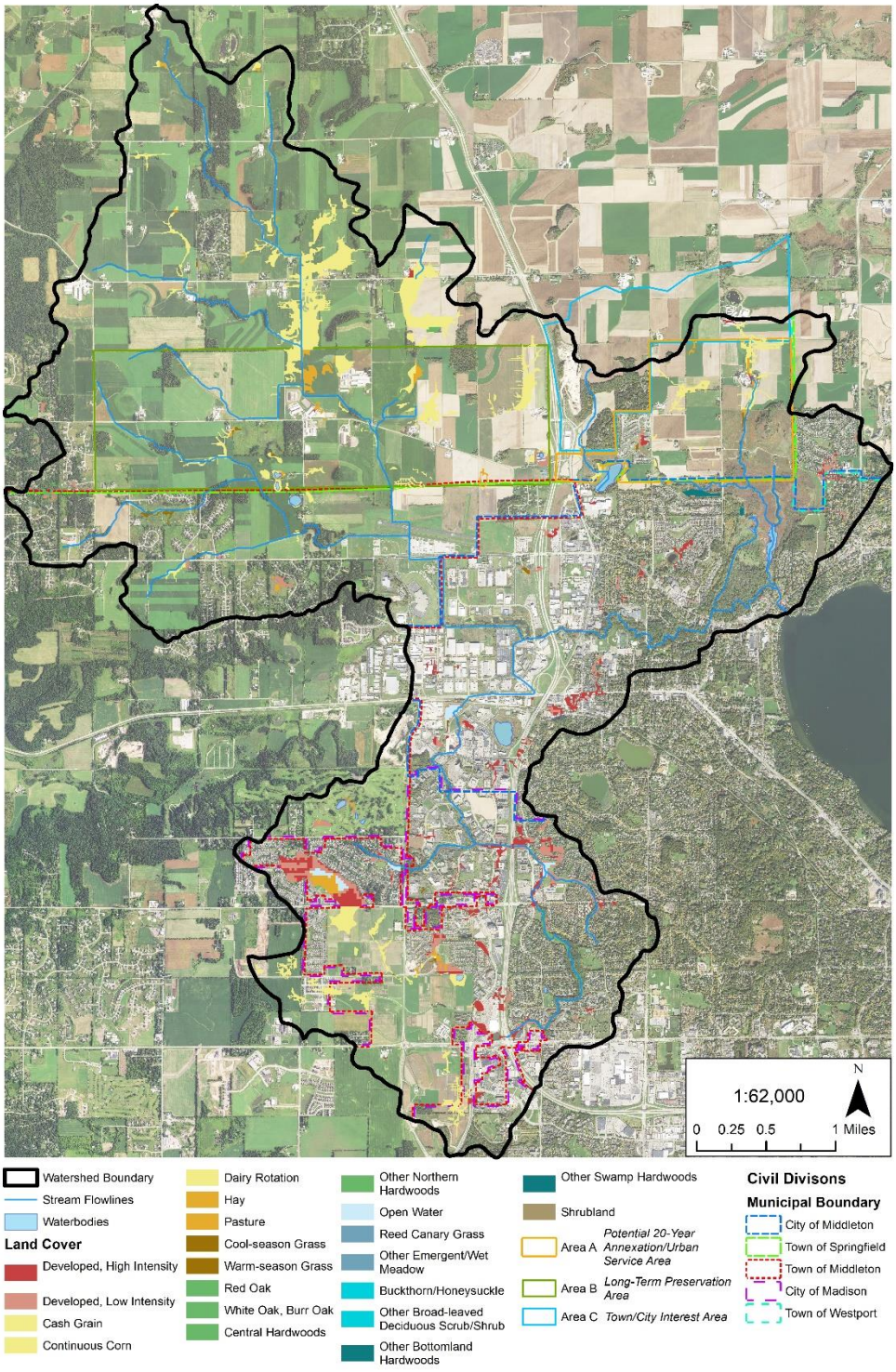
Appendix H: Final Analysis 1 including land cover

Pheasant Branch Watershed
Analysis 1: Desirability based on Soil Properties including Farmland Class
Land Cover



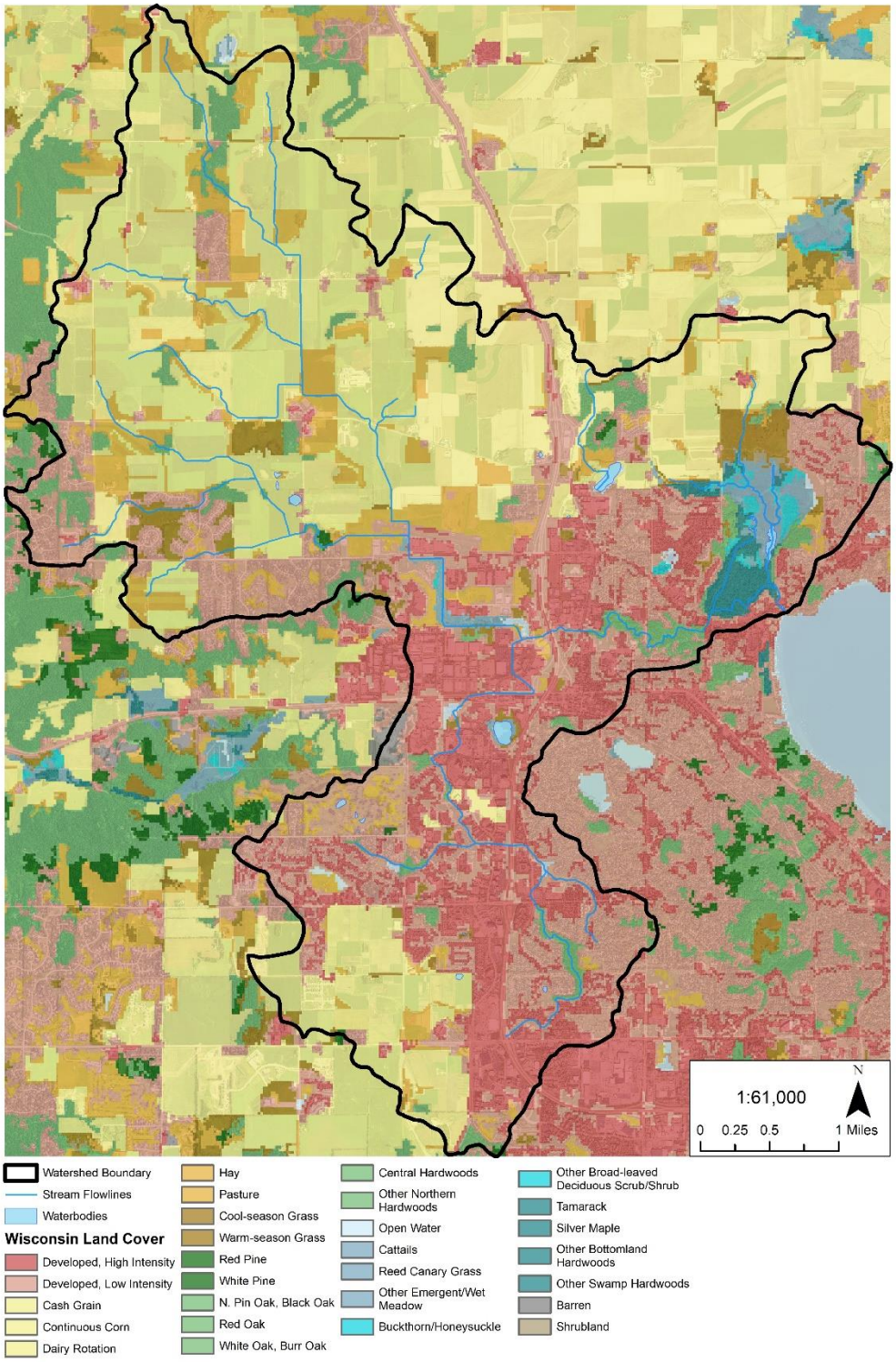
Appendix I: Land desirability from soil properties analysis

Pheasant Branch Watershed
Analysis 2: Desirability based on Soil Properties excluding Farmland Class
Land Cover



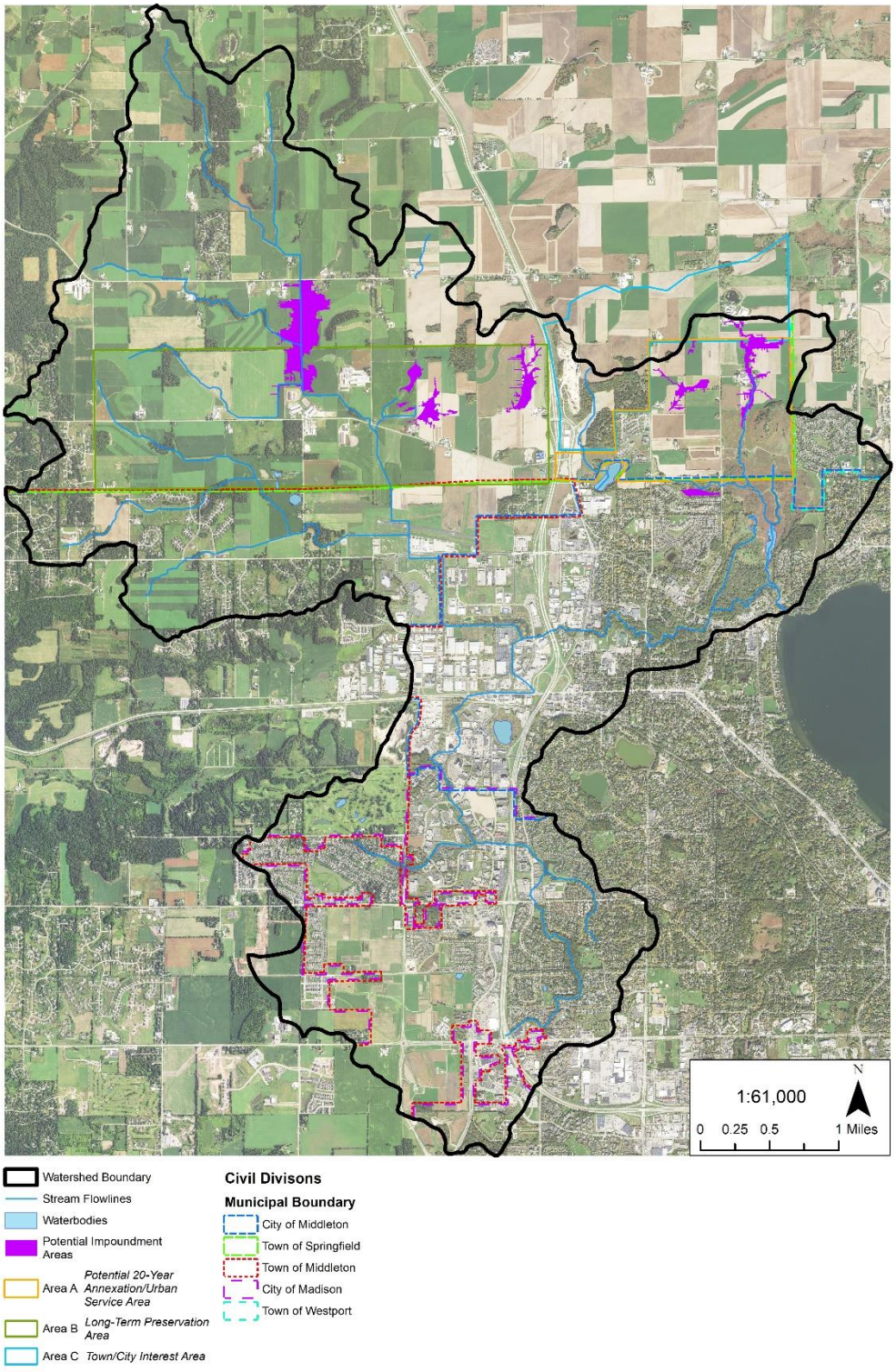
Appendix J: Land cover within the Pheasant Branch watershed

Pheasant Branch Watershed
Land Cover



Appendix K: Potential Water Storage Areas with Engineered Impoundments

Pheasant Branch Watershed
Suggested Areas for Engineered Impoundments Infrastructure



Appendix L: Land information of parcels identified within Potential Water Storage Areas

Zone	PARCEL ID	SITE ADDRESS	LONGITUDE	LATITUDE
1	80827190003		-89.528987	43.142321
	80827290010		-89.538512	43.142241
	80827295007	7054 CTH K	-89.533933	43.142233
	80827380003		-89.533886	43.138518
	80827385008		-89.537924	43.138327
	80827395006		-89.533847	43.134946
	80827485203	6957 CTH K	-89.527876	43.138704
	80827490000		-89.527665	43.135016
	80827490706		-89.530152	43.135004
	80834285100	7086 MEIER ROAD	-89.537192	43.132291
2	80828180003		-89.543962	43.14572
	80828190010		-89.54889	43.142093
	80828195015		-89.544	43.142385
	80828298700		-89.551567	43.141109
	80828298850		-89.552255	43.142038
3	80834195003	4953 PARMENTER STREET	-89.52383951	43.12773663
	80835290005	4951 PARMENTER STREET	-89.51811177	43.12778146
	80835290907		-89.52053272	43.12777614
4	70804280004	4797 CAPITOL VIEW ROAD	-89.552131	43.117446
	70804281000		-89.553969	43.115054
	70804186000		-89.549878	43.117711
	70804186300	4762 CAPITOL VIEW ROAD	-89.54606	43.117651
	70804186500	4772 CAPITOL VIEW ROAD	-89.550388	43.116705
	70804281000		-89.553969	43.115054
	80833395012		-89.553643	43.118904
	80833399303	4841 CAPITOL VIEW ROAD	-89.553794	43.119902

	80833390008		-89.558558	43.12008
	80833395012		-89.553643	43.118904
	80833390008		-89.558558	43.12008
	80833395012		-89.553643	43.118904
	80833390008		-89.558558	43.12008
5	70816304011	901 WINDING WAY	-89.55088902	43.07909407
	70816304029	905 WINDING WAY	-89.55133024	43.07907812
	70816304201	9501 BLUE HERON DRIVE	-89.55073321	43.07944316
	70816305019	906 WINDING WAY	-89.55156523	43.07856339
	70816305027	910 WINDING WAY	-89.55197311	43.07856239
	70816305035	914 WINDING WAY	-89.55238108	43.0785616
	70816408102	802 HIDDEN CAVE ROAD	-89.54388143	43.07722933
	70816408110	810 HIDDEN CAVE ROAD	-89.544272	43.077345
	70816408128	814 HIDDEN CAVE ROAD	-89.54463922	43.07747518
	70816408144	822 HIDDEN CAVE ROAD	-89.54540846	43.07779626
	70816408152	826 HIDDEN CAVE ROAD	-89.54569538	43.07802008
	70816408160	830 HIDDEN CAVE ROAD	-89.54597733	43.07823972
	70816408178	834 HIDDEN CAVE ROAD	-89.54633371	43.07839074
	70816408186	902 HIDDEN CAVE ROAD	-89.54675617	43.07855639
	70816408227	918 HIDDEN CAVE ROAD	-89.54820206	43.07911841
	70816408251	930 HIDDEN CAVE ROAD	-89.54928228	43.07954577
	70816408269	934 HIDDEN CAVE ROAD	-89.54939765	43.07978914
	70816408277	938 HIDDEN CAVE ROAD	-89.54936163	43.08006428
	70816408300	905 BEAR CLAW WAY	-89.54988124	43.08006789
	70816408318	901 BEAR CLAW WAY	-89.54996797	43.07981575
	70816408326	809 BEAR CLAW WAY	-89.55002808	43.07956603
	70816408334	805 BEAR CLAW WAY	-89.55003652	43.07929111
	70816408342	801 BEAR CLAW WAY	-89.55013085	43.079008

	70816408368	9306 OLD SAUK ROAD	-89.54869699	43.07854943
	70816408376	741 BEAR CLAW WAY	-89.54830264	43.0771588
	70816408384	9240 WATERSIDE STREET	-89.54550222	43.07606771
	70816408516	9320 OLD SAUK ROAD	-89.54656167	43.07554956
	70816408516	9320 OLD SAUK ROAD	-89.54656167	43.07554956
	70816409019	9201 WATERSIDE STREET	-89.54457489	43.0754431
	70816410058	758 BEAR CLAW WAY	-89.55106906	43.07777105
	70816411014	762 BEAR CLAW WAY	-89.55106352	43.07823808
	70816411022	902 WINDING WAY	-89.55106427	43.07856149
	70816413028	9134 WATERSIDE STREET	-89.54389	43.076404
	70816413028	9138 WATERSIDE STREET	-89.54389	43.076404
	70816414018	9322 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414026	9324 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414034	9326 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414042	9328 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414050	9330 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414068	9332 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414076	9334 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414084	9336 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414092	9338 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414109	9340 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414117	9342 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414125	9344 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414133	9346 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414141	9348 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414159	9350 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414167	9352 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414175	9354 OLD SAUK ROAD	-89.54656167	43.07554956

	70816414183	9356 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414191	9358 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414208	9360 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414216	9362 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414224	9364 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414232	9366 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414240	9368 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414258	9370 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414266	9372 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414274	9374 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414282	9376 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414290	9378 OLD SAUK ROAD	-89.54656167	43.07554956
	70816414307	9380 OLD SAUK ROAD	-89.54656167	43.07554956
	70821100991	9101 OLD SAUK ROAD	-89.54503179	43.07128337
	70816305118	14 GREYSTONE CIRCLE	-89.553093	43.07824
	70816305291	762 CRICKET LANE	-89.552391	43.07788
6	70822200980	8901 OLD SAUK ROAD	-89.539915	43.070873
	70822407057	8509 ELDERBERRY ROAD	-89.530696	43.067809
	70822407065	8501 ELDERBERRY ROAD	-89.530323	43.067811
	70822406124	8441 ELDERBERRY ROAD	-89.529722	43.067816
7	70822406116	8437 ELDERBERRY ROAD UNIT CDM	-89.52938	43.067822
	70822406108	8433 ELDERBERRY ROAD UNIT NOT	-89.529043	43.067826
	70822406091	8429 ELDERBERRY ROAD UNIT CDM	-89.528708	43.067829
	70822400986	8452 MINERAL POINT ROAD	-89.530204	43.064727