Cover Page

How Can Horticultural and Green Infrastructure Techniques Be Used for Stormwater Management in Communities with Combined Sewer Systems?

Andrew Lentz

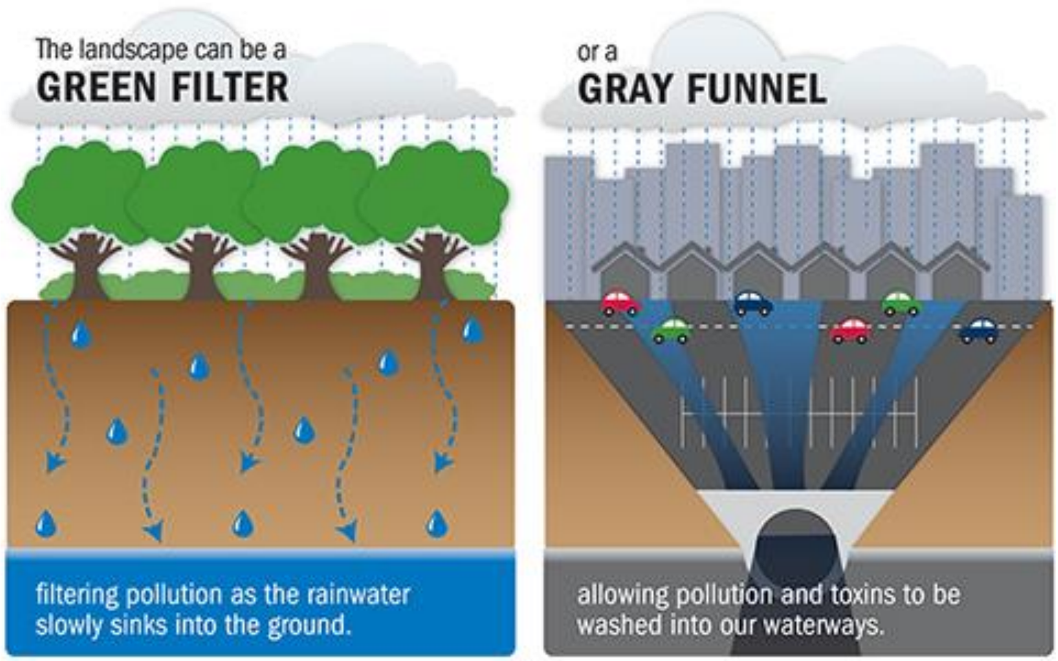

Figure 1. A diagram from the Pennsylvania Department of Natural Resources representing two types of stormwater management (Just What Is Green Infrastructure? 2021).

Title Page

How can stormwater runoff be mitigated and managed by using green infrastructure and horticultural improvements to reduce the pollution of untreated sewage into surface water due to combined sewer overflows (CSOs)?

Andrew Lentz

Faculty Adviser: Professor Stevie Famulari Gds.

University of Cincinnati

Bachelor of Science Horticulture

School of Planning – Horticulture Department

April 2024

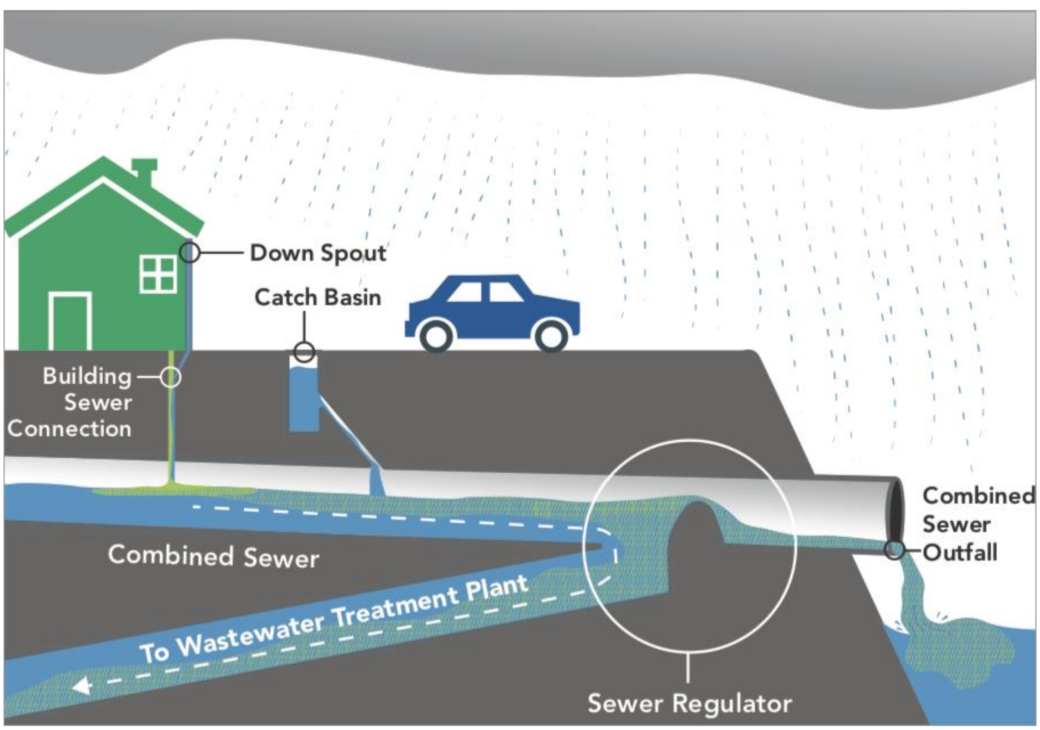

Figure 2. A diagram representing how a typical combined sewer overflow functions in wet weather conditions (Combined Sewer Overflows n.d.).

Table of Contents

Student Identification Page

lentzat@mail.uc.edu

Figure 3. Photo Credit: Rachael Curtis

“There's no such thing as bad weather, only unsuitable clothing.”

– Alfred Wainright, A Coast to Coast Walk

Spring 2024, Horticulture Senior Capstone, HORT 4092

Professor Stevie Famulari

Relevant assignments: Capstone project

Spring 2024, Urban Landscape IV: Roofs and Facades, HORT 3044

Professor Wendy Ellis & Rose Seeger

Relevant assignments: Research and design of green roofs

Spring 2024, Woody Ornamentals II, HORT 2031

Professor Steve Foltz

Relevant assignments: Identification of woody plants

Spring 2024, Soil Science and Plant Nutrition, HORT 3010

Professor Tania Hernandez and Dan Peterson

Relevant assignments: Understanding soil texture, structure, and use

Student Identification Page Continued

Autumn 2023, Sustainable Landscape Design I, HORT 2040

Professor Stevie Famulari

Relevant assignments: Final design project

Autumn 2023, Woody Ornamentals I, HORT 2030

Professor Steve Foltz

Relevant assignments: Identification of woody plants

Autumn 2023, Landscape History, HORT 3050

Professor Stevie Famulari

Relevant assignments: Essays detailing human impact on landscapes

Summer 2023, Independent Study in Horticulture, HORT 4091

Professor Brian Grubb

Relevant assignments: Real world industry experience

Spring 2023, Herbaceous Ornamentals I, HORT 2032

Professor Brian Grubb

Relevant assignments: Identification of herbaceous plants

Autumn 2022, Urban Landscape I: Urban Forestry, HORT 3040

Professor Dave Gamstetter

Relevant assignments: Application of knowledge of street trees

Spring 2020, Native Plants I, HORT 2034

Professor Donna McCollum and Dave Gressley

Relevant assignments: Identification of native plants

Abstract

Access to clean water is important, not only for drinking but also for recreational and environmental health. The US EPA recognizes that combined sewer systems are significant contributors to ground water pollution and has implemented policies to control combined sewer overflows (CSOs). The Clean Water Act, established in 1972, is a law regulating the pollution of surface water. Discharge from CSOs is a threat to water sources such as lakes, rivers, and streams.

While the Ohio EPA has prohibited the installation of new combined sewers, it is not feasible for older cities, such as Cincinnati, to do away with these systems entirely. Instead, existing systems must be managed and maintained to meet EPA and National Pollutant Discharge Elimination System (NPDES) standards. Since 2009, the Metropolitan Sewer District of Greater Cincinnati (MSDGC) has reduced sewer overflow by about 7.8 billion gallons per year. However, at least 6 billion gallons of sewage overflow from the combined sewer system each year (Wet Weather Program n.d.).

Horticultural techniques combined with green infrastructure can be used to reduce the amount of stormwater flowing into the sewer system due to rain events. Therefore, decreasing the amount of sewage and human waste that has been only partially treated, or not treated at all and is allowed to flow into surface water. This project examines which techniques have the most impact in managing excess rainfall and makes recommendations on how to implement them.

Keywords

Stormwater

Horticulture

Greening

Bioretention

Green Roof

Green Infrastructure

CSO

SSO

Water

Pollution

Cincinnati

Ohio

Figure 4. An example of green techniques being implemented to reduce stormwater runoff at the Lick Run project (Smith n.d.).

Problem Statement

Each year 6 billion gallons (Wet Weather Program n.d.) of stormwater overflows and pollutes Cincinnati's surface water. How can horticultural and green infrastructure techniques capture excess rainfall and eliminate stormwater from overwhelming combined sewer overflow systems?

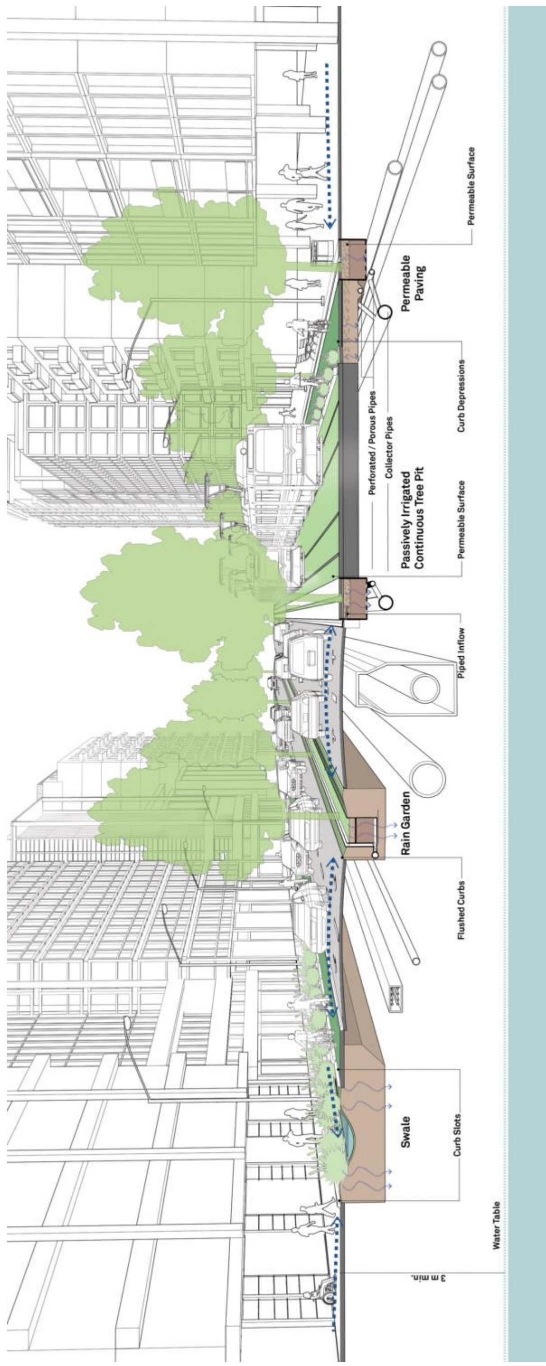

Figure 5. A visual representation of potential horticultural and green infrastructure that can assist in managing stormwater in the urban landscape (Green Infrastructure and Stormwater Management 2022).

Project Justification

In 2004 the Metropolitan Sewer District of Greater Cincinnati (MSDGC) entered into a consent decree with the U.S. EPA, Ohio EPA, and the Ohio River Valley Water Sanitation Commission related to CSOs, SSOs, wastewater treatment plants, and a capacity assurance program. Since then, MSDGC has created a wet weather improvement plan and to date have implemented phase one of their plan. Phase 2A is set to be completed at the end of 2024, but discussions have yet to be had with the EPA to determine the aspects of phase 2B.

According to MSDGC data, 7.8 billion gallons per year of sewer overflow has been reduced, however, at least 6 billion gallons of sewage overflow from the combined sewer system each year (Wet Weather Program n.d.). Work still needs to be done to reduce this 6 billion gallons of overflow.

Horticultural and green infrastructure techniques have the ability to close the gap and are a cost-effective way manage excess stormwater. According to MSDGC, it costs about “$0.23/gallon for green stormwater controls and about $0.40/gallon for gray solutions such as larger pipes and storage tanks” (Wet Weather Program n.d.). Therefore, green techniques are cheaper than upgrading sewers with additional concrete pipes and gray infrastructure systems. Horticultural improvements also create additional benefits such as providing ecosystem services, improve land values, and reduce the urban heat island effect.

Existing MSDGC projects to combat excess overflow vary in status from completed, in construction, and pre-planning. Some of the gray infrastructure solutions MSDGC has planned, including larger pipes and storage tanks, are not expected to be completed for another 24 years, in September of 2048.

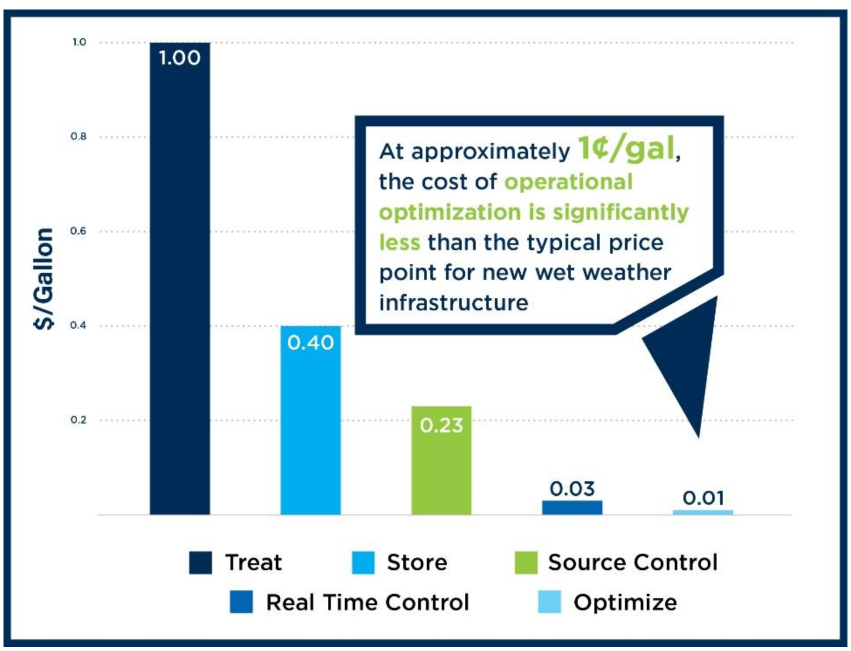

Figure 6. A bar chart comparing the cost of managing stormwater. “Store” in light blue refers to gray infrastructure, “Source Control” in green refers to green infrastructure (Using Smart Sewers to Reduce Overflows n.d.).

User Client Description

Users vary greatly as the sites in which green stormwater management techniques are used can be quite extensive. Examples of users who typically interact with a stormwater management site solely for installation or maintenance purposes include: MSDGC employees, horticultural contractors, construction contractors, and landscape architects. These groups of people will likely be different than the end user and will interact with these spaces on an as-needed basis.

There are at least two groups of end users:

1. The first group includes a diverse range of people including community members with varying abilities, race, economic status, sexual orientation, gender identity, language, and more, ranging in age from childhood throughout adulthood. These users have a stormwater management area in their neighborhood, near their workplace, or other scenario where they interact with horticultural and green infrastructure techniques that manage stormwater. Some specific examples include rain gardens, parking lots with permeable pavers, surface streams, detention basins, and more. These areas should be inclusive and mindful to the diverse user base while providing the intended environmental benefits. Some sites can be more suited to accommodate human traffic and add recreational services, while others are solely focused on environmental improvements.

2. Another group of end users are those who use waterways such as lakes, rivers, and streams for recreational purposes. These users also vary in age, abilities, race, economic status, sexual orientation, gender identity, language, and more. These users have the ability to partake in some type of activity such as swimming or kayaking. This group of people are directly affected by the water quality that is present in the waterway they recreate in. Clean water that is free of untreated sewage coming from CSOs should be accessible to these users.

User Client Description Continued

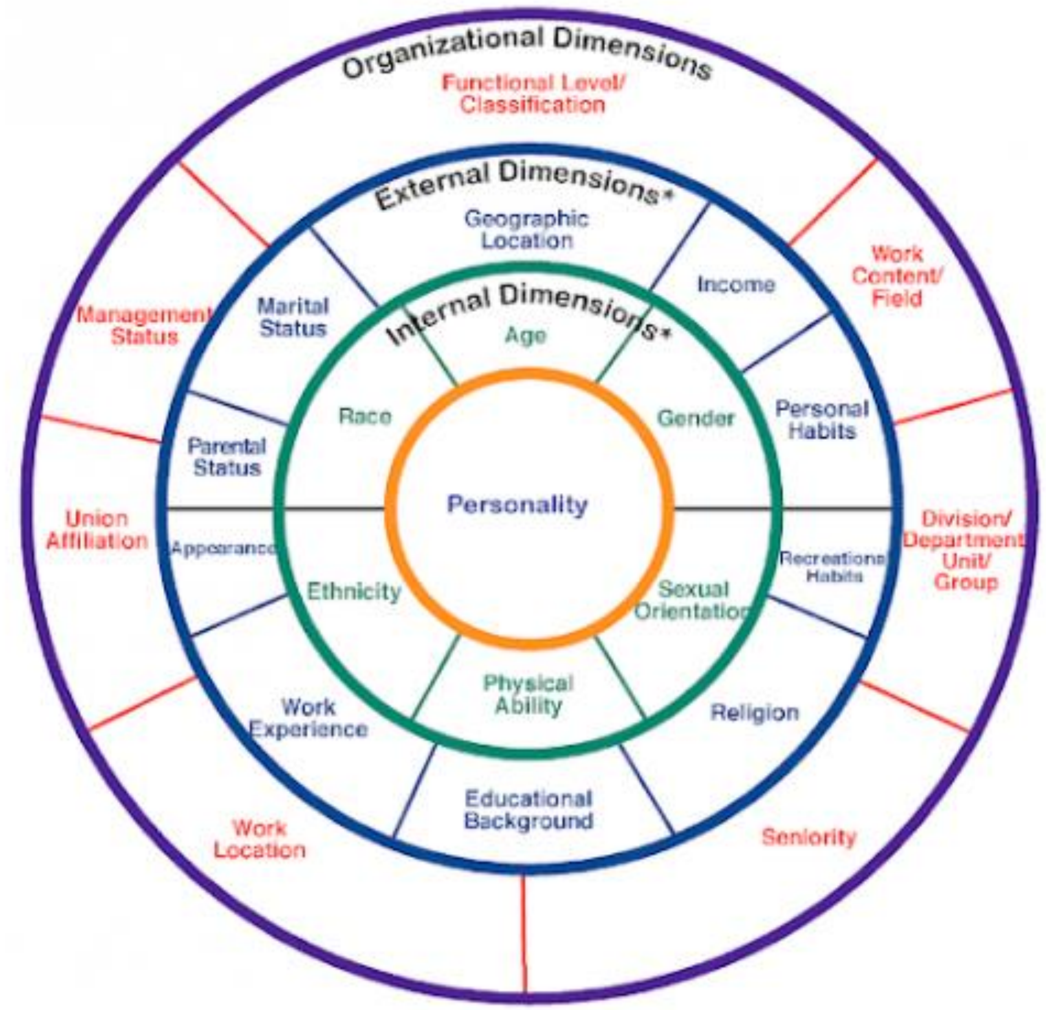

Figure 7. A diagram representing the diversity wheel which applies to all users (Diversity, Equity and Inclusion Defined n.d.)

Major Project Elements

Research:

The research portion includes gathering data and resources from sources with the purpose of determining solutions for mitigating CSOs. The effectiveness across horticultural and green infrastructure techniques is determined by comparing effectiveness and feasibility for implementation.

Design:

The design portion of the project is comprised of specific types of sites that exist throughout Cincinnati – 34 neighborhoods which contain a compact walkable quarter mile radius. Three of these neighborhoods have been selected to demonstrate a proposal of solutions that can then be applied to other neighborhoods in the city. Sites have been selected for perspective and conceptual designs. Horticultural and green infrastructure techniques which are determined as the most effective and feasible in the research stage of the project are showcased in the design portion. The goal is to represent a realistic way to implement green stormwater management techniques throughout the city, reducing CSO pollution.

Details of Compact Walkable Quarter Mile Neighborhoods:

- Impervious surfaces
    - Roofs
    - Roads
    - Sidewalks
    - Parking lots
    - Asphalt
    - Concrete
    - Compacted soil
- Limited greenspace
- Low availability of organic matter
- High levels of traffic
    - Automobile
    - Foot Traffic
- Entrances to water system (sewers)
- Variety in topography

Figure 8. Photo of Hyde Park square in Cincinnati Ohio (Murtha, L. 2018).

Inventory & Analysis Cincinnati Region

Average rainfall in Cincinnati: Cincinnati receives an average of 42.24 inches per year (Weather Averages Cincinnati, Ohio n.d.). Cincinnati gets above average rainfall compared to the national average of 30.9 inches (Average Annual Precipitation 2024). This means more wet weather where existing infrastructure may not be able to handle rainfall, leading to CSO overflows.

Change in rainfall averages: According to the EPA, annual precipitation has increased 5 to 10 percent in the last half century. Additionally, rainfall during the four wettest days increased 35%, and water in streams during floods is up 20% (What climate change means for Ohio 2016). This causes an increase in extreme wet weather events when flooding can occur. This will lead to a large increase in CSO overflows as rainfall events become more unpredictable and overload the existing sewer infrastructure.

Gallons of runoff per year: Based on MSDGC data, 6 billion gallons per year overflow from CSOs in Cincinnati (Wet Weather Program n.d.). This large number of overflow contributes to billions of gallons of sewage and pollution flowing into surface waters each year causing environmental and public health harm to Cincinnati water ways.

Number of outfalls in the city limits: "MSD has more than 200 CSO outfalls along the Mill Creek, Muddy Creek, Little Miami River, and the Ohio River and a number of their tributaries" (CSOs, SSOs, and Sewer Backups n.d.). 200 outfalls in the Cincinnati area alone represents a large number of CSOs. There is a need to do something about this to reduce Cincinnati's reliance on this method of stormwater management.

Health related concerns due to pollution of water: The EPA lists several different types of potential pollution related to CSO and SSO outfalls: bacteria, viruses, metals, synthetic organic chemicals, waterborne disease outbreaks, and contamination of fish and shellfish (Human Health Impacts of CSOs and SSOs n.d.). Health concerns could be curbed with a decreased reliance on CSOs. This would make recreational water areas safer for humans and wildlife. Additionally, excess pollution is a contributing factor to increased need for water sanitation.

Land use and types of sites: Cincinnati has a variety of land use types ranging from agricultural to bustling neighborhood centers. Over half of Cincinnati's land is classified as residential, compact walkable half mile, compact walkable quarter mile, neighborhood center, or existing industrial property. Neighborhoods and developed areas, especially neighborhood centers and walkable areas, have a high number of paved streets and roads that contribute to excess stormwater runoff.

On the other hand, industrial sites pollute heavily. In fact, "It shows the Ohio [River] topped the nation's waterways for pollution discharges from industry at 24,180,821 pounds in 2013" (Bruggers, 2015), reports a local Cincinnati newspaper in 2015. Low absorption in neighborhoods during rain events coupled with pollution from industries contribute significantly to Cincinnati's CSO problem.

Inventory & Analysis Cincinnati Region Continued

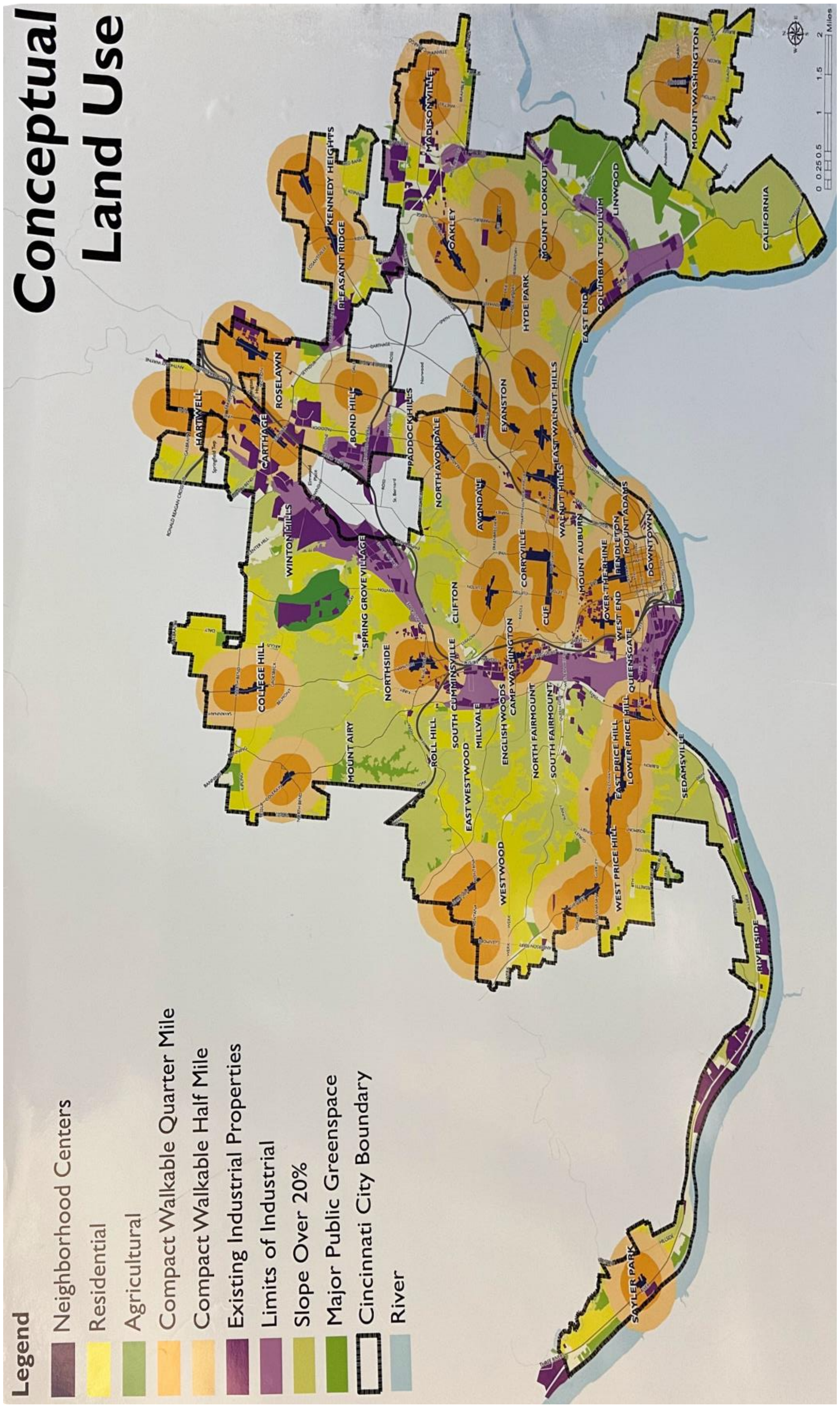

Figure 9. A conceptual representation of Cincinnati's land use (University of Cincinnati Planning Studio).

Case Study and Literature Review 1 – Lick Run Greenway

Mill Creek, located in Cincinnati Ohio, was declared the most polluted and endangered urban river in North America in 1997 (Sweet, 2023). This is largely due to the highest volume CSO in Cincinnati, CSO 5, which contributes 1.78 billion gallons annually to Mill Creek. MSDGC came up with two proposals to reduce overflow to this endangered waterway. One option was a deep underground storage tunnel which would have never seen the light of day. It would have aided in controlling stormwater but would not have provided any other benefits. The second approach combined a variety of techniques such as daylighting the previously buried Lick Run, creating a valley conveyance system, stormwater detention basins, and new infrastructure. (Smith n.d.). This option, which includes many horticultural and green infrastructure technologies, costs "about $200 million less expensive for ratepayers than the deep tunnel" (Smith n.d.) and was selected to be implemented as the Lick Run project.

Figure 10. CSO 5 discharging into Mill Creek (CSOs, SSOs, and Sewer Backups n.d.)

According to MSDGC, the Lick Run project reduces CSO flow by nearly 800 million gallons per year. They list community benefits such as: green space, recreational paths, community event space, basketball courts, playground, water spray park, and shelters. In addition, the water quality of Mill Creek has improved and is now safe for recreation and home to nine new fish species (Lick Run Greenway n.d.).

Figure 11a. Detailed plan of the green improvements for the Lick Run Greenway (Smith n.d.).

Figure 11b. Detailed plan of the green improvements for the Lick Run Greenway (Smith n.d.).

A combination of new sewers and green infrastructure improvements were used throughout the Lick Run project. Eleven biofiltration basins, eight stormwater detention ponds, permeable pavers, newly planted trees, and rain garden plants were the major green improvements used in the project.

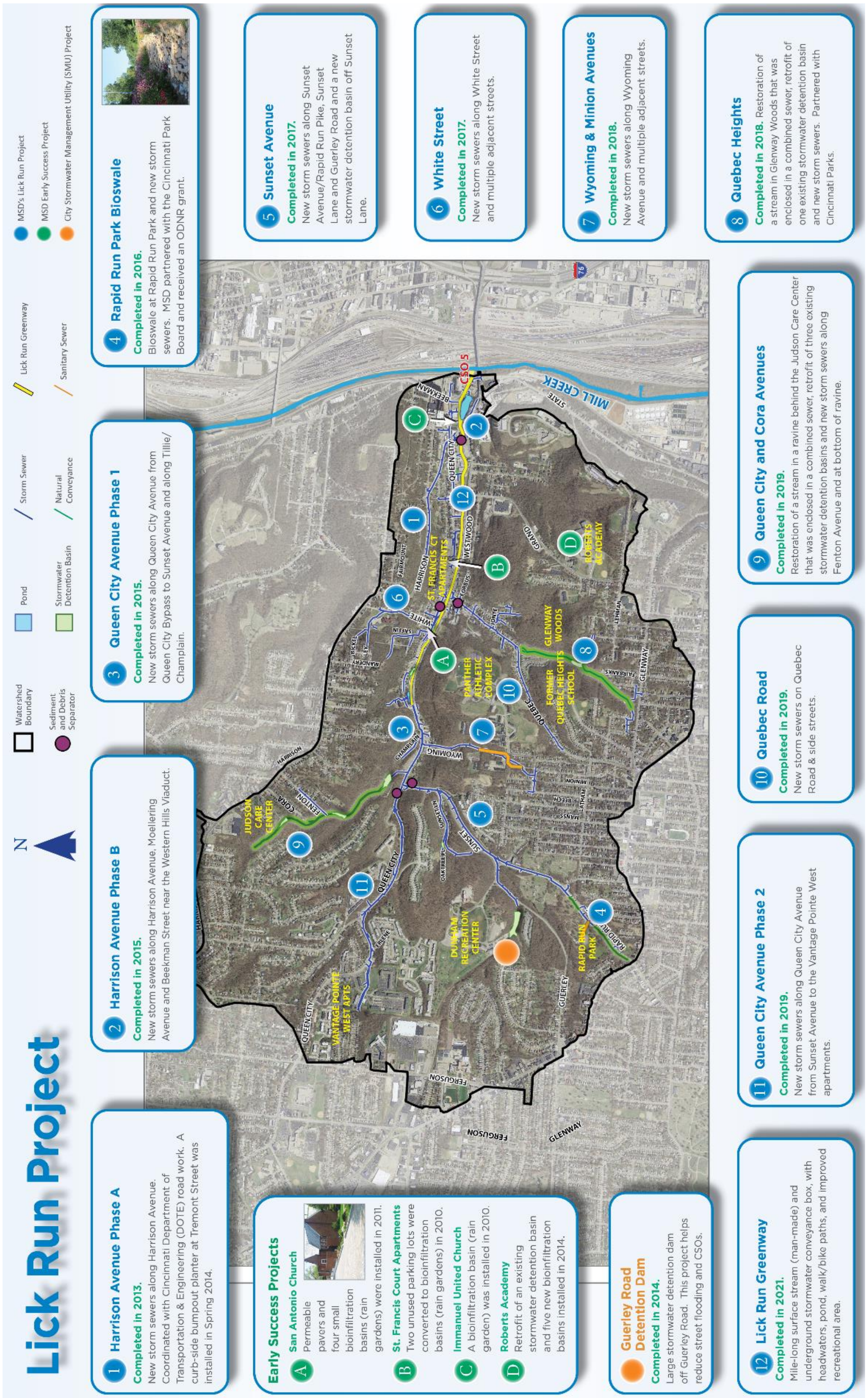

Figure 12. A map of accomplishments related to the Lick Run project (Smith n.d.).

Case Study and Literature Review 2 – Green Roofs

This article published by the US EPA in 2021 titled "Stormwater Best Management Practice Green Roofs" discusses green roof applicability, design, limitations, and effectiveness. It begins by claiming that green roofs can be applied to new projects as well as retrofitting them onto existing buildings. According to the EPA publication "Green roofs are ideal for urban areas "because they provide stormwater benefits and other valuable ecological services without consuming additional land" (2021). This suggests that green roofs may be worthwhile to install as a green way to manage CSOs. Furthermore, Figure 13 represents that during a rainfall event a green roof can hold on to more water which decreases the amount of water immediately being sent to the sewer system.

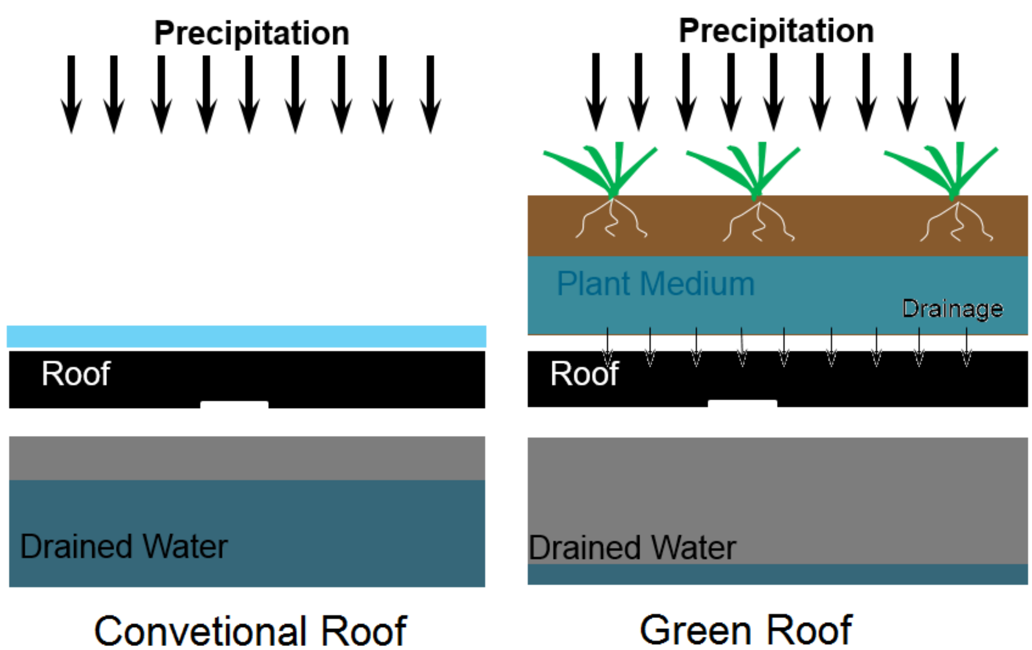

Figure 13. A graphic comparing the effects and materials between a conventional roof and a green roof. (Green Roof Research at Western n.d.)

"In a review of green roof hydrology, Li and Babcock (2014) found that green roofs can reduce total stormwater volume and peak flow rates by around 30 to 90 percent and capture greater portions during smaller rain events prior to media saturation" (Stormwater Best Management Practice - Green Roofs, 2021) the EPA states. Green roofs around found to be an effective means of increasing stormwater detention. This is due to 4" – 16" inches of soil supporting plant material. The downside to green roofs is that they have a higher upfront cost and more maintenance needs than a conventional roof. However, this can be contested with long term environmental benefits and a longer lifespan (Stormwater Best Management Practice - Green Roofs, 2021). Due to these benefits, green roofs are a more sustainable option than conventional roofs.

In addition to the EPA, Penn State Extension published an article in 2016 titled “Green Roofs for Stormwater” which outlines recommendations based on research conducted in Pennsylvania related to the use of vegetated roofs.

Urban centers such as Cincinnati and the many neighborhood centers in the surrounding area have limited greenspace and a large amount of square footage taken up by roof structures. Oftentimes, rain is directed off of roofs via gutters and transferred down to ground level. In areas where there is limited greenspace, this results in rainwater running over paved surfaces into the sewer system.

The state of Pennsylvania receives a similar amount of rainfall ranging from 38 to 46 inches (State Wide Data n.d.), compared to an average of 42.4 inches annually in Cincinnati. According to Penn State, “In Pennsylvania 50 to 60% of the rain falling on a green roof will be captured and evapotranspired back to the atmosphere, thus never entering the stormwater system” (Green Roofs for Stormwater, 2016). Reducing the amount of stormwater runoff from roofs by half is significant and would have a huge impact on reducing the amount of water flowing through CSOs each year.

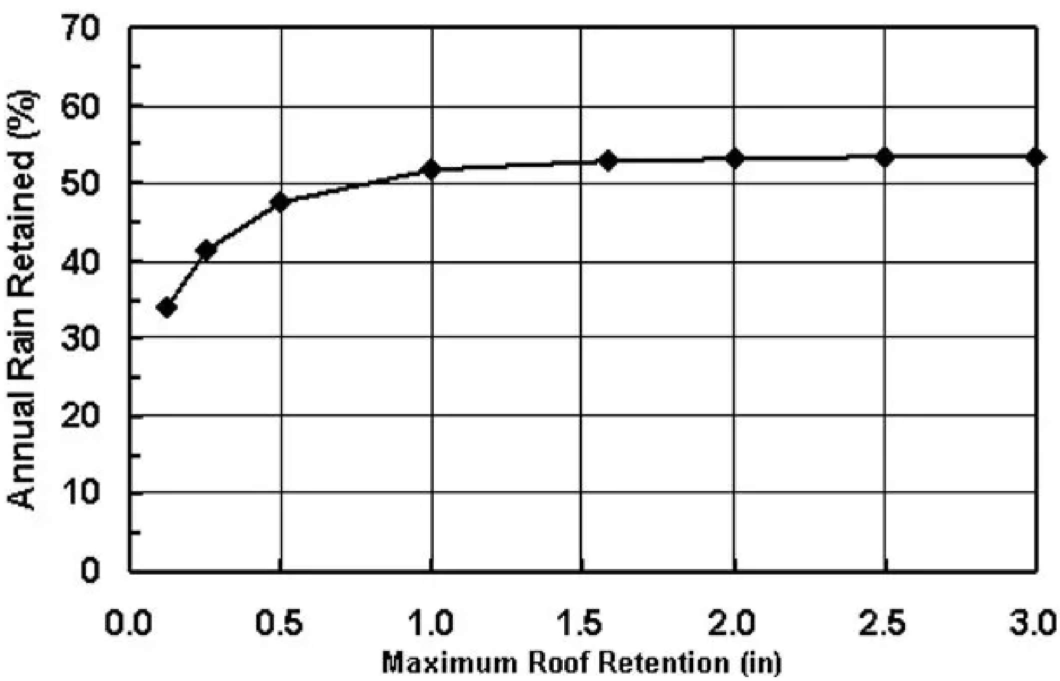

Figure 14. A chart showing the average retained percentage of stormwater on a green roof in State College, PA (Green Roofs for Stormwater, 2016).

Overall, green roofs should be considered as an effective option for capturing stormwater and delaying its entry into the sewer system. New construction projects should especially be aware of the benefits of green roofs as they are generally easier to install in a space that is specifically designed to meet the additional structural requirements.

Case Study and Literature Review 3

Rain gardens are another method to detain stormwater and are responsible for filtering out pollutants and absorbing rainwater as well as reducing peak flow during rain events. A rain garden is typically built on top of a detention basin. These gardens are made up of plants that have extensive root systems and are often native to that region. Installation of native plants aids in providing additional benefits to the installation.

To provide maximum benefit, water should be conveyed from impervious surfaces into the bioretention areas. The article mentions that "In addition, it can be difficult to convey flow from a large drainage area to a bioretention practice. In these cases, multiple successive bioretention practices may work better than a single large system" (Stormwater Best Management Practices Bioretention - Rain Gardens, 2021). Even small gardens make an impact on managing the effects of runoff during rain events are usually easier to direct water to.

Figure 15. A rain garden in downtown Lafayette, Indiana. Photo credit: Andrew Lentz

Some maintenance is required for bioretention areas to maintain their functions, but this is usually no more than other types of existing landscapes. Rain gardens have the ability to be installed as a retrofit to an existing area or built into new landscapes.

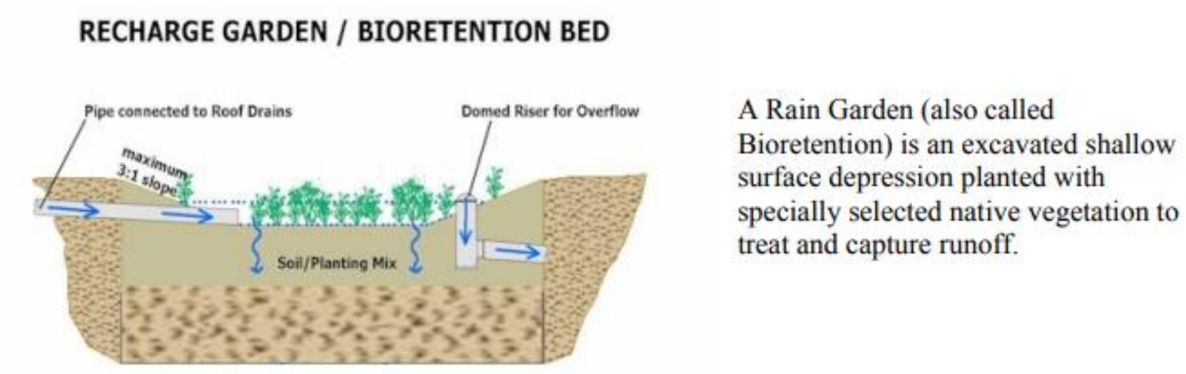

Figure 16. A graphic describing the function, design, and flow of water in a bioretention bed (BMP 6.4.5: Rain Garden/Bioretention, 2006).

In 2006 the Pennsylvania Stormwater Best Management Practices Manual was published to address the best techniques to implement for combatting excess stormwater. According to the manual “Bioretention can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMPs” (BMP 6.4.5: Rain Garden/Bioretention, 2006). Due to the flexible nature and wide variety of ways bioretention rain gardens can be installed, they are a great option for reducing stormwater runoff. In addition, these systems contribute to filtering out pollutants, promoting plant and animal biodiversity, and filtering out suspended solids.

Overall, bioretention installations are a cost-effective way to control stormwater. “Like other volume reduction practices, bioretention practices can save costs compared to the use of traditional structural stormwater conveyance systems” (Stormwater Best Management Practices Bioretention - Rain Gardens, 2021). An emphasis should be placed on installing these types of systems to reduce CSOs in an economical way while also providing other environmental services.

Summary of Case Studies

Each case study provides relevant findings and ways that horticultural techniques can be applied to communities with combined sewer systems. The Lick Run Greenway is an effective real-world example of implementing green infrastructure technologies to combat the highest polluting CSO in Cincinnati. A wide variety of stormwater mitigation techniques were used in this project including permeable pavement, increased greenspace, rain gardens, bioretention ponds, and more. Each of these technologies has a strong precedent for reducing the amount of rainwater entering the sewer system and is reported to be more cost effective than gray infrastructure. These techniques have already been applied to a community in Cincinnati, by MSDGC themselves. Therefore, it can be concluded that further implementation of these methods throughout other neighborhoods in the city will be effective.

Case studies two and three each provide evidence for specific technologies, green roofs, and rain gardens, respectively. Findings about green roofs make a strong case for effectively absorbing rainfall and slow down the flow of water into the sewer system during large storms, or potentially capturing the entirety of rainfall during smaller events. Additionally, the installation of green roofs has additional benefits such as reducing the urban heat island effect and improving the lifespan of the roof structure. There are many different types of green roof design options which allow this technology to be applied on a large scale to many different types of buildings. Similarly, data from rain gardens and bioretention beds reports that this technology can be installed in many different scenarios, making it a widely deployable green infrastructure technology throughout neighborhoods in Cincinnati. Rain gardens are most effective when directing the flow of water from impervious surfaces, which occur at a high rate in compact urban settings, to allow stormwater to infiltrate or filter through vegetation and soil.

Figure 17. A rendering representing how a rain garden can be installed on the edge of a curb (NYC Water 2017).

Historical Context

Cincinnati's sewer history begins in 1800. The first major improvement was the addition of a system that could collect stormwater with ditches and move it offsite. This process began in 1828 and moved water towards waterways such as rivers and streams.

About 27 years later "combined sewer systems were introduced in 1855, they were hailed as a vast improvement over urban cesspool ditches that ran along city streets and spilled over when it rained" (Tibbetts, 2005). Cincinnati began installing these combined systems to carry wastewater, and also served as a pipeline for stormwater during rain events. Mass adoption of CSOs led to the access of wastewater sewers for all Cincinnati residents.

It was not until the 1940's when the importance of designing separate sewers, called sanitary sewers, was recognized as a healthier way to manage sewage and stormwater. These separate systems allow only storm water to be discharged to streams and reduce pollution.

Cincinnati is an old city, originally settled in 1788, and is designed with a majority of CSOs instead of SSOs. According to ARCGIS "MSDGC currently has approximately 234 CSOs and 63 SSOs" (Person, 2022). Only about 27% of Cincinnati sewers are SSOs and the remaining are CSOs.

In 1979 an infrastructure study was conducted and concluded that regular maintenance must be performed in order to keep up with the sewer system and to ensure working function of the sewer system.

1984 brought with it the creation of the Stormwater Management Utility (SMU). This is a group in charge of determining how to best handle issues with flooding, stormwater management, and maintaining existing storm sewers.

In 2004 MSDGC entered into a consent decree with the U.S. EPA, Ohio EPA, and the Ohio River Valley Water Sanitation Commission related to CSOs, SSOs, wastewater treatment plants, and a capacity assurance program. This spurred action within MSDGC to begin a series of projects to reduce the amount of flow due to CSOs.

New CSO systems are no longer allowed to be built, however it is not feasible for established cities such as Cincinnati which has 75% CSOs to completely replace these systems. The EPA now mandates that MSDGC monitors pollution and wastewater flowing into waterways. Moving forward, MSDGC must continue to meet requirements in the federal consent decree and the National Pollutant Discharge Elimination System (NPDES), while reducing the amount of water overflowing from CSOs.

Historical Context Continued

Figure 17. Construction of a combined sewer outfall into the Mill Creek in Cincinnati Ohio, 1933 (Smith, Trail location 8: History of a Watershed n.d.).

Program Requirements

Figure 18. Aerial photo of Oakley Station in Cincinnati Ohio (3895 Isabella Ave. n.d.).

Figure 19. Aerial photo of the Mt. Lookout neighborhood in Cincinnati Ohio (R/Cincinnati 2020).

Program Requirements Continued

Figure 20. Aerial photo of the Walnut Hills neighborhood in Cincinnati Ohio (Walnut Hills n.d.).

Figures 18, 19, and 20 are compact quarter mile neighborhood sites located in Cincinnati, Ohio and are receiving concept and perspective plans.

The goal is to reduce stormwater runoff from impervious surfaces and collect excess rainwater so that it does not overwhelm the combined sewer system.

Some design techniques may include:

- Implementation of green roofs
- Use pervious pavers in areas like parking lots
- Create bioswale retention areas
    - Funnel stormwater from roofs or other surfaces to these bioretention ponds
- Install rain gardens in areas such as the edge of roadways/intersections

Final Project Solutions

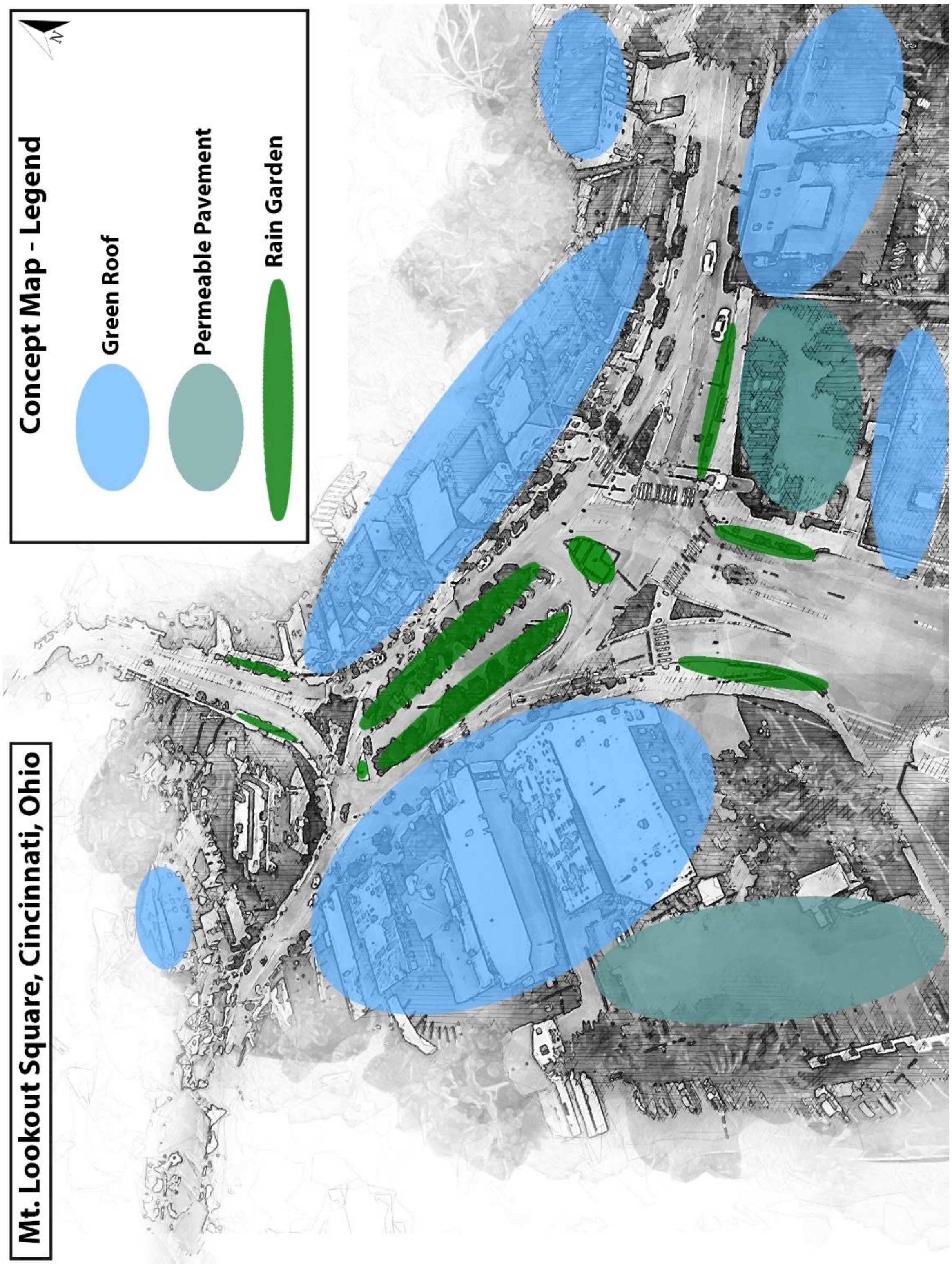

Figure 21. Proposed concept plan for the Mt. Lookout neighborhood in Cincinnati, Ohio (Lentz 2024).

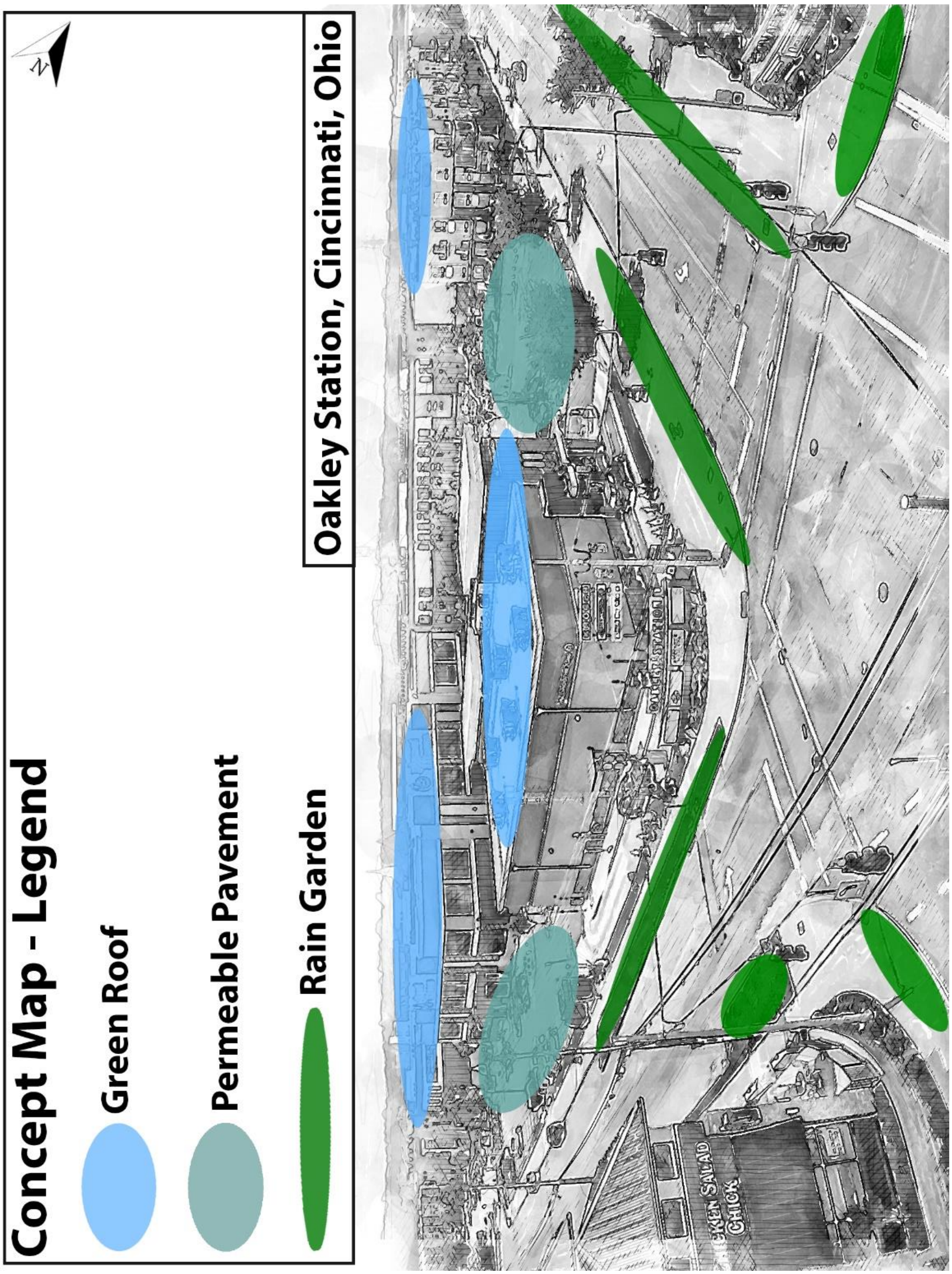

Figure 22. Proposed concept plan for the Oakley Station shopping center in Cincinnati, Ohio (Lentz 2024).

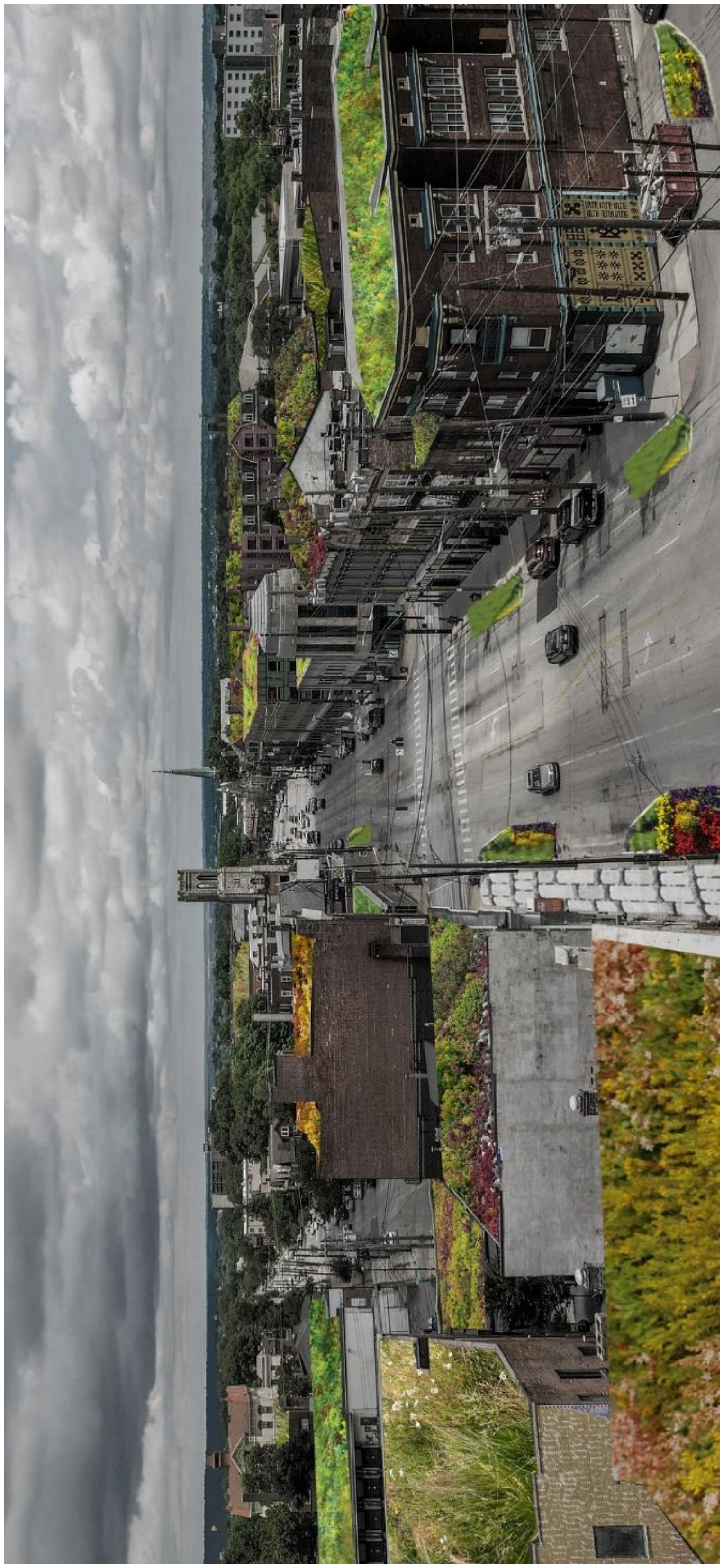

Figure 23. Proposed perspective for the Walnut Hills neighborhood in Cincinnati, Ohio (Lentz 2024).

Stormwater runoff can be mitigated effectively and efficiently by designing urban landscapes to incorporate green design and allow for rainwater to infiltrate into soil, stopping or delaying it from entering the sewer system. Green roofs, rain gardens, bioretention areas, and permeable pavement are all effective ways to manage stormwater during heavy rainfall events. By reducing the amount of rainwater entering the sewer system during heavy rain events, this will have a direct correlation to the occurrence of discharge into surface waters from CSOs.

Bibliography

3895 Isabella Ave. Finn Team, Coldwell Banker. (n.d.). https://finn-team.com/property/isabella-ave/

Average Annual Precipitation. IBISWorld Industry Reports. (2024, January 10). https://www.ibisworld.com/us/bed/average-annual-precipitation/489/#:~:text=Climate%20change%20has%20caused%20more,has%20averaged%20around%2030.0%20inches.

BMP 6.4.5: Rain Garden/Bioretention. Pennsylvania Stormwater Best Management Practices Manual . (2006, December 30). https://greenport.pa.gov/elibrary/GetDocument?docId=7666&DocName=CHAPTER+6.4.5+BMP+RAIN+GARDEN+BIORETENTION.PDF++%3Cspan+style%3D%22color%3Agreen%3B%22%3E%3C%2Fspan%3E+%3Cspan+style%3D%22color%3Ablue%3B%22%3E%3C%2Fspan%3E

Bruggers, J. (2015, March 15). *Ohio River again tops list for industrial pollution*. USA Today. https://www.usatoday.com/story/news/nation/2015/03/14/ohio-river-tops-list-industrial-pollution/24784863/

Cincinnati, Ohio - Code of Ordinances. Municode Library. (n.d.). https://library.municode.com/oh/cincinnati/codes/code_of_ordinances?nodeId=TITVIIGERE_CH743URFO

Combined Sewer Overflow Control Program. Ohio Environmental Protection Agency. (n.d.). https://epa.ohio.gov/divisions-and-offices/surface-water/permitting/combined-sewer-overflow-control-program

Combined Sewer Overflows. Combined Sewer Overflows - DEP. (n.d.). https://www.nyc.gov/site/dep/water/combined-sewer-overflows.page

Combined Sewer Overflows. NYC Environmental Protection. (n.d.). https://www.nyc.gov/site/dep/water/combined-sewer-overflows.page#:~:text=Expanding%20grey%20infrastructure%20and%20making,pollutants%20out%20of%20our%20waterways.

CSOs, SSOs, and Sewer Backups. Metropolitan Sewer District of Greater Cincinnati. (n.d.-a). https://msdgc.org/programs/wet-weather-program/csos-ssos-and-sewer-backups/

Diversity, Equity and Inclusion Defined. Worthington Schools. (n.d.). https://www.worthington.k12.oh.us/Page/4732

Environmental Protection Agency. (n.d.). *Combined Sewer Overflows (CSOs)*. EPA. https://www.epa.gov/npdes/combined-sewer-overflows-csos

Green Infrastructure and Stormwater Management. Global Designing Cities Initiative. (2022, October 25). https://globaldesigningcities.org/publication/global-street-design-guide/utilities-and-infrastructure/green-infrastructure-stormwater-management/

Green Infrastructure Practices to Reduce Flooding and CSOs. Water Rutgers. (n.d.). http://water.rutgers.edu/PVSC/Flooding&CSOBrochure_lowres.pdf

Green Roofs for Stormwater. Penn State Extension. (2016, May 24). https://extension.psu.edu/green-roofs-for-stormwater

Green Roof Research at Western. Green Roofs. (n.d.). https://www.eng.uwo.ca/research/greenroof/

History - Stormwater Management Utility. Home - City of Cincinnati. (n.d.). https://www.cincinnati-oh.gov/stormwater/history/

Human Health Impacts of CSOs and SSOs. (n.d.). https://www3.epa.gov/npdes/pubs/csossoRTC2004_chapter06.pdf

Just What Is Green Infrastructure?. DCNR.PA. (2021, October 13). https://www.dcnr.pa.gov/GoodNatured/pages/Article.aspx?post=183

Lick Run Greenway. Metropolitan Sewer District of Greater Cincinnati. (n.d.-b). https://msdgc.org/community/lick-run-greenway/

Murtha, L. (2018, October 16). *On the market: A colorful condo on Hyde Park Square*. Cincinnati Magazine. https://www.cincinnatimagazine.com/homefrontblog/on-the-market-a-colorful-condo-on-hyde-park-square/

NYC Water. (2017, June 22). *More Rain Gardens to choose from*. Medium. https://medium.com/nycwater/more-rain-gardens-to-choose-from-3797dc107687

Person. (2022, July 15). *MSDGC*. ArcGIS StoryMaps. https://storymaps.arcgis.com/stories/791923beb2b245d9a7f70534f160a929

R/Cincinnati. Reddit. (2020). https://www.reddit.com/r/cincinnati/

Smith, J. (n.d.-a). *Lick Run Project*. Project Groundwork. https://projectgroundwork.org/projects/lowermillcreek/sustainable/lickrun/index_new.htm

Smith, J. (n.d.-b). *Lower Mill Creek watershed*. Project Groundwork. https://projectgroundwork.org/projects/lowermillcreek/index.htm

Smith, J. (n.d.). *Trail location 8: History of a Watershed*. Heritage Trail: Location 8. https://projectgroundwork.org/projects/lowermillcreek/sustainable/lickrun/alternative/HT_Loc_8_History_Watershed.htm

State Wide Data. Pennsylvania State Climatologist. (n.d.). https://climate.met.psu.edu/data/state/#:~:text=Precipitation%20is%20fairly%20evenly%20distributed,receive%2038%20to%2046%20inches.

Stormwater Best Management Practice - Green Roofs. EPA. (2021, December). https://www.epa.gov/system/files/documents/2021-11/bmp-green-roofs.pdf

Stormwater Best Management Practices Bioretention (Rain Gardens). (2021, December). https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf

Sweet, E. (2023, June 19). *The historic Mill Creek and the Mill Creek Alliance*. Welcome to UACC. https://uacvoice.org/2023/06/the-historic-mill-creek-and-the-mill-creek-alliance/#:~:text=Waste%20from%20soap%20production%2C%20pork,endangered%20urban%20waterway%20in%20America.

Tibbetts, J. (2005, July). *Combined Sewer Systems: Down, Dirty, and Out of Date*. Environmental Health Perspectives. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1257666/

Using Smart Sewers to Reduce Overflows. Metropolitan Sewer District of Greater Cincinnati. (n.d.-c). https://msdgc.org/programs/smart-sewers-program/

Walnut Hills. Homes.com. (n.d.). https://www.homes.com/cincinnati-oh/neighborhood/walnut-hills/

Weather Averages Cincinnati, Ohio. U.S. Climate Data. (n.d.). https://www.usclimatedata.com/climate/cincinnati/ohio/united-states/usoh0188

What climate change means for Ohio - US EPA. EPA. (2016, August). https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-oh.pdf