Name of Student: Richard Owusu-Ansah

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TITLE OF RESEARCH

RiverSmart Homes; A Green Infrastructure Approach to Urban Water Management, The Case of the Anacostia River in Washington DC.

CHAPTER 1

1.0 Introduction

The Anacostia River, a tributary of the Potomac River, is a crucial waterway that runs through Washington D.C. and Maryland. It symbolizes the region's rich history and also showcases the environmental issues caused by urbanization and industrial development. The main course of the river runs through the southern region of Washington DC, although the Anacostia basin includes 13 important sub-watersheds that span over both Maryland and the District of Columbia. The river's Northwest and Northeast Branches collectively contain a multitude of rivers and streams in Montgomery and Prince George's counties. According to Murray et.al (2015), Maryland comprises 84% of the watershed, while Washington DC comprises the remaining 16%. The main course of the river extends around 8 miles, passing through both forested and heavily populated regions. The system gathers water from many storm drains, combined sewer overflows (CSOs), and urban drainage ditches (Velinsky et. al 1994). The river possesses a significant historical background, originating in the 1600s when Captain John Smith navigated upstream on the river. During the last 200 years, the Anacostia River has undergone a transformation from its natural state to a highly affected river due to urbanization and industrialization, resulting in notable ecological issues.

The Anacostia River has seen substantial environmental degradation throughout its history, primarily attributed to human activities that commenced in the early 19th century. The watershed has historically suffered from trash, toxins, sewage, runoff, oil, heavy metals and more due to adjacent agricultural, industrial and urban land uses (United States Environmental Protection Agency, 2023). The first degradation of the river's ecological condition can be attributed to the actions of European settlers who engaged in extensive land clearance for agricultural purposes. In the past, the Anacostia River supported a flourishing environment. Nevertheless, the Anacostia River has fallen a long way from the vibrant health it enjoyed in the early 17th century, when Europeans first arrived in the region. The central artery of a watershed that straddles both wooded hills and coastal flats, it runs through lush forests and rich tidal wetlands. The water teemed with shad, herring, perch, and other fish that had long been a staple food of the local Nanchotank people (Turrentine, 2016). Once the European settlers started clearing fields for agriculture, which led to heavy erosion and sedimentation in the early 19th century, the river began to suffer (Turrentine, 2016). The process of deforestation contributed to significant erosion, which subsequently led to heightened levels of sedimentation within the river.

The development of the Washington, D.C., area in the late 19th century onwards led to a deterioration of the situation (NRDC, 2016). The process of industrialization of the Anacostia River commenced during the 18th century, resulting in substantial environmental contamination. The pollution of the river was attributed to the activities of shipbuilding at the Washington Navy Yard and the operation of an upriver coal gasification facility by the Washington Gas Light Company's East Station, which was in operation from 1888 until 1948. The manufacturing facility utilized both coal and oil as fuel sources, resulting in the generation of by-products such as tar and petroleum coke. These by-products have had detrimental effects on the surrounding environment, leading to contamination of the soil, groundwater, and river silt. The demolition of the station in 1986 resulted in enduring environmental consequences for the Anacostia River (Fishman et al., 2021). The companies and industrial complexes situated in close proximity to the river were found to release untreated waste, comprising heavy metals and harmful chemicals, directly into the water body as well as through storm drains (Anacostia Riverkeeper, 2022). Urbanization led to the reduction of forests and wetlands, which are crucial ecosystems for a diverse array of wildlife species. This alteration involved not just the tangible aspect, but also the environmental side, as the river began to encounter heightened levels of pollution. The river's water quality and aquatic biodiversity have experienced substantial deterioration as a result of the prevalence of agricultural runoff, industrial waste, sewage, and heavy metals, all of which have emerged as prominent contaminants.

The problem of Combined Sewer Overflows (CSOs) has posed significant challenges. The outdated sewer infrastructure, which was originally intended to accommodate the collection of rainwater runoff, home sewage, and industrial wastewater within a single pipeline, frequently experiences excessive strain during periods of heavy rainfall. Consequently, the result is the release of untreated sewage that has been combined with rainwater into the river. According to a study conducted by the National Resources Defense Council (NRDC) in 2016, it is estimated that a significant proportion, ranging from 75% to 90%, of pollution in the Anacostia River is attributed to the phenomenon of stormwater runoff. The runoff from various sources introduces a range of contaminants, including silt, toxins, heavy metals, agricultural waste, trash, fecal bacteria, oil, antifreeze, and other pollutants, into the river (NRDC, 2016). Hazardous substances, including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), heavy metals, and several other compounds, have been discharged into the Anacostia River from these facilities, as well as other specific and non-specific sources. These toxic contaminants also become bound to river sediments and can persist there for several years due to their chemical nature (Velinsky et. al 1994: Hwang & Foster, 2008). The phenomenon has a dual impact, as it not only alters the aesthetic value of the river but also presents a potential hazard to the biodiversity of aquatic organisms.

Over the years, there have been numerous efforts to restore the Anacostia River. Some of the efforts to restore the river include Anacostia Corridor Restoration Plan, Kingman Lake Restoration Design, Stream and Habitat and Restoration and Natural Resource Damage Assessment and Restoration (NRDAR) (DOEE, n.d). Also, there have been policies around stormwater and sewage management to help restore the health of the Anacostia River. The policies and activities targeted at restoring the health and vitality of Anacostia have undergone evolution and growth in tandem with the development of the capital city. At the core of these endeavors lies the Sustainable DC 2.0 Plan, a comprehensive and ambitious framework devised by Washington D.C. to foster the development of a more environmentally sustainable, healthier, and more habitable urban environment. The city's multidimensional approach to environmental restoration and conservation is exemplified by the implementation of a comprehensive sustainability plan and the strategic development of specific infrastructural developments.

Restoring the Anacostia River holds significance for reasons. Firstly, it will contribute towards enhancing the river's water quality, which has deteriorated due to pollution from sources. This restoration will have an impact on the river's ecosystem benefiting fish and wildlife populations while also making it safer for activities like swimming and fishing. Additionally, residents in proximity to the Anacostia face an impact from its contamination. By improving the water quality through this restoration project, we can reduce health issues. Enhance the quality of life for those residing near the river.

1.1 Purpose of the Study

The research aims to delve into the restoration efforts of the Anacostia River, with a specific focus on the RiverSmart program, a key component of the stormwater retrofit initiative within the broader context of stream and habitat restoration in the Anacostia watershed. Specifically, the main objective of the study is to explore the role of Low Impact

Development designs and green infrastructure in addressing pollution of the Anacostia River. Also, the study’s objective is to examine how the RiverSmart program with its green features contributes to stormwater capture and water reuse.

1.2 Justification of the Study

This study is particularly significant in light of the observation by Keeley and Benton-Short (2018, p.203) regarding the dual water challenges faced by US cities: ensuring the supply of high-quality water to residents and safeguarding the water quality in adjacent natural water bodies from the adverse effects of wastewater and stormwater runoff. By examining the RiverSmart Program's role in mitigating stormwater runoff through green infrastructure and Low Impact Developments designs, this research contributes to understanding and addressing these critical urban water management challenges, highlighting the program's impact on improving water quality and ecosystem health in urban river systems like the Anacostia. Again, after the establishment of the Clean Water Act of 1972, the United States has been able to restore the integrity of its water bodies especially in ameliorating pollution from point sources (including industrial plants, sewage treatment plants and outfalls) (Keeley & Benton-Short, 2018, p.205). However, sources of water pollution have shifted from point source to non-point source pollution after 45 years of passing the Clean Water Act, with runoffs from farms and cities becoming the leading cause of water pollution in the United States (Keeley & Benton-Short, 2018, p.206).

1.3 Organization of the study

This study is organized into three chapters. The first chapter begins with the introduction of the study, followed by the purpose of the study, the justification of the study and the organization of the paper. The second chapter explores the early history and significance of the study. The last chapter will begin with an examination of the Sustainable DC 2.0 Plan with emphasis on the water section of the plan. It also talks briefly about clean-up activities ongoing in the Anacostia River with a particular focus on the big tunnel under the Anacostia exploring why it was chosen over green infrastructure. The study then narrows to the RiverSmart Homes program. It discusses the Low Impact Development and green features used in the RiverSmart Homes Program. This section also explores the impacts of the RiverSmart Homes program on stormwater capture and water reuse within the district. Also, the chapter discusses how the program has contributed to the restoration of the

Anacostia River in relation to the water goals of the Sustainable DC 2.0 plan. It will also discuss some of the challenges associated with the program.

CHAPTER 2

2.0 Early History and Significance of the River

The Anacostia River watershed covers an area of 176 square miles in the District of Columbia and Maryland. It supports a diverse ecosystem, including more than 40 species of fish, over 200 species of birds, and a human population of over 1 million (Schlyer, 2018). In 1608, Captain John Smith documented one of the oldest English language accounts of this area when he navigated the Potomac River and reached the point where it meets the Anacostia River. Similar to other tributaries that flow into Chesapeake Bay, the Anacostia is a tidal river. In the past, an astounding 2,500 acres of wetlands were sustained by its fluctuating waterline (Anacostia Watershed Society, n.d.). The Nacotchtank culture flourished in the region known as the piedmont, which is between the Appalachian foothills and the Atlantic coastal plain (Schlyer, 2018). This area was rich in fish and game, and the dense forests were teeming with life. Before European colonization, the Anacostia River was regarded as a vital habitat for several species including birds, amphibians, fish, reptiles, insects, and humans. Significant shad populations once inhabited the area, where they laid their eggs in the wetlands prior to returning to the Atlantic (Anacostia Watershed Society, n.d.). Kingfishers, bald eagles, and ospreys derive their sustenance from eel, herring, and cod. Bears, cranes, and cardinals can all be revitalized with a bath and a revitalizing beverage. The Nacotchtank people depend on water and fishing grounds for sustenance. The river in question possessed great importance for all forms of life that called this region home prior to the advent of Europeans. The Nacotchtank Indians, the indigenous inhabitants of the area, traversed these wetlands via canoes while gathering wild rice and angling for perch and bass. Anacostia's ecology and use underwent a profound transformation shortly after Europeans established themselves along its banks (Anacostia Watershed Society, n.d.).

Throughout the last four centuries, the Anacostia River has been referred to by several names, including the Eastern Branch of the Potomac, the other national river, the dirtiest river in the country, and the forgotten river (Schlyer, 2018). During the seventeenth and eighteenth centuries, as European colonists flocked to the New World, port cities including Bladensburg, Colmar Manor, and Cottage City emerged along the Maryland bank of the river. According to historian John R. Wennersten, the region's erstwhile inhabitants were rendered uninhabitable by the colonists, who were attracted by its pleasant landscape and moderate climate (Wennersten, 2008, p.16). Early European settlers on the banks of the Anacostia immediately began altering the topography, as they had brought with them land use philosophies that were diametrically opposed to those previously observed by the Nacotchtank Indians. Tobacco cultivation was arguably the most revolutionary practice introduced to the New World by the Europeans (Wennersten, 2008, p.16). Significantly contributing to the contamination of the Anacostia River in Washington, DC, was the tobacco industry. The adoption of wasteful land practices by colonists resulted in significant alterations to the watershed's topography, including the expansion of tobacco cultivation and the depletion of forests. The intensive nutrient extraction of the crop incentivized colonists to adopt inefficient land practices that significantly altered the watershed's topography. Within a span of less than ten years, the land underwent a transformation from forest to tobacco fields to broom sedge and sparse pines. Although the financial gains were substantial, the cultivation of tobacco had a profound negative impact on the ecological well-being of the Anacostia watershed (Wennersten, 2008, p.21).

The watershed region did not experience significant agricultural exploitation until the late 1770s, which led to a critical point where a series of rapid ecological changes occurred. Following over a hundred years of extensive farming, which had almost entirely eliminated the forested area in the region, the river was steadily consuming the soils of the watershed. Due to the significant erosion caused by heavy rainfall, the Anacostia River's once deep channel became heavily filled with sediment, making it impossible for ships to access the port at Bladensburg. The tobacco plantations in the watershed and trading posts along the Chesapeake Bay were historically linked by a river that served as a convenient transportation route. Nevertheless, at the time of the country's establishment, the river had already seen a significant ecological transformation (Wennersten, 2008, p.34).

The Anacostia River in Washington, D.C. was crucial in the city's economic and naval operations as the capital of the United States. Pierre L'Enfant's great ambition for the river was hindered by the opposition of landowners in Georgetown and a dearth of investor interest. The Southeast shoreline underwent urbanization with the building of the Washington Navy Yard in 1799, a process that continued until the 1960s. The Yard's extensive industrial activities significantly influenced the ecological health of the river, shifting from shipbuilding to the manufacturing of weapons (Wennersten, 2008, p.50). During the Civil War the Anacostia River faced increased pressure due to activities and the growing population of the District. To cope with the city's expansion officials implemented services to handle the disposal of waste. Similar to how the Los Angeles River suffered from population growth and industrial development, the Anacostia also experienced a decline as it became a dumping ground for Washington's effluence (McCool, 2014 p.205). The sewer system that emerged was not uniform—by the 1900s Northwest D.C. Had an established network of pipes while Capitol Hill and the navy yard still relied on gravity flow pipe sewers that empties directly into the Anacostia River (Wennersten, 2008 p.78). Eventually during or around the time of the Civil War this gravity flow model was replaced with a combined sewer system that remains in use today. This system collects both rainwater and raw sewage in one set of pipes. Can only handle a capacity of waste. Consequently heavy rainfall or snowfall often leads to overflow situations where two billion gallons of raw sewage flow into the Anacostia through outlets, on an annual basis.

"In the century the district faced a significant issue, with its sewage system. Shockingly there were seventeen Combined Sewer Overflows (CSOs) that directly released untreated sewage and storm runoff into the river " (McCool, 2014, p.205). These overflows not led to an increase in bacteria like coliform but also resulted in dangerously low levels of dissolved oxygen, in the Anacostia River. Consequently, this made it impossible for various aquatic species to survive in its waters (African American Environmentalists Association, 2000 p.26). Anthropologist Brett Williams sheds light on Washington's sewage system during the war era;

> *When the tide fell during these years, sewage choked the thick aquatic grasses, burbled and fermented, and welcomed malarial mosquitoes, especially during Washington's oppressive summers. Employees at the Navy Yard, along with inmates at the D.C. Jail and the Government Hospital for the Insane suffered and died from malaria at alarming rates* (Williams, 2001, p.416-417).

In the early 1900s, after establishing a connection between malaria and wetlands, the focus shifted from the insufficient sewage system to the Anacostia river itself. Congress allocated funds for engineering projects aimed at improving the river's navigability and reclaiming its wetlands to prevent the further spread of malaria. Although there have been gradual improvements to the sewer system in Southeast, the sewage outfalls persist and continue to discharge untreated sewage and storm water runoff directly into the river during instances of system overflow. The stormwater in these overflows can have an equally harmful impact on the river's well-being. This is because the runoff from heavily used city streets carries with it significant amounts of heavy metals, lubricants emitted by vehicles, and any garbage that has been discarded along the walkways (Haynes, 2013, p.53).

CHAPTER 3

3.0 Dc's Sustainability Plan with Emphasis on Water

The Sustainable DC 2.0 Plan, developed in 2013, is a comprehensive sustainability plan for Washington DC which aims to make DC the healthiest, greenest, and most livable city for all residents (Sustainable DC Plan, 2013). The plan encompasses a comprehensive range of 13 subjects, including governance, equity, built environment, climate, economy, education, energy, food, health, nature, transportation, waste, and water. Additionally, it includes a substantial number of over 150 activities that outline how these themes contribute to the simultaneous advancement of equity, environmental protection, and economic development.

On the water aspect of the sustainability DC 2.0 plan, the goals are to:

- Improve the quality of waterways to standards suitable for fishing and swimming.
- Reduce the volume of stormwater runoff.
- Reduce demands for potable water and increase rainwater reuse.
- Ensure safe, accessible drinking water.

These broad goals have specific targets. For the purpose of this paper, we discuss a few of those targets. One of the targets is to implement green infrastructure practices to capture, retain, or reuse stormwater from at least 10 percent of the District's land area (Sustainable DC Plan, 2013). Narrowing it more, the district plans to audit 1200 properties per year via the RiverSmart program and increase participation in areas of the city where enrollment has been historically low. Another target within these broad goals is to develop incentives for water-efficiency measures in landscaping and buildings. With this, the district has instituted water efficiency incentives to reduce consumption, encourage low and zero-water technologies and promote water-efficient landscapes design using native species and green infrastructure. Another target is to ensure that 100 percent of DC residents have access to clean, affordable water (Sustainable DC Plan, 2013). A comprehensive approach, as seen in the Sustainable DC 2.0 Plan, offers clear advantages over isolated sustainability strategies. Such a comprehensive plan promotes a holistic view, highlighting synergies like linking transportation to air quality or energy to water use. This not only leads to better solutions, like public transit reducing both traffic and emissions, but also streamlines resources. Combining efforts, such as waste reduction and water conservation campaigns, can save time, costs, and ensure a consistent message. Moreover, a unified plan enhances community engagement by showing residents the interconnectedness of sustainability initiatives.

3.1 Highlights of some of the initiatives within the Water Section of the Sustainability DC 2.0

DC Water's Clean Rivers Project, with a budget of $2.6 billion, has significantly improved the Anacostia River's quality by reducing sewer overflows by 96% via extensive underground tunnels in the Anacostia. Complementing this, the District Government, under the EPA's Municipal Separate Storm Sewer System (MS4) permit, is actively reducing stormwater pollution through green infrastructure like permeable pavements and rain gardens (Sustainable DC, n.d.). Innovative initiatives like the Stormwater Retention Credit Trading Program incentivize property owners to contribute to stormwater management. Additionally, the "A Cleaner Anacostia River" project, with a $45 million investment, focuses on remediating contaminated sediments. The rehabilitation of five tributary streams further enhances the river's water quality. Environmental legislation, including the foam ban and bag law, also plays a crucial role in preserving the river's ecological and recreational value (Sustainable DC, n.d.).

Also, based on the findings presented in the 2023 Progress Report, the District has made notable progress in the development of restoration plans for various significant stream projects. These projects encompass a range of areas, such as the restoration of 18,600 feet of stream and five acres of wetlands at Fort Dupont, approximately 1,000 feet of stream at Stickfoot Branch, 1,300 feet of stream at Park Drive, and 21,000 feet of stream at Oxon Run.

3.2 Clean-up efforts in the Anacostia River

Given the pollution of the Anacostia River numerous governmental initiatives, community involvement, infrastructure improvements and technological interventions are currently underway to address the challenges associated with its contamination. Despite facing obstacles, efforts to tackle pollution and restore the Anacostia River show promise for its revitalization and the adoption of practices. The government has launched cleanup programs, including the Anacostia Watershed Restoration Plan (AWRP) in 2010. The AWRP has employed strategies to assess water quality and enforce pollution control regulations since its inception. Regular and extensive monitoring of water quality and contamination in the Anacostia River is conducted by AWRP (Anacostia Watershed Society, 2023). The U.S. The Geological Survey has also installed equipment to provide real time reporting on water quality parameters such as pH levels, dissolved oxygen concentration, temperature, specific conductance and turbidity (Sauer & Turnipseed 2018). These methods enable surveillance of water quality in the Anacostia River by identifying patterns, potential hazards and monitoring restoration efforts. Local community organizations have also played a role in supporting cleanup efforts. An excellent example of community involvement in the restoration process can be seen through the work of Anacostia Riverkeeper. This organization organizes cleanup events, educational programs and advocacy campaigns (Anacostia Riverkeeper, 2021). The impact of these community driven initiatives, on raising awareness and rallying individuals to tackle river pollution has been remarkable. The district has also constructed a large tunnel beneath the Anacostia River to deal with the issue of combined sewer outflows from DC's antiquated combined sewer system.

3.3. Reason why DC chose the Anacostia River Tunnel (Grey Infrastructure) Over Green Infrastructure

When urban areas engage in infrastructure development, they frequently encounter the decision between implementing grey infrastructure or green infrastructure. The primary factor behind the choice of constructing a substantial tunnel beneath the Anacostia River, also known as "grey infrastructure," rather than green infrastructure, was the imperative to mitigate the persistent problem of sewage overflow into the Anacostia River. According to DC Water (2021), the sewer infrastructure in the District of Columbia, which is outdated, proved inadequate in managing instances of intense rainfall, leading to the discharge of untreated sewage into nearby rivers, such as the Anacostia. The tunnel, with a diameter of 23 feet, is situated at a depth ranging from 80 to 120 feet below the surface. It traverses through the densely populated urban corridor of Washington D.C., encompassing various notable monuments. The implementation of a substantial infrastructure endeavor within a highly populated urban region posed notable engineering obstacles; yet it was considered imperative in order to accomplish the project's environmental objectives (Hudson & Chung, 2020).

Although green infrastructure solutions are frequently regarded as more sustainable and environmentally friendly, their effectiveness in mitigating the extensive pollution issue in the Anacostia River may have been inadequate. The selection of a tunnel system indicates that the authorities placed a high emphasis on promptly and efficiently addressing the issue of sewage overflow. Nevertheless, it is important to acknowledge that green infrastructure remains a viable option. According to Rice (2018), DC Water has stated that the construction of a tunnel will solely be pursued as a measure to enhance drainage in the vicinity of Rock Creek, but only if alternative methods to mitigate sewage overflow prove to be ineffective. This implies a readiness to contemplate the implementation of green infrastructure solutions in cases where they are practical. This study argues for cities to use green infrastructure and other Low Impact Development designs in urban stormwater water capture as this green infrastructure comes with multiple benefits such as climate mitigation, and creation of green jobs.

The above clean-up efforts by the different agencies and local communities are all intended in making the Anacostia River a swimmable and fishable water in 2025 as defined in the Clean Water Act of 1972 (Anacostia Watershed Society, 2023). One of the key agencies coordinating the activities in restoring the Anacostia and other water bodies in the District of Columbia is the Department of Energy and Environment (DOEE). Generally, restoration activities in the Anacostia include the Anacostia Corridor Restoration Plan, Kingman Lake Restoration Design, Natural Resource Damage Assessment and Restoration, and Stream and Habitat Restoration. Other projects include stormwater and sewage management and the Anacostia River Sediment project (DOEE, n.d.). This paper focuses on an innovative stormwater retrofit project which is part of the broader stream and habitat restoration initiative of the Anacostia river. DOEE's Stream and Habitat Restoration Program supervises the design and construction of outfall repair, low impact development (LID) stormwater retrofits, and stream restoration in the public right-of-way, federal parkland, and District parkland, among other locations throughout the District (DOEE, n.d). Enhancing wildlife habitat, restoring natural stream flow, reducing erosion and stormwater pollution, providing high-quality outdoor recreational space, and ensuring the long-term protection of stormwater and sanitary sewer infrastructure are all objectives of these initiatives (DOEE, n.d).

3.4 Innovative Stormwater Retrofit

The innovative stormwater retrofit projects around the district are funded through the DOEE's Stormwater Enterprise Fund and grant funding that DOEE receives from the Environmental Protection Agency (EPA). The DOEE supervises the design and construction of these Low Impact Development (LID) stormwater retrofit projects within the district. The goal of these projects is to to improve water quality in the Anacostia and Potomac Rivers for the benefit of District residents, visitors, wildlife and the environment, while providing high quality outdoor recreational space and facilities for children and adults to learn, play, and connect with nature (DOEE, n.d). A further goal of these projects is to reduce the stormwater pollutants that enter the local waters including the Anacostia. One of the most successful of the projects within this area is the RiverSmart programs that provide incentives to property owners to take action to reduce stormwater pollution on their properties.

3.6 RiverSmart Programs

RiverSmart Washington is a collaborative effort spearheaded by DOEE, which encompasses the District Department of Transportation, DC Water, the Rock Creek Conservancy, and private enterprises. The project comprises a $800,000 grant from the National Fish and Wildlife Foundation, $1 million from DC Water, and $1.4 million from District Stormwater Enterprise Funds. The DDOE personnel participating in the study are funded by the EPA's Clean Water Act Section 319 program, which focuses on addressing non-point source pollution (US EPA, 2015). Washington D.C.’s Department of Energy and Environment (DOEE) administers a variety of "RiverSmart" programs to fund projects that reduce stormwater runoff and water pollution in the Anacostia and Potomac Rivers. The programs provide financial incentives, in the form of grants and rebates, to fund green infrastructure projects that reduce and treat stormwater runoff from impervious surfaces. Although the RiverSmart program was developed to help the District address water pollution from stormwater runoff, it also supports climate resilience by diverting rainwater from the city’s stormwater system to manage increasingly heavy rainfall events (Georgetown Climate Center, 2006). With this program, District property owners who install rain barrels, green roofs, permeable pavers, shade trees, and landscaping projects that reduce and/or treat stormwater runoff from impervious surfaces on their property are eligible for grants and rebates from these programs to offset the costs of the investment. DOEE offers a variety of grants for green infrastructure projects through RiverSmart Homes, RiverSmart Communities, and RiverSmart Schools. These programs used low impact development (LID) features for capturing stormwater from properties such as single homes, apartments, churches and schools. In the subsequent sections, we explore the RiverSmart Homes program in much detail. The study will investigate the success stories, with a particular emphasis on the impacts on water reuse and pollution reduction in the district’s waterways particularly the Anacostia River.

3.7 RiverSmart Homes

RiverSmart Homes is a district-wide program offering incentives to homeowners to reduce runoff from properties. With this initiative, homeowners receive a stormwater assessment to determine their eligibility for financial and technical assistance to install one or more of the following features including rain barrels, rain gardens, BayScapes (native plantings), shade trees, and permeable pavers (RiverSmart, DOEE, n.d.). According to DOEE, all residential properties within the district that have four or fewer units are eligible for the RiverSmart Homes Program. However, large property complexes such as apartments, condominiums, and offices are currently not eligible for RiverSmart Homes but are eligible for other programs such as RiverSmart Rebates and RiverSmart Communities (RiverSmart, DOEE, n.d.) which will be discussed in the subsequent sections of this paper. Before homeowners can have any of the items such as rain barrels, rain gardens, bayscapes installed, DOEE will first conduct a site audit to determine which of the items will be suitable for the area. The site audit involves taking measurements of the area, recording notes and making recommendations on the item that best suits the area (DOEE, n.d.). DOEE collaborates with contractors and local nonprofits that work directly with homeowners to have the appropriate items installed. Homeowners are responsible for the maintenance of the features installed based on the maintenance information provided by DOEE. The DOEE conducts random inspection of the site to verify and assess installed items and maintenance (DOEE, n.d.). Since 2008, RiverSmart Homes has implemented more than 20,000 green features on residential buildings (RiverSmart, DOEE, n.d.). The next section will take a look at these LIDs and green features that are used in the RiverSmart program

3.7.1 Rain Barrels

DC's RiverSmart Homes offers two types of rain barrels including the RainGrid RiverSides rain barrel and the Stormworks Hydra rain barrel with each barrel costing $50 (RiverSmart, DOEE, n.d.). Since 2008, RiverSmart Homes has installed 7,288 rain barrels in Washington, DC (RiverSmart, DOEE, n.d.). These rain barrels capture and store the rainwater running off of a rooftop. The harvested rainwater can be stored for later use, released slowly over time, or used immediately. It can be used for watering lawns and landscaped areas or washing vehicles. Figure 1 indicates a rain barrel

Figure 1: Rain Barrel

Source: RievrSmart, DOEE

3.7.2 Rain Gardens

A rain garden is essentially a depression in the ground that is planted like a garden, and its primary purpose is to collect stormwater runoff and allow it to infiltrate into the soil. Rain gardens can significantly reduce the amount of stormwater that flows into sewers and drainage ditches, thereby reducing erosion and sedimentation problems (Sipes, 2009, p.30). Rain gardens are known to filter around 90 percent of copper, lead and zinc; 50 percent of nitrogen; and 65 % of phosphorus, which could otherwise flow into storm drains and eventually bodies of water (Paus et al., 2014). The RiverSmart rain gardens in Washington DC involves the installation of up to two rain gardens per property with each costing $100. The standard rain garden size RiverSmart homes installs approximately 50 square feet (DOEE, n.d). They are customized to meet individual site characteristics, factoring in topography, soils, drainage patterns, and sun exposure. Since the inception of the RiverSmart Homes program, about 1639 rain gardens have been installed in the district (RiverSmart, DOEE, n.d.) helping in retaining and soaking rainwater into aquifers and filtering out pollutants picked by stormwater. Plants used in rain gardens are very small when they are first planted and so homeowners are required to water, weed and mulch the garden especially in the first two years. Homeowners are also responsible for replacing dead plants and the general maintenance of the garden (DOEE, n.d).

Figure 2: A rain garden

Source: RiverSmart, DOEE

3.7.3. BayScaping

BayScaping is a low-cost landscaping practice that replaces grass with native plants from the Chesapeake Bay region. Some of these plants include the Atlantic white cedar, River Birch, Black Gum, American Holly, Eastern Purple Coneflower, Sweetbay Magnolia. These plants have deeper root systems that absorb more stormwater, reduce erosion, increase infiltration, and are more drought-resistant than turf grass ornamental species. It is always recommended for areas or slopes that show erosion (DOEE, n.d.). After site assessments have been done and homeowners prefer to use bayscaping for stormwater capture from their rooftops, DOEE installs native plant gardens for a copayment of $100 per 120-square foot and there is a limit to gardens per property (DOEE, n.d.). The Department of Energy and Environment through the RiverSmart program has installed 3,003 bayscapes throughout the district (RiverSmart, DOEE, n.d.). To Washington DC, BayScaping helps improve the health of the Potomac and Anacostia river and other waterways by absorbing more stormwater. Native plants within the Chesapeake bay region are more adapted to local climate conditions, resulting in less need for herbicides, fertilizers, pesticides, or soil conditioning. BayScaping also helps remove pollutant sediments and heavy metals from groundwater, stabilize soils, and prevent erosion. It also supports local wildlife by providing food and habitat (DOEE, n.d.).

Figure 3: A Bayscape

Source: RiverSmart, DOEE

3.7.4 Shade Trees

The RiverSmart Homes program also includes shade trees. Urban trees significantly contribute to stormwater management in several ways. They absorb large quantities of water from the soil for photosynthesis and release it as vapor into the atmosphere through transpiration. Their leaves, branches, and trunks intercept rainfall, reducing the amount reaching the ground and delaying peak flows. Tree canopies lessen soil erosion by reducing rainfall volume and velocity, and root growth enhances soil's water infiltration capacity. Additionally, trees perform phytoremediation by absorbing and transforming harmful chemicals from the soil, thereby reducing stormwater runoff and pollution (US EPA, 2013, p.4). The program has ensured the planting of 8765 shade trees throughout the district (RiverSmart, DOEE, n.d.). Unlike the bayscaping, rain gardens and the rain barrels discussed above, the shade trees are planets for free and there are no limits to the number of trees a resident can have on their property (DOEE, n.d.). Like other features within the RiverSmart Homes program, the shade trees are also intended to be used to reduce stormwater runoff to the Anacostia and the Potomac Rivers in the district.

Figure 4: Shade Tree

Source: RiverSmart, DOEE

3.7.5 Permeable pavers

Permeable pavement is a porous urban surface composed of open pore pavers, concrete, or asphalt with an underlying stone reservoir. Permeable pavement catches precipitation and surface runoff, storing it in the reservoir while slowly allowing it to infiltrate into the soil below or discharge via a drain tile. The most common uses of permeable pavement are parking lots, low-traffic roads, sidewalks, and driveways (Danz et al., 2019). (Danz et al., 2019). The Department of Energy and Environment (DOEE) offers a Permeable Surface Rebate Program to encourage homeowners to manage stormwater runoff. Homeowners receive rebates for replacing impervious surfaces like concrete or asphalt with permeable pavers or vegetation. The rebate rates are $10 per square foot for permeable pavers and $5 per square foot for vegetation. The average installation cost ranges from $30 to $40 per square foot. Eligibility requires replacing existing impervious surfaces, with a minimum of 100 square feet for pavers and 200 square feet for vegetation. Walkways and small patios are not eligible for this program (DOEE, n.d.). This program has ensured the installation of 698 permeable pavers within the district since 2008 (RiverSmart, DOEE, n.d.). According to U EPA (2015), a total area exceeding one acre is covered with permeable pavement in alleyways, streets, parking lanes, and walkways in DC, employing a range of materials and techniques.

Figure 5: Permeable Pavers

Source: RiverSmart, DOEE

Applying for the RiverSmart Homes programs for the installation of any of the features takes about one to four months, which some homeowners may not have the time to wait for. For this reason, the Department of Energy and Environment (DOEE) in Washington DC offers several rebate programs to encourage property owners to adopt green infrastructure solutions themselves (RiverSmart, DOEE, n.d.). The Rain Garden Rebate Program provides up to $2,200 for installing rain gardens that capture and infiltrate stormwater, with a minimum project size of 50 square feet. The Permeable Surface Rebate Program offers rebates for replacing impervious surfaces with permeable pavers or vegetation, requiring a minimum of 100 square feet for pavers and 200 square feet for vegetation. Lastly, the Green Roof Rebate Program offers $10 to $15 per square foot for installing green roofs on properties of any size, with additional funds available for structural assessment on smaller buildings (RiverSmart, DOEE, n.d.).

Table 1: Summary of LIDs and green infrastructure installed in DC since 2008 through the RiverSmart Homes Program.

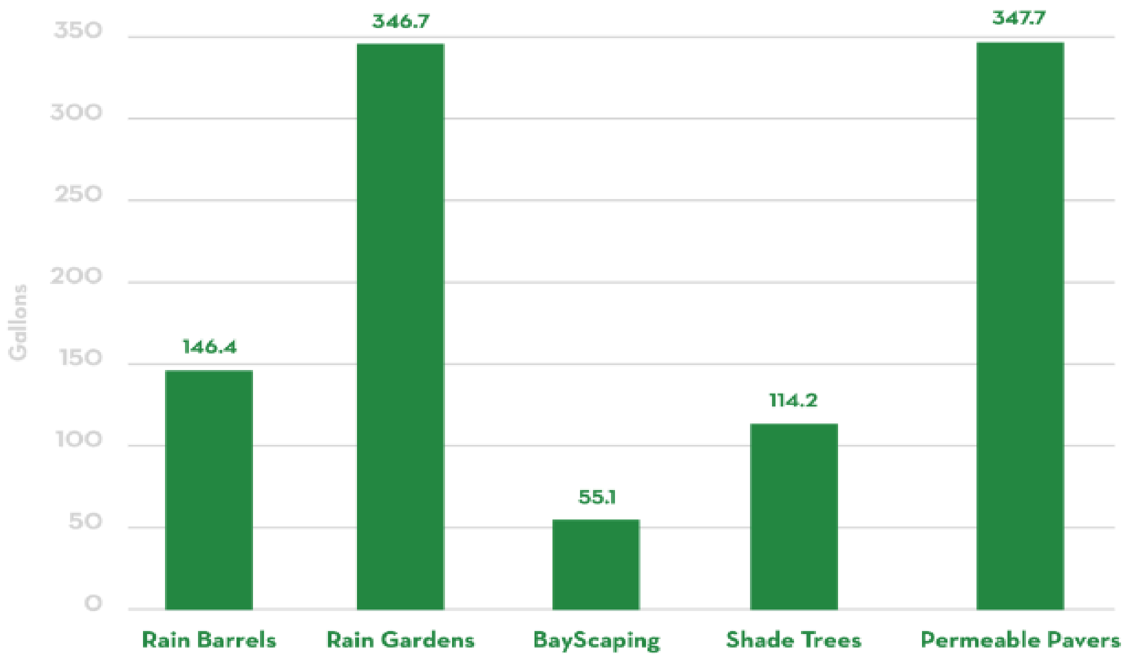
RiverSmart Homes Features	Total number installed
Rain barrels	7288
Rain gardens	1639
BayScaping	3003
Shade Trees	8765
Permeable Pavers	698

Source: RiverSmart, DOEE

3.8 The Impact of the RiverSmart Homes Program on Enhancing Stormwater Capture and Promoting Water Reuse.

Figure 1 displays the amount of stormwater captured in gallons by different types of Low Impact Development (LID) features used in the RiverSmart Homes program in Washington DC. The bar graph shows that rain barrels and permeable pavers capture the most stormwater, while shade trees capture the least. The Department of Energy and Environment (DDOE) expects that the practices have the capacity to collect over 440,000 gallons of rainwater for every 1.2 inches of rainfall (US EPA, 2015). These features have contributed to water reuse as captured stormwater is treated before being used for purposes such as irrigation, watering lawns and other non-potable water uses. Since the implementation of the RiverSmart Homes, the district has treated 2.7 million gallons of water with its installed LIDs and green features (RiverSmart, DOEE, n.d.). This confirms a report by NRDC (cited in Waterline, 2012), that capturing stormwater in rain barrels, and other LIDs can help to ease water shortages and prevent pollution. The NRDC report analyzed the capability of eight diverse US cities including Washington DC, for capturing rainwater on roofs of buildings and found out that if these cities are able to capture all the water on their rooftops, it would meet the water supply needs of 21% to 75% of the population of each city (NRDC cited in Waterline, 2012).

Figure 6: Amount of Stormwater captured by LIDs per Rain Event in DC



Source: RiverSmart Homes, DOEE.

3.9 Impacts of the RiverSmart Homes addressing Pollution in the Anacostia River

The RiverSmart Homes program has played a role in the efforts to revive the Anacostia River in Washington D.C. It has achieved this through an approach that combines solutions for managing stormwater, community involvement and ecological restoration. The combined effect of these initiatives has resulted in an improvement in the health of the Anacostia River. By capturing stormwater and promoting balance the program has significantly contributed to rejuvenating the river. This comprehensive approach to restoring waterways, which integrates stormwater management with ecological conservation, can serve as a blueprint for similar projects aimed at revitalizing urban rivers.

New data confirms that the Anacostia River is getting cleaner as there have been improvements in two major water quality measurements (Gunnerson, 2023). Within the Chesapeake Bay region, multiple factors go into determining the safety of any of the tributaries in the Chesapeake Bay. E. coli, chlorophyll-a, and water clarity are key water quality parameters that need to be evaluated (Gunnerson, 2023). E. Coli and fecal coliform bacteria are commonly used as indicators to detect harmful bacteria that can pose health risks to humans and animals. When these bacteria are found in environments it indicates the presence of pollution which may contain more dangerous pathogens (Gunnerson, 2023). Water clarity is a parameter that is often assessed using a Secchi disk. This method involves immersing a disk into the water and observing the point at which it becomes invisible. Measuring water clarity helps determine the levels of sediment present in the water. Excessive sedimentation can block sunlight penetration negatively affecting the growth and development of plant life (Gunnerson, 2023). Chlorophyll-a concentrations found in algae and other plant species provide an indication of the condition of a water ecosystem. Low concentrations of chlorophyll-a suggest a scarcity of phytoplankton leading to disruptions in the food chain. Conversely high levels may indicate blooms caused by nutrient rich runoff. These blooms have the potential to create environments with oxygen levels to sustain most marine organisms. The Anacostia River has been dealing with a problem regarding levels of chlorophyll-a. This issue primarily stems from the influx of nutrients originating from the surrounding lands. These nutrients serve as a food source for algae resulting in imbalances as mentioned earlier (Gunnerson, 2023).

According to the new data by Gunnerson (2018), there are improvements in water clarity occurring over the long term and reductions in chlorophyll-a occurring in the short term. Also, there are signs of improvements in the health of the Anacostia as bacteria levels are now far lower than what once were (Gunnerson, 2023). The 2022 DC Citizen Science Water Quality Monitoring Report shows that Kingman Island, Buzzard Point and the Washington Channel which are all part of the Anacostia River passed the state bacteria standard 90% of the time or more (Gunnerson, 2023). The new data indicates that the improvement in the Anacostia is due to the many restoration efforts that are ongoing around the river (Gunnerson, 2023). Some of these initiatives include the RiverSmart programs which uses LIDs and green infrastructure to capture stormwater. This has particularly contributed to the decrease in the amount of pollutants that enter the Anacostia River reducing the historically elevated levels of chlorophyll-a. Other projects that have contributed to the improvement in the Anacostia River include the Anacostia Tunnel System which is designed to reduce combined sewer overflow volume by 98% in a year of average rainfall. This will also provide a high level of treatment for captured Combined Sewer Overflows at the Blue Plains Advanced Wastewater Treatment Plant.

According to the Anacostia Watershed Society (Anacostia Watershed Society, n.d.), a swimmable and fishable Anacostia is possible by 2025, indicating how restoration efforts including programs such as the RiverSmart is helping in reducing pollutants that runoff to streams in the district. This is supported by the recent regulatory changes implemented by the Department of Energy and Environment (DOEE) that permit swimming in the Anacostia River. This exemplifies the substantial enhancement in water quality of a formerly severely polluted river. Due to environmental degradation, swimming in the Anacostia River was prohibited for more than half a century (Anacostia Riverkeeper, 2023). Monitoring, debris removal, and stormwater management through initiatives such as RiverSmart Homes, have significantly improved the river's condition. The DOEE recognized this advancement in 2018 when it determined that the water quality was acceptable for restricted aquatic activities. These efforts were recognized on September 23, when the Splash event was scheduled to mark the first legal swim in the Anacostia River in over fifty years. While the event was canceled as a result of heavy precipitation, there were no water safety concerns involved, as the water quality had substantially improved to satisfy the recreational standards set by the EPA (Housman, 2023).

Aside from RiverSmart Homes addressing water pollution, DOEE emphasized that an essential element of the initiative involved actively engaging with the community. One objective of the project was to retrofit a maximum number of private properties through the RiverSmart Homes program, given that approximately 40 percent of the impermeable surface in the project areas was situated on private land. Out of the total of 134 property owners, 64 of them have implemented stormwater management on their properties. The Department of Energy and Environment (DOEE) anticipates a higher level of stormwater capture than originally expected (US EPA, 2015).

3.9.1 Challenges of the RiverSmart Homes Program

The RiverSmart Homes program, implemented by the DDOEE aims to address runoff and enhance infrastructure resilience. However, it faces challenges, in achieving distribution due to the impact of zoning regulations and racial disparities in Washington D.C. A study by Ippolito et al. (2021) examines how income, race and environmental programs allocated reveals that the distribution of RiverSmart Homes is primarily influenced by DC zoning laws and racial demographics other than the actual flood risk of neighborhoods. This pattern reflects DC’s historical practices like redlining and housing discrimination that have led to implementation of uneven environmental initiatives like RiverSmart Homes. Consequently, this unequal allocation raises concerns about achieving United Nations Sustainable Development Goal 11 which promotes resilient and sustainable urban environments. It is crucial to address these disparities in zoning to ensure equal access to metropolitan sustainability initiatives. Furthermore, the implementation of the RuverSmart Homes in Washington DC has unintentionally resulted in changes in the population distribution. According to a study by Chan et al., (2021, p.11-12), Stormwater Control Measures (SMCs) implemented through the RiverSmart Homes Program are often installed in areas with a concentration of Black and Hispanic/Latino residents. However, post-installation data indicates a decrease in Black populations and an increase in White populations in these areas suggesting a displacement effect. This displacement seems to occur regardless of the area's pre-existing income levels and is not solely due to an influx of White populations but also due to the decrease of racial/ethnic minorities. This pattern holds true for types of Stormwater Control Measures except low profile infiltration SCMs. The RiverSmart Homes Program despite its advantages and incentives for homeowners to install measures like rain gardens and bayscaping may inadvertently contribute to gentrification and social displacement highlighting the relationship between urban environmental initiatives and community demographics.

3.9.2 Conclusion

The RiverSmart Homes initiative, in Washington D.C. Has made strides in improving stormwater capture and promoting water reuse, which ultimately leads to improved water quality in nearby rivers, especially the Anacostia. By incorporating Low Impact Development (LID) features this program has effectively managed millions of gallons of water helping to reduce pollutants and enable the use of non-potable water. This improvement aligns with goals that aim to make the Anacostia River suitable for swimming and fishing by 2025, and also aligns with DC water goals of reducing the volume of stormwater runoffs and encouraging rainwater reuse . However there are challenges related to population distribution and equity that need attention. Research indicates that the allocation of RiverSmart Homes is influenced more by zoning restrictions and racial demographics than flood risk neighborhoods. As a result, these policies have unintentionally caused changes, including a decline in Black Population after installation of LIDs. While the initiative has yielded outcomes it is crucial to prioritize addressing these inequalities to ensure equitable access, to sustainable urban development and prevent unintended social displacement and gentrification.

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