INTERDISCIPLINARY SYNTHESIS AND POLICY RECOMMENDATIONS FOR THE IMPROVEMENT OF WELLS RUN STREAM QUALITY AND STORMWATER FLOW IN RIVERDALE PARK, MARYLAND

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I. EXECUTIVE SUMMARY

Key Messages

- It is very likely that projected climate change and urbanization patterns will negatively impact the stream water quality and flooding conditions in Riverdale Park.
- Despite having different needs and long-term goals, each relevant stakeholder group will benefit from improving the Wells Run watershed quality.
- A holistic method was recommended to address the restoration of community watershed ties, and the improvement of the Wells Run water quality and flood conditions.
- Policies that can be implemented at multiple levels have the highest potential for success.

Summary

This report investigates the socio-environmental problems in relation to Riverdale Park and Wells Run in order to produce policy recommendations that address these problems, with stormwater management as the top priority. Riverdale Park is a residential community located in Prince George's County, Maryland. Wells Run Stream is a tributary in the greater Anacostia River watershed that flows through this community. Riverdale Park has been experiencing increased flooding events, resulting in property damage, public nuisance, and decreased water quality. Urban development upstream of Riverdale Park and climate change projections for the area are both expected to impact the water quality of the Wells Run stream. Major precipitation events and increased impervious surfaces are expected to increase stormwater runoff and aggravate the flood conditions in the community. Likewise, it will increase urban runoff, pollution, and average stream temperatures, all of which would degrade the health of the Wells Run watershed.

The project's primary goal is to determine how Riverdale Park can strengthen its community watershed ties, and improve the Wells Run water quality and flood conditions, given the anticipated urban development upstream and predicted climate change impacts. In regard to this problem definition, the various stakeholder groups have differing levels of interest and influence. However, an extensive analysis of the socio-environmental factors and values that influence each stakeholder group indicates that each relevant stakeholder would benefit from the implementation of stormwater management practices in Riverdale Park.

Based on the evaluation of various stormwater management policy options, the best option for Riverdale Park is a holistic municipal policy approach that specifically revolves around implementing green infrastructure throughout a community. When green infrastructure mechanisms are implemented on a singular, household basis they have varying degrees of effectiveness, but when implemented across a community, in combination with multiple mechanisms, the impact is significantly stronger in terms of achieving the defined objectives. The recommended municipal green infrastructure plan specifically proposes implementing a number of green infrastructure practices by using a strategic policy framework that includes voluntary and regulatory provisions for public and private property at the community, neighborhood, and household/site levels. This is an ideal approach for Riverdale Park because it integrates stakeholder needs, and combines a variety of policy mechanisms to achieve high success in each objective.

II. Addressing Wells Run Watershed Conditions in Riverdale Park

Geographical Area

Water flowing through backyards and neighborhood streams inherently defines the health of entire river systems. Wells Run is a small waterway that begins in Hyattsville and passes through University Park and Riverdale Park, ultimately feeding into the Northeast Branch of the Anacostia River. Improving the long-term health of the Anacostia River Watershed depends on restoring and maintaining the ecological integrity of small local streams. Given the planned urban development surrounding Wells Run and projected climate change impacts, it has become increasingly important to address the stream's water quality and flood potential.

As the furthest downstream, the Riverdale Park community has a unique role in maintaining the water body's ecological integrity. The stream flows through Riverdale Park within a channelized cement covert. It passes behind the neighborhood's homes and then it crosses under the MARC train tracks. From there it runs along/under the MD 410 East West Highway and eventually flows into Northeast Branch Anacostia River. This is shown in the map below.

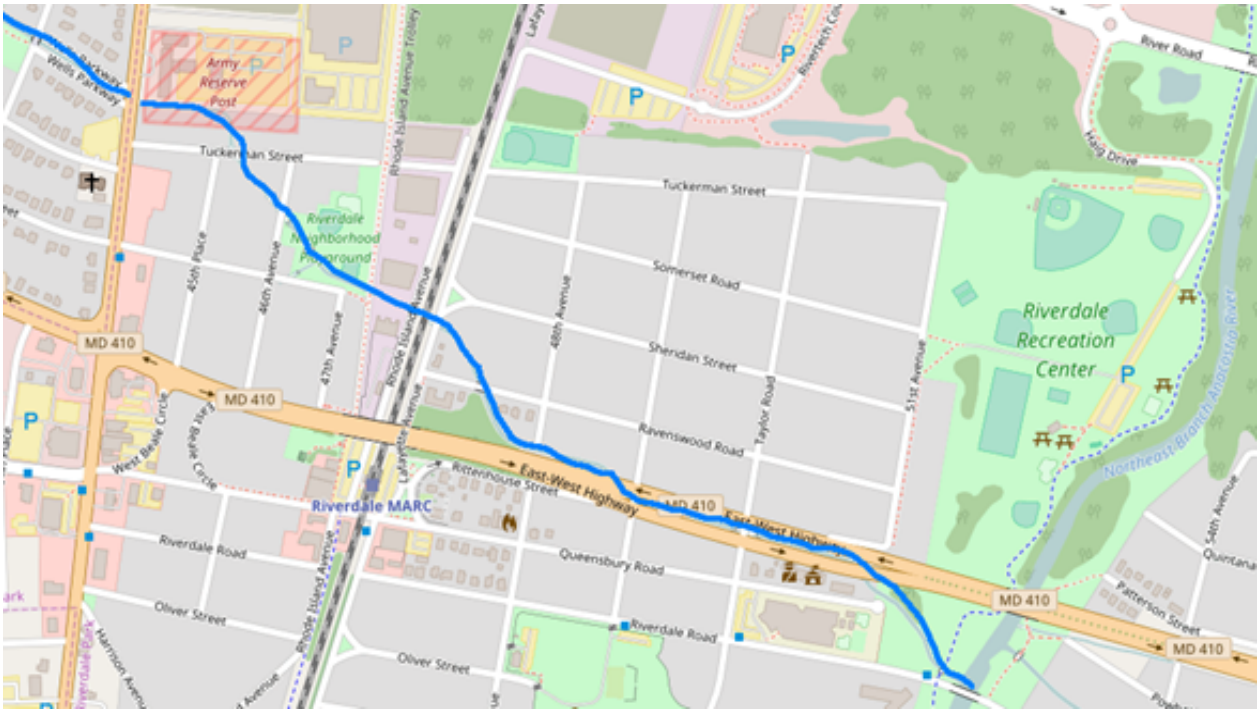

Figure 1. Map of Riverdale Park. The blue line shows the course of Wells Run within Riverdale Park, MD. (EPA EJ Screen 2016)

The Riverdale Park community's stakeholders identified flooding a primary objective, in addition to improving the Riverdale Neighborhood Park as an amenity. The goal for this project will be to determine how to meet Riverdale Park's priorities while addressing the stream's overall hydrological and ecological needs. The challenges associated with this task are relatively complex due to the interactions between the built environment and the physical, chemical, and biological components of streams. Riverdale's location within the watershed is particularly important to the Wells Run water quality because it is downstream from an increasingly urbanized community, and it's also the closest community upstream from the Northeast Branch

of the Anacostia River. The cement covert is an initial obstacle because it detracts from the stream's ecological health and intrinsic value to the community and neighborhood park. However, the covert is part of the region's hydrological infrastructure and plays an important role in current flood management.

Problem Definition

Given the anticipated urban development upstream and predicted climate change impacts, how can Riverdale Park strengthen its community watershed ties, and improve the Wells Run water quality and flood conditions

Environmental Context

Flood Management and Concrete Stream Beds

The severity and frequency of flooding for a particular inland water system depends on a combination land use and precipitation patterns. Inland flooding results from stormwater runoff that exceeds the capacity of the stream and river system. Modifications in land use (i.e. urbanization) reduce the functionality and extent of the natural landscape, soils and small waterways within a watershed; moreover, these waterways become stressed during severe or prolonged precipitation events (Watson and Adams 2011). One primary land use change associated with urbanization is the increase in impervious cover. This prevents water from percolating into the ground, thus increasing the amount of stormwater runoff in the watershed. In addition, the destruction of wetlands and modifications to streambeds prevents proper water retention (Kim and Park 2016). The development plans for Hyattsville will likely increase peak runoff and streamflow, thus increasing the stream's flood potential. In addition, climate change will likely increase the frequency and severity of heavy rainfall events in the area.

The unobstructed hydrological system maintains ecosystem and human health. When part of the system is altered, the entire system is as well. By manually directing streams through a concrete bed, thus not allowing natural flow, the water table is not able to recharge. This is especially important considering that Riverdale is in the Coastal Floodplain and "Coastal Plain streams have been attributed to less runoff generation associated with the greater infiltration capacity of the soils" (Hardison et al. 2009). Flooding will not address the water table problems, as they do not compensate enough for the water that was not allowed to percolate year round (Hardison et al. 2009). Lower water tables can have negative effects on other parts of the ecosystem, such as nutrient cycling and livable habitat (Hardison et al. 2009). To demonstrate this, Hardison et al. studied channel incision along the Appalachicola River and found that water level declined "up to 1.9 meters during late spring and summer low flow periods and these hydrological changes were shown to reduce flood durations, decrease the number of trees, and cause a shift towards drier tree species in floodplain areas" (Hardison et al. 2009).

In addition to affecting the water table, concrete streambeds take away the meanders within a stream. These meanders provide habitat for small organism, such as insects. With organisms come prey. A study conducted in Japan about stream geomorphology showed that meanders increase insectivorous bird abundance (Iwata et al. 2003).

Stream Water Quality and Watershed Conditions

Riverdale Park is located downstream from a progressively urbanized community, University Park. Connecting the two locations is Wells Run stream, which is currently generating flood problems, water quality issues, and aesthetic concerns among citizens who live

in and around the area. Water quality in the Wells Run stream is decreasing due to the increase of urbanization along with other components that directly impact the Anacostia River Watershed. Similar to the Wells Run stream running through Riverdale Park, streams in general can be polluted in various possible ways including runoff from agricultural areas, stormwater intrusion, urbanization and developmental waste, erosion, nutrient loading, and the improper use of residential trash disposals. Focusing on nutrient loading and its relation to development, more nutrients will enter a waterway as urbanization increases. These chemical stream factors increase toxicity, impact ecosystem health, and create problems for residents living downstream (Beaulieu et al. 2012). Urbanization has the potential to "alter habitats that provide living spaces for the biota in and around the stream," along with disturbing human life that may live near a polluted waterway (Bell et al. 2012). An increase in development can also lead to watershed alterations and differences in hydrology or referenced as "the movement of water through a watershed," (Bell et al. 2012). As the number of impervious sources are built, water moves faster over these newly developed lands, giving no time for seepage into the soil. Without groundwater seepage and water table regeneration, all of the water rushes into the stream causing flooding, as well as stormwater runoff (Bell et al. 2012).

Increasing global temperatures cause climates to change, and as climates change so do weather patterns (Groisman et al. 2013). One consequence of the changing climate is that it is projected to be very likely that there will be increased incidences of intense precipitation. These events result in increased erosion and flooding, which in turn degrades stream quality. Increased, fast moving water causes large amounts of erosion, results in heavy sedimentation of the stream (Gellis et al. 2017). Finally, these effects combined can lead to a condition, soil sealing, which essentially acts as a positive feedback loop to these previously mentioned issues (Lepeska 2016). The soil becomes increasingly impervious, causing even more flooding, erosion, and sedimentation into the stream. With the highly likely increased flooding events, more surface water will be traveling over the warm urban surfaces, resulting in increased water temperatures of streams, in addition to expected increased stream temperatures directly caused by the increased air temperatures (Carroll et al. 2016; Scientific and Technical Working Group 2008). The increased temperatures could potentially create environments more suitable for certain bacteria that would further decrease the water quality of the Anacostia River.

Community Health and Aesthetics

In terms of social factors and impacts, there are several research studies that examine the effect of urban green spaces on human beings. From the psychological and psychiatric perspectives, research has shown that urban green spaces help people reduce stress, cope with major crisis, as well as restore attention. (Tzoulas et al. 2007)

Moreover, Community parks and gardens can positively impact residents' behavior as well as residents' quality of life. Most Americans, including the residents of Riverdale Park, do not meet the national physical activity guideline of 150 minute per week for adults. Physical inactivity is a huge health risk factor (Cohen et al. 2013). Cohen et al. ran a quantitative research involving 183 eligible parks in the City of Los Angeles and 50 neighborhood parks. They found with intervention of park directors and park advisory boards, on average 600 more visits and 1830 more park based physical activity hours are observed per week per park (Cohen et al. 2013). Thus building a neighborhood park in Riverdale will impact community health in general. Furthermore, neighborhood parks and greenspaces provide many different types of ecosystem services that have economic, cultural, and natural values. For example, neighborhood parks

fulfill aesthetic needs, inspire people to create art as well as provide sites for school education (Groot et al. 2002).

Influence Diagram

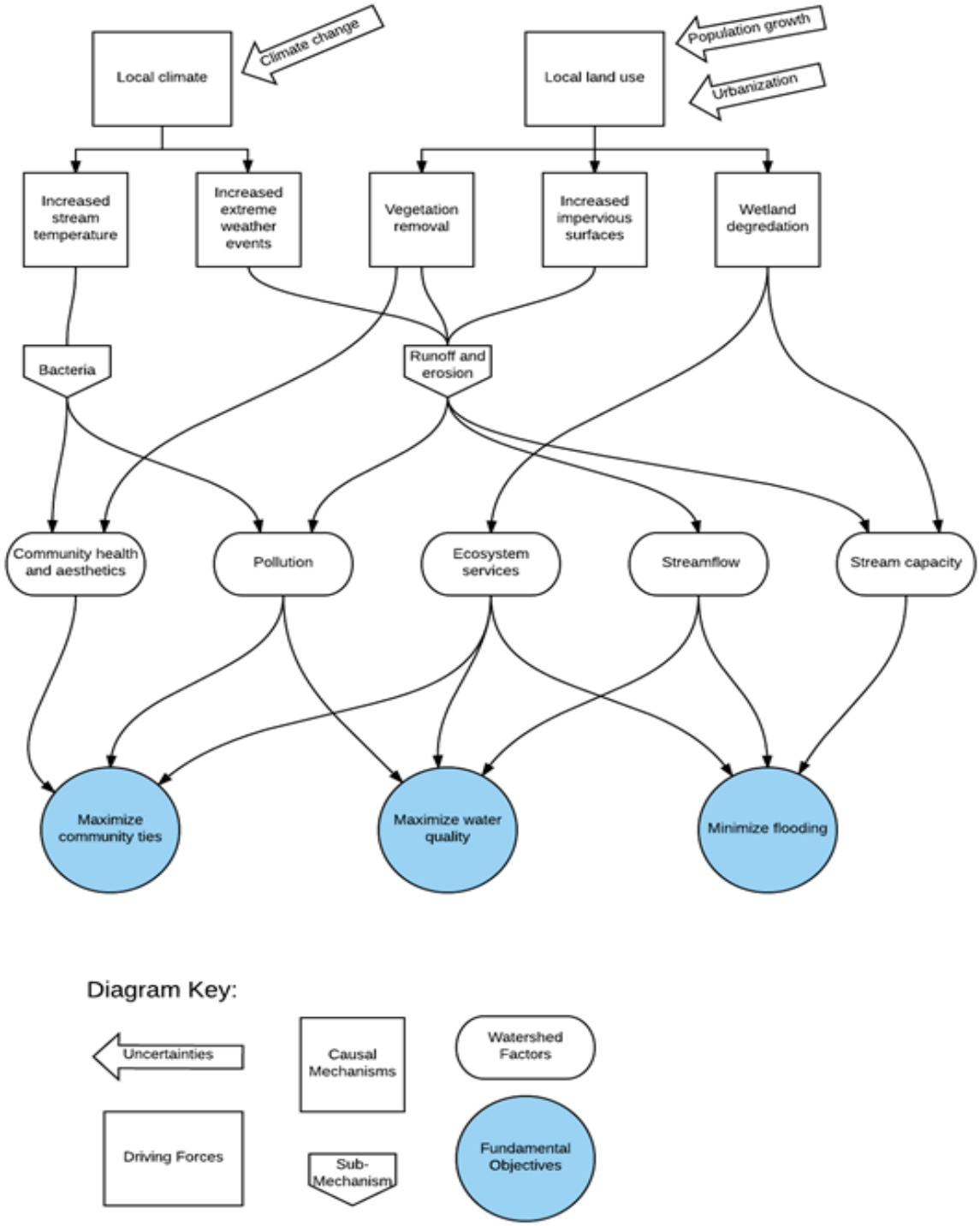

Figure 2. Influence Diagram. This diagram demonstrates the dynamic relationships between the various socio-environmental factors that impact the Riverdale Community and Wells Run Watershed.

There are four apparent levels within the diagram. These levels have corresponding shapes, which are indicated in the diagram's key. The first level includes the two primary driving forces that shape the community and watershed, in addition to the various sources of uncertainty that influence them. The driving forces each have environmental implications that are shown in the second level. These implications are causal mechanisms that determine the watershed conditions shown in level three. The arrows between level two and level three indicate which factors each mechanism has an impact on. The fundamental objectives derived from the problem definition make up the last level. Ultimately it shows how each of the conditions in level three influence the primary objectives. Considering each of these levels and how they impact one another is essential to framing the problem.

Key Relationships in Influence Diagram

Runoff and erosion ties to all of the fundamental objectives including maximizing community ties, maximizing water quality, and minimizing flooding. Acting as the main driver for many of the watershed factors, and the resulting conclusion of the driving forces which include increased extreme weather events, vegetation removal, and increased impervious surfaces, runoff and erosion is one of the sub-mechanisms responsible for many of the fundamental objective ties. By reducing one and/or the other, our fundamental objectives would be met at a faster rate. Increased temperatures affects the bacteria that are able to thrive in the stream, thus affecting the water quality and the community's health. As aforementioned, a community park connects community health and aesthetics with the objective to maximize community ties which in turn connects with ecosystem services. Vegetation removal and wetland degradation affects wildlife, which in turn directly impacts community ties to the watershed.

III. Synthesis of Multidisciplinary Watershed Literature

Key Messages

1. There is high confidence and is virtually certain that Wells Run has a role in the Anacostia Watershed's streamflow, water quality, and flood conditions, as a tributary that feeds directly into the Northeastern Branch.
2. Urbanization taking place upstream in University Park and climate change scenarios projected to affect Riverdale are likely to negatively affect stream water quality, wildlife in the river and the surrounding area, flooding conditions, and temperature changes (high confidence).
3. It is very likely that the Wells Run water quality in Riverdale Park will be impacted with increased bacteria and pollutants as a result of the increased temperatures and extreme weather events projected for the area.
4. It is likely that the water quality of the Wells Run stream in addition to the quality of the surrounding green spaces in Riverdale Park will have significant impact on the well-being of the community.
5. While there is variation among the stakeholder groups, there's high agreement to effectively manage stormwater and minimize flooding in Riverdale Park.

Overview of Synthesized Literature

Riverdale Park is located in Prince George's County, Maryland. This area is characterized as a temperate, broad-leafed, deciduous biome. The climate varies significantly

year-round with four distinct seasons. However, precipitation levels are consistent throughout the year. Wells Run creek runs through Riverdale Park. Wells Run is a part of the Northeast Branch of the Anacostia River, a river that runs 8.4 miles, with a 17 square-mile drainage basin (USEPA 2008). While Riverdale Park itself is a suburban, residential environment its close proximity to highly developed areas including Hyattsville, University Park, and College Park, Maryland exposes it to more urban stressors. Wells Run is also affected by these urban stressors. The Maryland Department of the Environment listed the Anacostia Watershed as an impaired waterway on the State's 303(d) list. It is reported to be impaired by nutrients, sediments, fecal bacteria, and toxins including poly-chlorinated biphenyls and heptachlor epoxide.

Stream water quality of Wells Run, is influenced by multiple factors including erosion levels, water temperature, salinity, pH, and the various forms of runoff. Upstream from Riverdale is University Park and Hyattsville, two up-and-coming urbanized communities, looking to broaden residential outreach and destination popularity with more developed land area. This development is causing increased nutrient pollution and elevated sediment loads in the Wells Run stream. Wells Run is also being affected agriculturally by the close proximity to resident's backyards. Yards, parks, and personal gardens, depending on management strategies, can be over fertilized, excessively sprayed for rodents or insects. These toxins and pollutants are then introduced to the Wells Run stream during precipitation events via storm runoff.

Flooding is another key concern and top priority in regard to the Wells Run stream water quality. Due to Riverdale Park's close vicinity to the Northeast Branch confluence of the Anacostia River, the area is prone to flash flooding, but also a FEMA (Federal Emergency Management Agency) designated 100-year floodplain (AWRP 2010). While there is limited information on the Wells Run stream watershed, data from the Anacostia watershed and other regional studies can be applied in this context. The severity and frequency of flooding for a particular inland water system depends on a combination of land use and precipitation patterns. Inland flooding results from stormwater runoff that exceeds the capacity of the stream and river system. Modifications in land use (i.e. urbanization) reduce the functionality and extent of the natural landscape, soils and small waterways within a watershed; moreover, these waterways become stressed during severe or prolonged precipitation events (Watson and Adams 2011). The primary modification is the increase in impervious surfaces that prevent water from percolating into the ground, increasing the amount of stormwater runoff. In addition, the destruction of wetlands and modifications to streambeds prevents proper water retention. (Kim and Park 2016). The development plans for Hyattsville will likely increase peak runoff and streamflow, thus increasing the stream's flood potential.

A portion of the Wells Run stream in Riverdale Park is underground. One option is to "day-light" the stream. Stream day-lighting results in changes in stream habitat, thus resulting in changes to the habitat of the various flora and fauna species that surround the stream. The biodiversity of the stream largely impacts the health of the watershed. Carefully planned urban landscapes can provide habitat to local wildlife, such as birds and deer, but such planning needs to take into account residential opinions. Understanding the Town of Riverdale Park's residential opinions towards cats and other wildlife is key to understanding the town's urban wildlife and maximizing the wildlife for the watershed's health.

Flooding and Urban Development

Flood Characteristics

Flooding is a condition that occurs when the volume of water exceeds the capacity of a given waterway channel. Several factors influence peak discharge of a flood, such as the intensity and duration of storms, the topography and geology of stream basins, vegetation, and the hydrologic conditions preceding storm and snowmelt events (Coles et al. 2012). Riverine or non-tidal bodies of water are those that drain upland areas and are not influenced by coastal and tidal processes. In addition to rivers, non-tidal bodies of water include streams and creeks and other small flowing waters (Joyce & Scott 2003). Wells Run is characteristic of this type of water body. Most of Maryland's inland nontidal watersheds are relatively small in areal extents. Prolonged or intense rains run off quickly, accumulating in tributary streams and main channels within hours. The waters typically rise quickly often resulting in flash flooding, but fall just a quickly as the water moves on downstream (Joyce & Scott 2003).

The pattern of stream flow variation is referred to as the flow regime of a stream. Flow regime includes factors such as the magnitude and frequency of floods vs. low flow periods, the seasonal occurrence of various flow rates, the rates of flow change, and the frequency of flow reversals (Baker et al. 2004). This has multiple impacts on the physical and chemical habitat of a stream, and furthermore on the biological communities inhabiting a stream. The term "flashiness" refers to the frequency and rapidity of short-term changes in streamflow, especially during runoff events (Baker et al. 2004). Frequent flash flooding can alter channel and floodplain structure, in particular causing channel incision and widening. These changes in channel morphology can potentially impact the frequency of overbank flooding and associated flood hazards (Smith & Smith 2015, Walsh et al. 2005). Some of flashiest watersheds in the contiguous United States are small urban watersheds concentrated in the mid-Atlantic I-95 corridor in Maryland, Virginia, and North Carolina (Smith & Smith 2015). The Smith study also found that watersheds located northeast of urban centers are flashier than watersheds located in any other direction from the city center. These are both characteristics of the Wells Run. FEMA designated 100-year floodplain areas are those that have a 1% chance of flood inundation in any given year. The area in Riverdale Park surrounding the Northeast Branch of the Anacostia is a 100-year floodplain. This is important when considering flood risk in the region (AWRP 2010).

Urbanization and Impervious Surfaces

Increased impervious surface cover is the primary agent responsible for the hydrologic changes associated urbanization (Paul & Meyer 2001, Shuster et al. 2007). The construction of roads and buildings often involves removing vegetation, soil, and depressions from the land surface. Permeable soil is replaced by surfaces such as roads, rooftops, parking lots, and sidewalks that store little water, thus reducing infiltration of water into the ground (Konrad 2003). When naturally vegetated areas are replaced with impervious surfaces, rainfall flows more rapidly into adjacent streams (Rosburg 2017). As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. As the percent catchment impervious surface cover (ISC) increases to 10–20%, runoff increases twofold; 35–50% ISC increases runoff threefold; and 75–100% ISC increases surface runoff more than fivefold compared to forested catchments (Paul and Meyer 2001). The Smith study found that impervious surface cover is positively correlated with flashiness, particularly for small watershed gauges (Smith & Smith 2015). The relationship between streamflow and development is shown in the figure below.

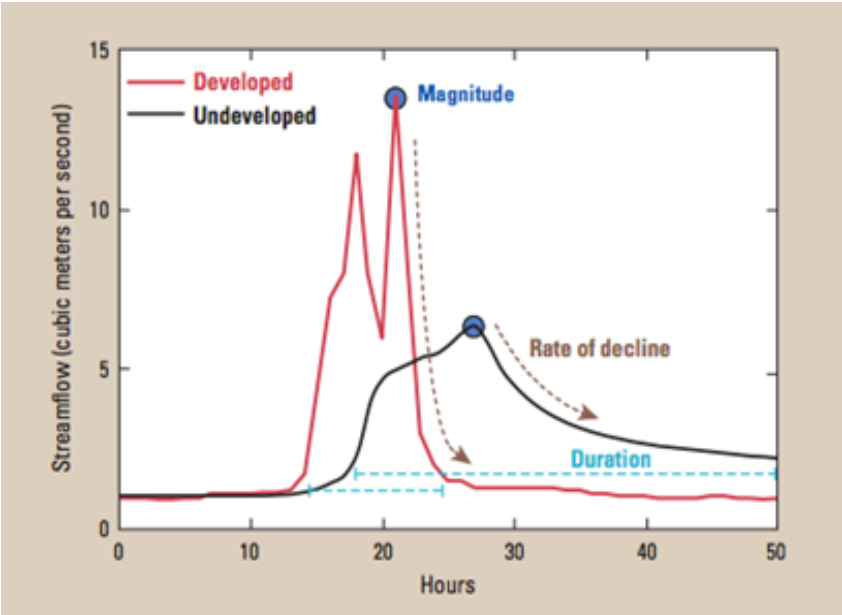

Figure 3. Impervious Cover Increases Streamflow Flashiness (Coles et al. 2012).

The Sexton study found that heterogeneous and nonlinear growth of impervious surfaces among the municipalities of the Baltimore – Washington metropolitan region correlated with well-known patterns of urban growth and development. Their results demonstrate the significant relationship between population growth, urban development, and impervious surface cover (Sexton et al. 2013)

In terms of geomorphology, urbanization alters basin drainage density, which is a measure of stream length per catchment area (km/km2). Natural channel densities decrease in urban catchments as small streams are filled in, paved over, or placed in culverts. However, artificial channels and road culverts can actually increase overall drainage densities, leading to greater internal links or nodes that contribute to increased flood velocity. For example, storm sewers and artificial drainage networks also contribute to reduced lag time and increased flood peaks (Paul and Meyer 2001). Hydrologic change also influences a wide range of environmental stream components that impact aquatic biota, such as flow regime, aquatic habitat structure, water quality, biotic interactions, and food sources (Booth et al. 2002).

Wells Run is a tributary in the Northeast Branch of the Anacostia watershed. Approximately 37% of the land area in the Northeast Branch is impervious surface cover (AWRP 2010). More than 70-percent of the Anacostia River watershed had been developed. Residential development, including single-family houses, townhouses, and apartments, is currently the most common land use and comprises approximately 45-percent of the watershed. As new development continues, roads and buildings constructed in these flood-prone areas are exposed to increased flood hazards, including inundation and erosion (USGS 2003).

The proposed Prince George's Plaza Transit District development project in Hyattsville, MD includes approximately 281 acres of land. This includes the Prince George's Plaza Metro Station, the enclosed shopping mall currently known as the Mall at Prince George's, the University Town Center mixed-use residential development, and other properties long MD 410/East West Highway, Belcrest Road, and Toledo Terrace. The predominant land uses in the TDDP are commercial retail, multifamily residential, and office. Approximately 146.4 acres of the TDDP is within the Wells Run watershed (Soltesz 2015).Furthermore, it is likely that the

development of this area will increase the runoff and storm water flow in the watershed. The water quality and flood conditions will be stressed downstream in Riverdale Park.

Overall Implications

Though Wells Run is a small tributary, its flood potential is relatively high, as a result of channelization and urbanization. An increase in the frequency of high flows is the most common and strongest hydrologic response to urban development (Coles et al 2012). Furthermore, it is likely that upstream urban development in Hyattsville will impact Wells Run flood conditions. In a broader context this will have an impact on the stream's water quality and ecosystem health, in addition to the social implications of flooding. Climate change impacts are also important to consider in regard to stream hydrology, because of the potential changes in precipitation and land-water storage.

Runoff and Erosion

Urban Runoff and Effects Downstream

Nutrients are being discharged from the urban site and are being carried by large storm or rain events and are travelling downstream to various locations, where groundwater and stream quality will then be negatively impacted. Urban runoff is considered a non-point source and "has been established as a major cause of receiving water degradation," (Tsihrintzis et al. 1997). While traveling downstream, water is said to encounter many sources of pollution. These sources could include runoff coming from impervious sources around the stream, inputs from point source pollutants, and contaminants carried from different locations upstream. Due to Riverdale's location, urban pollutants such as suspended solids from streets, heavy metals in the form of particulates, chlorides from snow salt, and non-aqueous solutions such as oil can travel down from University Park (Tsihrintzis et al. 1997).

In an impact study measuring the "use of low impact development techniques on a watershed scale," the results found that there were "significant logarithmic increases in stormwater runoff and nitrogen and phosphorous export," as urbanization and construction projects took place without management (Dietz et al. 2008). Various types of chemical runoff can also be attributed to snowmelt, flooding, and storm systems. These chemical stream factors are observed to increase toxic contaminants in streams, change ecosystem health, impact biodiversity, and create problems for communities downstream (Beaulieu et al. 2012). The process of urbanization occurring in University Park has the potential to "alter habitats that provide living spaces for the biota in and around the stream," along with those communities affected (Bell et al. 2012). Water flow from these urban areas are attributed to overland flow or "water that flows over the soil surface and occurs from areas that are impervious or locally saturated or from areas where the rainfall rate exceeds the infiltration capacity of the soil," especially takes place in the ecoregion that Maryland falls into (Brooks et al. 1997, Pg. 78). From large storm systems, an influx of organic carbon is usually found, along with other suspended solids such as iron and zinc. These solids are attributed to lowering oxygen levels in streams, and leading to a degradation in stream water quality (Characklis et al. 1997). Degradation in stream water quality can be measured by the presence of an excessive amount of certain nutrients such as nitrogen and phosphorous, the growth of algal blooms, various chemical concentrations such as chlorophyll *a*, and negative landscape impacts, such as erosion. Degradation is reliant on wet periods versus dry spells as well as the amount of storms occurring in the area being measured (Mallin et al. 2009). The relationship between storm flow, and waste loads are dependent on each

other, and "cannot be neglected," when measuring pollution from urban sources (Weibel et al. 1964). These measures are determined by probability framework that can analyze the severity of the situation before embarking upon further research (Toro 1984).

Erosion and Agricultural Runoff through Maintenance Practices

Urban runoff and stormwater runoff can bring chemicals and suspended solids towards downstream communities, creating erosion due to the fast moving water taking place. Due to impervious sources, water moves faster than its natural speed, giving not much time for soil infiltration. These fast moving waters creates heavy sedimentation in the stream, and affects stream life substantially (Gellis et al. 2017). With all of these environmental effects now taking place, a positive feedback loop occurs within the contaminated elements that runoff brings, and the erosion that follows (Lepeska 2016). Runoff and the erosion that occurs after storms can also be due to climate. Climate factors such as wind, temperature and the intensity of the rainfall can impact the physical force that water is moving down the stream. This forces can "dislodge, disperse, and transport," soils throughout the waterway system (Brooks et al. 1997, Pg. 140). It has been observed and measured that "runoff from typical urban and suburban landscapes may contain significant levels of nitrogen, phosphorous, and a broad spectrum of various pesticides," due to gardening practices that happen in residential communities (Hipp et al.1993). Although these amounts may not be the main pollution occurring in nearby streams, it still exists, and contributes to the overall nutrient loading. Especially for the Riverdale Park area, this location where the Wells Run stream flows, gardens and yards that use fertilizers are attributing to the overall pollution loads. Soil provides many positive biological feedbacks to organisms and the quality of the water, and also can be an indicator of land use which leads into the development of best management practices concerning runoff (Zuazo et al. 2007).

Overall Implications

Wells Run stream quality, is an issue that residents find concerning. Water quality is degraded by agricultural runoff, urbanization, stormwater runoff and flow, imperviousness, and erosion. From observations, it can be inferred that the section of Wells Run located in Riverdale is polluted by the urbanization happening upstream in University Park, followed by the erosion that takes place during storms, as well as by the gardens and yards that Wells Run travels through.

Impacts of Climate Change

Climate Change Projections

Globally, the average temperature has been increasing over the past two hundred years. However, according to a report compiled by Peterson and Baringer in 2008, as well as NASA in 2017, the majority of the global warming has occurred over the past thirty-five years. In fact, in 2015, the global temperature had increased one degree Celsius above the average temperature in 1890 (NASA 2017). The increase in temperature results in more than just warmer average temperatures. Rather, the increasing global temperatures cause climates to change, and as climates change so do weather patterns (Groisman et al. 2013). One consequence of the changing climate is that it is projected to be very likely that there will be increased incidences of intense precipitation. These events result in increased erosion and flooding, which in turn degrades stream quality. Increased temperatures also affect the ecosystems of regions, and more specifically, where different species are found.

The Anacostia Watershed is already listed as impaired in part because of fecal bacteria (USEPA 2008). In Maryland, there are several temperature projections based on different climate scenarios. It is projected the by 2080, the annual average temperature will have increased between three and ten degrees Fahrenheit (United States Global Research Program 2014). Increased air temperature has two cascading effects, including increased temperatures of urban and natural surfaces (Mark et al. 2015). With the highly likely increased flooding events, more surface water will be traveling over the warm urban surfaces, resulting in increased water temperatures of streams, in addition to expected increased stream temperatures directly caused by the increased air temperatures (Carroll et al. 2016; Scientific and Technical Working Group 2008). The increased temperatures could potentially create environments more suitable for certain bacteria that would further decrease the water quality of the Anacostia River.

Flooding and Stream Quality

The 2008 National Climate Assessment reported variable river behavior based on surroundings. More urbanized areas frequently experience higher levels of flooding (Hawkins & Austin 2012). It is very likely that Wells Run will experience increased flooding with climate change. The overwhelming consensus is that with the changing climate, Maryland will experience increased precipitation (USEPA 2016). Since 1890, Maryland has had a five percent increase in annual precipitation (Scientific and Technical Working Group 2008). Increased precipitation in the urban environment will increase flooding. The flooding will negatively impact residents of Riverdale Park. The residents will also be affected by the water quality of Wells Run will degrade due to sedimentation of the watershed caused by the increased flooding (Hayhoe et al. 2007). Additionally, the increased flooding, especially in the urban environment, will increase pollution of the watershed (Hawkins & Austin 2012). Flash flooding in urban areas can lead to the saturation of sewage systems, which in turn can contaminate recreational water and sources of drinking water (USEPA 2016).

Temperature and Stream Quality

Increased stream temperatures will negatively affect species found in the Anacostia River and create a niche for bacteria to thrive (USEPA2016). Previously, the Anacostia watershed was listed as impaired partially because of exceedingly high maximum daily loads of fecal bacteria (USEPA 2008). With warming temperatures, other bacteria will likely be a concern for the Wells Run and Riverdale Park area. Many parts of Northern Europe have similar climates to the Mid-Atlantic Region of the United States. A study by Austin et al. 2016 reported higher incidences and infection of water-borne infections in parts of Northern Europe. These outbreaks were often correlated with heat waves. The major bacteria present are Vibrios, which is the group of bacteria that can cause cholera. These bacteria are found in abundance in warm, low-salinity waters. As the temperatures increased, urban streams, such as Wells Run, are likely become more suitable for water-borne illness causing bacteria.

Vulnerability Level of the Riverdale Park Community

According to EPA, climate change is projected to increase both frequency and intensity of extreme weather events, which include the flooding problem Riverdale Park community, is already facing (EPA 2016). Different population groups have different vulnerable levels. People in poverty are more susceptible to effects of climate change because they have financial constraints of relocating as well as other coping strategies. Younger children are more vulnerable

as well because their immune system and other body functions are still in development. Urban populations are susceptible to effects of climate change especially because aged city infrastructures (EPA 2016). For the Riverdale Park community, the drainage and sewer systems as well as the flood and storm protection are the top two concerns of aged infrastructures. The table below displays various population characteristics for Riverdale Park and the U.S. in regard to climate change vulnerability

Table 1. Climate Change Vulnerability Population Analysis. (U.S. Census Bureau 2017)

Population Characteristics	Riverdale Park Town	U.S
Persons under 5 years, percent, April 1, 2010	9.3%	6.5%
Persons under 18 years, percent, April 1, 2010	27.7%	24%
Persons without health insurance, under age 65 years, percent	34.4%	10.5%
Per capita income in past 12 months (in 2015 dollars), 2011-2015	22242	28930
Persons in poverty, percent	17.7%	13.5%

From the table, it is evident that Riverdale Park has a higher young children population as well as a higher population without health insurance than those of U.S. Moreover, the Riverdale Park community has a lower per capita income and higher poverty rate comparing to those of U.S. Thus the specific population portfolio of Riverdale Park makes this community more vulnerable to the impacts of climate change.

Overall Implications

The projected climate change for Riverdale Park and Prince George's county is most likely to affect the water quality of the watershed by increasing pollutants, sedimentation, and bacterial growth, all of which were already concerns for the Northeast Branch of the Anacostia River. While definitive temperature increases are difficult to project, there is little uncertainty that the Wells Run watershed and the residents of Riverdale Park will be significantly affected by climate change.

Urban Biodiversity and River Containment on Wildlife

River Control through Culvert Usage and Stream Daylighting and its effects on Wildlife

Movement of wildlife is affected by food, shelter and water sources. The easiest way to track movement of wildlife is by following their water source. If the water source is contained underground, it will impact which animals use it. If a water source is directed under a roadway through a culvert, certain animals may also use the culvert. The use of culverts in urban areas is immense; 66% of streams in Baltimore are culverted (Neale and Moffett 2016). In a study on drainage culverts and wildlife movement, researchers were able to discover patterns of use (Clevenger et al. 2001). The most common theme was the effect that traffic volume, noise, and road width had on species use of culverts (Clevenger et al. 2001). Vegetation cover near the culverts will bring different mammals than those without vegetation (Clevenger et al. 2001). At a couple points during Wells Run in Riverdale Park, culverts are used to get the river underneath roadways. Based on Clevenger et al.'s study, it is safe to say that wildlife also uses the culverts. To fully understand culvert use, the town of Riverdale Park could use cameras to determine what animals use the culverts and if their travel could be affected by a change.

While channelizing streams is common in urban areas, streams are also contained in underground pipes. In order to restore streams in urban environments, a type of restoration known as stream daylighting is used. Neale and Moffett summarize the intent of day-lighting well stating, "Daylighting projects can hypothetically reduce the impact of urbanization on streams by restoring natural stream structure and opening up the channel to sunlight and aerial colonization" (2016). In their study conducted on a stream pre and post daylighting, scientists found differences in macroinvertebrate taxa present (Neale and Moffett 2016). It was found that 24 taxa were recorded both before and after daylighting, 11 taxa were found pre daylighting but not post daylighting, and 44 taxa were found post daylighting but not pre daylighting (Neale and Moffett 2016). These differences can be attributed to changes in the geomorphology of the stream. Comprehensive data analyses of daylighting stream effects on other species are hard to quantify and have not been studied yet. By daylighting a stream, there is medium confidence that there would be changes in surrounding flora as well as biodiversity present.

Daylighting streams may seem problematic to some, such as the residents of Riverdale Park, but if the construction also includes catchment and riparian buffer zones, flooding can be managed. Catchment planning can help landscape restoration, but water quality also needs to be addressed (Vietz et al. 2015). Reinforced channel banks and management of riparian areas would reduce the economic damage of flooding (Hajdukiewicz et al. 2015). Daylighting, as Neale and Moffett found, would very likely impact other wildlife. Other mammals, birds, or invertebrates could use the stream if it is daylighted and thus Riverdale Park residents would see more wildlife in their backyards than currently, since Wells Run is channelized underground.

Urban Green Space and Biodiversity

While the above examples relate to the engineering and containment of streams and wildlife, this section addresses a more fluctuating aspect of urban living, lawns, which are a type of urban green space, and biodiversity.

Manicured lawns are seen as natural and a compulsory element in many Western societies (Ignatieva et al. 2016). In fact, lawns compose of 70-75% of urban green spaces and can contain "over one-third of land area in a city" (Ignatieva et al. 2016) (Belaire et al. 2014). Thus lawns are a large factor in determining how much biodiversity is present in urban areas.

Lawns are important habitat for many species. One group of researchers decided to study birds in Chicago and determine how important yard design is for bird habitat (Belaire et al. 2014). The researchers found that groups of neighboring yards that provide habitat could overcome environmental characteristics at the landscape scale (Belaire et al. 2016). One option is through the use of corridors, which "are defined as functional habitat connecting two habitat patches," and positively impact urban biodiversity (Beninde et al. 2015). These findings agree with what Aronson et al. 2014 found when comparing plant and bird diversity in many cities throughout the world. They found that biodiversity in cities was more impacted by human impact on the landscape than abiotic factors such as climate (Beninde et al. 2015). This means that management of lawns as urban green spaces needs to be coordinated at a larger scale than individual households. However this is challenging, as there are usually a large number of stakeholders involved in lawn management. Some of these stakeholders include individual households, neighborhood organizations, local municipalities, and architects (Devy et al. 2009). These groups or individuals all have different interests in how lawns should be managed and if they do not involve the conservation of biodiversity than some lawns could not be beneficial to the protection of urban biodiversity. However, if sustainable yard management is to be expected in some communities, then social pressure could lead to lawns that improve urban biodiversity (Aronson et al. 2017).

Another group of researchers studied how lawn care, including mowing, application of fertilizers and pesticides, shading, and usage, affected biodiversity (Bertoncini et al. 2011). Results indicated that higher mowing frequency had a negative correlation with species richness and diversity (Bertoncini et al. 2011). Frequent mowing does not allow for plant reproduction and reduces the amount of pollen present for birds and bees to use for pollination, as a result, more frequently mowed lawns have less species present (Bertoncini et al. 2011). Another factor in lawn biodiversity is the use of pesticides. Bertoncini et al. (2011) found that regardless of dosage, pesticides have a negative impact of lawn biodiversity.

With regards to Riverdale Park and lawn care, it is virtually certain that there are many stakeholders that have interest in the care of residential lawns and connectivity of these urban green spaces. Based on the studies from Bertoncini et al. (2011), Devy et el. (2009), Aronson et al. (2017), Belaire et al. (2014), and Beninde et al. (2015), there is high confidence that lawns as urban green spaces effect biodiversity.

Residential Effects on Wildlife Movement and Population

A study in Canada revealed that residents have intentionally provided deer food (McCance et al. 2015). Urban areas provide ample needs for deer in terms of open space, shelter, water, and food (McCance et al. 2015). Deer eat everything, such as ornamental trees, shrubs, flowerbeds, vegetable gardens, and fertilized lawns (McCance et al. 2015). By providing food, people are teaching animals that are supposed to fend for themselves that they can rely on people. Understanding why people give wildlife food is important in understanding urban wildlife and human interaction. Human "values are deeply rooted, slow to change, and often formed early in life" (McCance et al. 2015). The study in Winnipeg, Canada wanted to better understand intentional feeding of deer (McCance et al. 2015). While the data was collected on a case-by-case basis, the lessons learned can be applied to other residents in urban areas, such as Riverdale Park, and other animals found in urban areas. Deer visited properties that were associated with a food source (McCance et al. 2015). Those that feed the deer had a mutualistic wildlife value orientation and indicated that bylaws might change their behavior (McCance et al.

2015). Another example humans directly affect urban wildlife is through their pets, specifically cats. Whether they are feral or pets, cats have an effect on urban wildlife. Some of the problems they cause include: "unwanted hunting of wildlife, transmission of disease to humans, livestock to wildlife, interbreeding with feral populations" (Hall et al. 2016). "In the U.S. alone, free-ranging cats are estimated to kill 1.3 to 4 billion birds and 6.3 to 22.3 billion mammals each year" (Elizondo and Loss 2016). These numbers prove that cats, whether as pets or feral, have negative consequences on urban wildlife.

To quantify how owners perceive their pet cats' impact on wildlife, an international survey was conducted. There were six countries that participated: China, New Zealand, Japan, the USA, Australia, and the UK (Hall et al. 2016). Response to "pet cats killing wildlife in cities, towns, and rural areas is a serious problem," had a U.S. support rate between 12% and 62% of owners (Hall et al. 2016). For "pet cats on farms are harmful to wildlife," only 8% of cat owners in the U.S. agreed (Hall et al. 2016). This is in high contrast to 40% of owners and 60% of non-cat owners in the U.S. agreeing with "pet cats in nature reserves are harmful to wildlife" (Hall et al. 2016). The estimated pet cat population of 90 million and feral population ranges from 30 to 120 million in the U.S. (Elizondo and Loss 2016).

If Riverdale Park would like to be as sustainable as possible and welcoming to wildlife, they need to understand their cat population, both residential and feral as there is high confidence that cats are very likely to impact urban biodiversity. Riverdale Park also needs to understand residential perception of urban wildlife and possible human-wildlife interaction. If there is extensive interaction between humans and wildlife, then there is high confidence that wildlife movement will change, as the McCance et al. (2015) study showed. If cats are properly managed and residential interaction of wildlife ceases, their effects on urban wildlife can be mitigated.

Overall Implications

Culverted streams likely impact urban wildlife movement. Stream day-lighting results in changes in stream habitat, thus resulting in changes to the habitat of the various flora and fauna species that surround the stream. Management of lawns as urban green spaces has more of an impact on urban biodiversity than climate. Cats, domestic or feral, directly impact local wildlife populations. Carefully planned urban landscapes can provide habitat to local wildlife, such as birds and deer, but such planning needs to take into account residential opinions. Understanding the Town of Riverdale Park's residential opinions towards cats, other wildlife, and lawn management is key to managing urban biodiversity.

The Impact of Neighborhood Parks on Human Health and Communities

Tzoulas et al. conducted a comprehensive literature review of whether green infrastructure can improve ecosystem and human health in urban areas. After reviewing numerous studies and models, they reached the conclusion that green infrastructure in urban areas improve ecosystem as well as provide physical and psychological benefits to people living close to those areas (Tzoulas et al. 2007). More specifically, green infrastructure is defined as "all natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales" (Tzoulas et al. 2007). Thus a neighborhood park at Riverdale Park fits perfectly with this green infrastructure definition.

For the ecosystem service, green infrastructure increases overall vegetation cover thus improve biodiversity in urban areas (Flores et al. 1998). Species diversity is one of the most important indicators of ecosystem health (Rapport 1995). A healthy ecosystem can provide

numerous ecosystem services ranging from natural to cultural services. For the matter of this scientific synthesis for Riverdale Park, I am going to focus on listing four of ecosystem services pertaining to cultural functions of a possible neighborhood park. First, landscape features provide aesthetic information, which contributes to enjoyment of scenery. Second, variety in landscapes can provide recreation function, which can include outdoor sports, etc. Third, natural features with cultural and artistic value can inspire people to use nature as motive in all kinds of art forms. Finally, nature with scientific and education value can provide materials for scientific research and school education (Groot et al. 2002). Thus adding a neighborhood park at Riverdale Park can possibly increase species diversity and provide many ecosystem services to local population.

Urban Green Spaces and Human Health

Moreover, urban green structure can directly impact both physical and psychological health of human beings. For physical health, people who actively use urban green space have greater longevity comparing to those ones who do not use urban green space (Takano et al. 2002). Older adults who use urban parks reported that they perceived themselves to have better health. They also increased physical activity and increased relaxation from using urban parks (Payne et al. 1998). Furthermore, for the psychological health perspective, urban populations who can regularly have visual access to nature settings can better restoring one's capacity to focus (Hartig et al. 1998). Green views in the inner city can help people cope with major crisis in their life as well as reduce mental tiredness of people (Kuo 2001). Exposure to environment can help people recover from stress and increase positive emotions (Ulrich et al. 1991). Green space in urban space can also increase a sense of community and increase potential social interactions (Kim & Kaplan 2004). Thus adding a neighborhood park at Riverdale Park can possibly increase physical actives of local residents and possibly improve overall health level. After Tzoulas et al. wrote the paper back in 2007, more studies have examined the effect of green infrastructure. I am going to summarize some of the benefits provided by green infrastructures that were not discussed earlier. Green infrastructures can help regulate the quality of air and water. They can also absorb carbon dioxide and possibly mitigate the health damage of climate change. Green infrastructures can also help protect in land from flooding, storm surging as well as reduce temperatures in the cities. Exposure to nature can also improve cognition and attention of human (Coutts & Hahn 2015).

Notably, although the relationship between green infrastructures and human health is well studies, green infrastructures are not specified by size or distance or type. This gap of knowledge may impact our confidence level of scientific evidence (Jorgensen & Gobster 2010). More specifically, one study has evaluated that the usual 300-meter metric as walk able distance for green infrastructure is not backed up by scientific evidence.

Moreover, more studies have been conducted to investigate the relationship between biodiversity and human health. As discussed before, a neighborhood park can likely increase local biodiversity. However, there is still not causality between loss of biodiversity and human health because researchers could not decouple biodiversity and socioeconomic statuses (Hough 2014). For Riverdale Park, having a neighborhood park is very likely to increase overall health level of local residents as well as increase sense of community.

IV. Analysis of Wells Run Stakeholder's Needs

Riverdale Park is a small semi-urban town located in Prince George's County, Maryland. The town has population of approximately 7000 people. In terms of local governance, Riverdale has a Mayor and small town council. These stakeholders range from the local residents that live in vicinity to Wells Run, the local officials of Riverdale Park in addition the Riverdale community members as a whole. There are also stakeholders outside of Riverdale Park, such as the upstream communities of University Park and Hyattsville, in addition to the encompassing county government and potential advocacy groups. Each of these stakeholders have unique perspectives and needs in regard to Wells Run. A table assessing these specific stakeholders can be found below. Each stakeholder has a different level of influence and interest in regard to the Riverdale Park - Well's Run problem definition. Level of influence is described as high, medium or low. Influence is determined by the stakeholders' available resources and capacity to affect the outcomes for Wells Run and Riverdale Park. Similarly, the table describes the stakeholders' interest as high, medium or low. This is the stakeholders' level of attention, concern and engagement in regard to the problem definition.

Identification and Evaluation of Stakeholder Groups

The table below defines various stakeholders involved in the Riverdale improvements. These stakeholders range from low to high influence and low to high interest. Each stakeholder was assigned a category and major and minor objectives were defined.

Table 2. Stakeholder Groups and Objectives.

Stakeholder Category	Stakeholder Organization	Stakeholder POC	Stakeholder Major Objectives	Stakeholder Minor Objectives	Stakeholder's Influence	Stakeholder's Interest
Local Constituents	University Park Elementary School	Toi Davis Principal 301-985-1898[1]	"Believes success requires communication, collaboration, and community."[2]	"Develop socially responsible citizens."[3]	Low	High
Local Constituents	University of Maryland Extension in Prince George's County	Alicia Harrison (301) 868-9366[4]	"Support Maryland's agricultural industry as well as protect its valuable natural resources."[5]	Improve of individual well-being as well as increase community engagement.[6]	Medium	Medium
Local Government	Waggertail Dog Park	Friends of Waggertail Dog Park 301-927-6381[7]	"Make recommendations on improvements	"Create a greater feeling of community."[9]	Low	High

[1] University Park Elementary School. "Principal's Page." http://www1.pgcps.org/universitypark/
[2] ibid.
[3] ibid.
[4] University of Maryland Extension. Prince George's County. "About Us." https://extension.umd.edu/prince-georges-county
[5] ibid.
[6] ibid.
[7] Waggertail Dog Park Brochure. http://www.riverdaleparkmd.info/about/Brochure.pdf

			to the dog park and inform the Town of maintenance and other issues."[8]			
Local Business	Calvin Cafritz Enterprises (Riverdale Park Station development)	Calvin and Jane Cafritz (202) 248-5811[10]	Sustainable community and economic development[11].	"Protecting water quality and providing some control of the 100 year flood zone"[12]	High	High
Local Business	The Neighborhood Design Center	Evan Richardson President 301-779-6010[13]	"Provides access to design services in underserved communities in Prince George's County...in collaboration with neighborhood groups."[14]	"Support locally driven initiatives for neighborhoods pursuing improved quality of life within their built environments."[15]	Low	Medium

[9] ibid.
[8] ibid.
[10] Cooper, Rebecca."Prince George's County is getting a new hotel at the Whole Foods site" *Washington Business Journal. http://www.bizjournals.com/washington/blog/top-shelf/2015/05/prince-georges-county-is-getting-a-new-hotel-at.html?ana=fbk*
[11] Riverdale Park Station. "Discover." http://riverdaleparkstation.com/discover/
[12] Riverdale Park Station. "Stormwater." http://riverdaleparkstation.com/community/storm-water/
[13] The Neighborhood Design Center. http://www.ndc-md.org/
[14] ibid.
[15] ibid.

Local Business	Brown Insurance Group	Insurance Agent 301-993-5500[16]	"Offer affordable Maryland flood insurance policy premiums to individuals and families located in Riverdale, MD, etc."[17]	"Solving our clients' problems and taking care of their needs."[18]	Low	Medium
Local Government	Town Mayor	Vernon Archer[19] Mayor 240-832-2257	"Insure that Riverdale Park continues to be the safe, clean and the beautiful town that it is."[20]	"Maintain the high quality public infrastructure"[21]	High	High
Local Government	Town of Riverdale Park Municipality	John Lestitian Town Manager 301-927-6381 [22]	"Protect and preserve the history of the town."[23]	Services include the mayor, town council, Riverdale Police, Riverdale Fire Department, public works, and Town Administration.[24]	Medium	High
Local Government	Hyattsville Department of Community Development	Jim Chandler Director 301-985-5000[25]	"Acquires and administers grant funding, and manages local community planning."[26]	"Report on development work in the area, collect and map local assets, and work to strengthen our local businesses."[27]	Medium	Medium

[16] Brown Insurance Group. "Maryland Flood Insurance Information - Montgomery County Area." http://www.browninsurancegroup.com/Flood_Insuranc.html
[17] ibid.
[18] Brown Insurance Group. "About Us." http://www.browninsurancegroup.com/About_Brown_In.html
[19] Riverdale Park MD, "The Mayor." http://www.riverdaleparkmd.info/mayor/index.cfm
[20] Dasgupta, Sonia, "Incumbent Vernon Archer Hopes for Fourth Term as Riverdale Park Mayor." The Patch. https://patch.com/maryland/riverdalepark/mayoral-candidate-vernon-archer
[21] ibid.
[22] Riverdale Park MD, "Town Administrator",http://www.riverdaleparkmd.info/townadministrator/index.cfm
[23] ibid.
[24] Riverdale Park, MD. "Services." http://www.riverdaleparkmd.info/services/index.cfm
[25] City of Hyattsville. "Community & Economic Development." http://www.hyattsville.org/180/Community-Economic-Development
[26] ibid.
[27] ibid.

Local Government	PG County Department of Environment	Adam Ortiz, Director 301-883-5810[28]	"Provide clean water services, and flooding prevention for buildings and structures."[29]	Providing sustainability services to reduce greenhouse gas emissions, and processes and diverts waste from landfills."[30]	Medium	High
Local Government	Riverdale Park Public Works Department	Facility Office 301-925-8100[31]	Provide maintenance to parks and playgrounds. Provides regular trash collection as well as participates in street debris removal.[32]	"Participate in the collection of hazardous waste so it is not improperly disposed of, and also recycling."[33]	Medium	Medium
State Government	State of Maryland Governor	Governor Larry Hogan 410-974-3901	"Make large steps towards regulations and environmental advancements in communities. Has funded the most amount of money towards environmental policy integration, and Chesapeake Bay cleanup"[34]	"Maximize community outreach, maximize water quality and overall quality of life. Maximize river, road, and air quality"[35].	High	Low
State Government	USGS Water Resources of Maryland	Wendy S. McPherson443-498-5548[36]	Maximize water quality in all waters of Maryland.[37]	Values of community partners and the people affected if water quality is bad[38].	High	Medium

[28] Prince George's County Maryland. "Department of the Environment." http://www.princegeorgescountymd.gov/179/Environment
[29] ibid.
[30] ibid.
[31] Riverdale Park, MD. "Public Works Department." http://www.riverdaleparkmd.info/publicworks/index.cfm
[32] ibid.
[33] ibid.
[34] Office of Governor Larry Hogan. "About." http://governor.maryland.gov/governor-larry-hogan/
[35] ibid.
[36] USGS. "Employee Director Directory." https://md.water.usgs.gov/profiles/mcpherson.html
[37] USGS. "Water Science for Maryland, Delaware and the District of Columbia." https://md.water.usgs.gov/
[38] ibid.

Federal Government	Army Corps of Engineers	Karen J. Baker 202-761-7690[39]	"Restore degraded ecosystem structure, function and dynamic processes to a more natural condition through large-scale ecosystem restoration projects, s"[40]	"The Anacostia River Watershed is one of the main priorities for restoration in the Bay watershed[41],"	High	Medium
Non-Profit Organization	Chesapeake Bay Foundation	President William C. Baker Maryland Headquarters 410-268-8816[42]	"Fight for effective, science-based solutions to the pollution degrading the Chesapeake Bay and its rivers and streams."[43]	Create a clean, environmentally-friendly community within the Chesapeake Bay area[44].	Medium	Medium
Non-Profit Organization	Anacostia Watershed Society	James Foster, President, 301-699-6204[45]	"Protect and restore the Anacostia River and its watershed communities"[46]	Strong partnerships and coalitions, with all parts of the community, government, and other stakeholders[47].	Medium	Medium

[39] US Army Corps of Engineers "Environmental Program." http://www.usace.army.mil/Missions/Environmental.aspx
[40] ibid.
[41] US Army Corps of Engineers. "Anacostia Watershed Restoration." http://www.nab.usace.army.mil/Missions/Environmental/Anacostia-Watershed-Restoration/
[42] Chesapeake Bay Foundation, "Contact Us." http://www.cbf.org/about-cbf/contact-us
[43] Chesapeake Bay Foundation, "Our Mission." http://www.cbf.org/about-cbf/our-mission
[44] ibid.
[45] Anacostia Watershed Society, "Staff." http://www.anacostiaws.org/about/staff
[46] Anacostia Watershed Society, "Purpose." http://www.anacostiaws.org/about/purpose
[47] ibid.

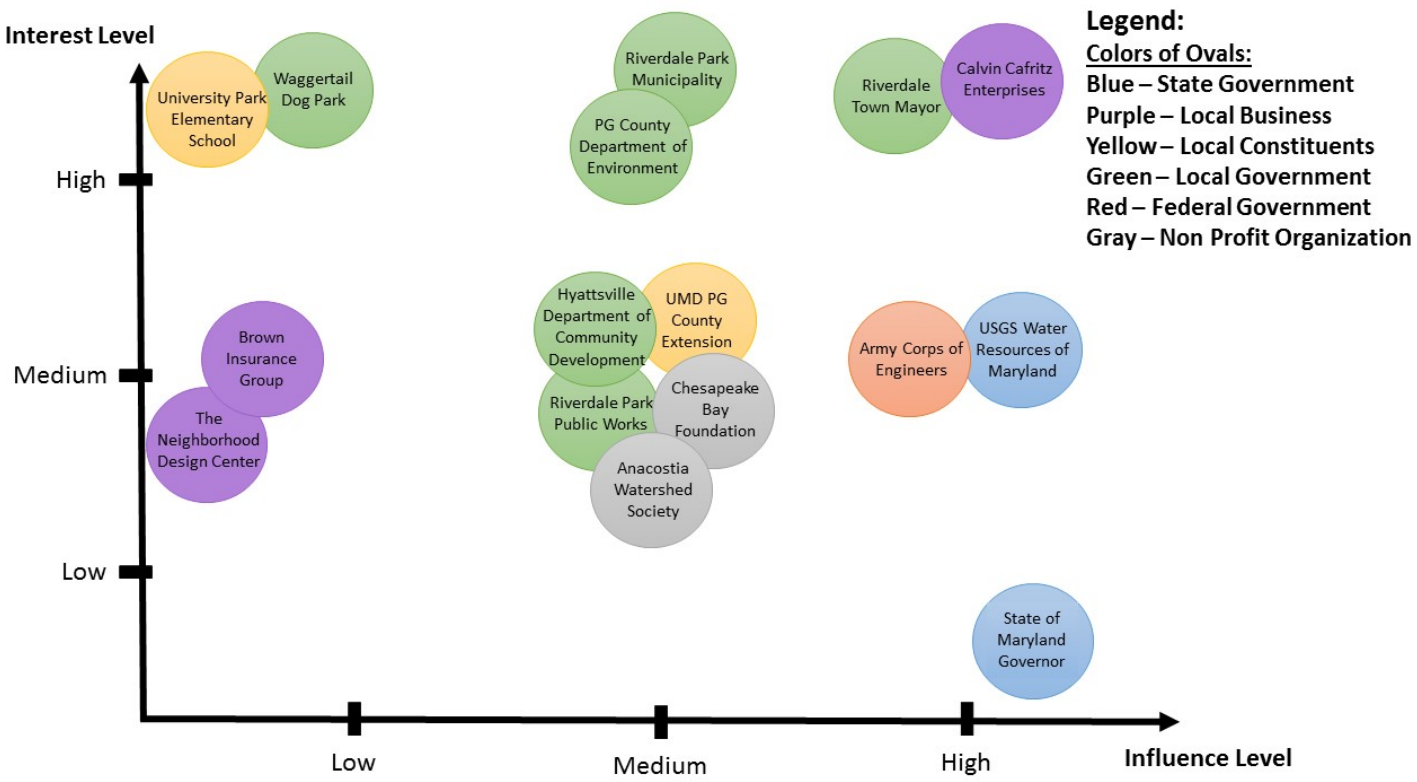

Figure 3. Stakeholder Influence vs. Interest Diagram.
This diagram shows the relationship between different stakeholder's interest levels and their corresponding influence level on the location and problems surrounding Riverdale Park. The various circles represent each stakeholder's level of influence on the community and their interest in assisting with the improvement of Riverdale Park, while the different colors represent the different stakeholder categories we discovered.

Discussion of Stakeholder Perspectives

Stakeholders for Riverdale Park can be broken down into six major categories; local constituents, local businesses, nonprofit organizations, the local government, the state government, and the federal government. The local constituents include the University Park Elementary School, and the University of Maryland Extension in Prince George County. Not included in our stakeholder table was the Riverdale Community. They have been sighted as a sustainable community in Maryland, and Prince George's County has identified this community as one where it will invest money towards increasing the general quality of life for its residents.[48] Improving the Wells Run watershed is encompassed in this goal. Being unable to find a specific community name, we included the residents as a whole, and only part of our discussion rather than in the table shown above. University Park Elementary has indicated that their primary concerns as protecting the quality of stream and being able to inform their students of the different environmental impacts of streams. They are also concerned with the aesthetic value of Wells Run because the stream flows directly by its property.[49] The University of Maryland

[48]http://news.maryland.gov/dhcd/2015/05/15/four-new-maryland-sustainable-communities-added-including-the-hometown-of-baseball-great-jimmie-foxx/
[49] http://www1.pgcps.org/universitypark/

Extension in Prince George County has a different objective. They are focused on support Maryland's agricultural industry, a large part of Maryland's economy, as well as protecting natural resources.[50]

The next major category of stakeholders includes local businesses, such as the Neighborhood Design Center, Riverdale Park Public Works Department, the Calvin Cafritz Enterprises, and the Brown Insurance Group. The Neighborhood Design Center support locally driven initiatives for neighborhoods pursuing improved quality of life within their built environments, and would likely be strongly involved with any projects involving the Wells Run stream in Riverdale. [51] The Riverdale Public Works Department provide maintenance to parks and playgrounds in the Riverdale community as well as providing regular trash collection and street debris removal. However, the department contributes to the nutrient runoff factor into Wells Run stream and will be affected by possible sustainable or alternative options for maintenance.[52] The Brown Insurance Group has a large stake in the watershed conditions of Riverdale because they offer flood insurance policy premiums to individuals and families located in Riverdale, Maryland. They are directly impacted by future flood conditions in Riverdale.[53] The Calvin Cafritz Enterprises is interested in the implementation of sustainable communities and the development that follows as well as the restoration of water quality to streams, specifically near Riverdale Park.[54]

The next category of stakeholders encompass the local government. This includes the Town Council, Waggertail Dog Park, Hyattsville Department of Community Development, Prince George's County Department of Environment and the Town of Riverdale Park Municipality. The town council's primary objective is, by definition, the quality of life of its residences. They Hyattsville Department of Community Development would like to continue developing Hyattsville into an urban community, however they desire to do so with sustainable practices. [55] The Prince George's County Department of Environment wants to increase the water quality of Wells Run because it is listed as an impaired waterway by the United States Environmental Protection Agency. The Riverdale Park Municipality is mainly focused on development, however they feel the pressure of doing so sustainably, and this impacts how they address the Wells Run watershed. [56] The Waggertail Dog Park is a green space in Riverdale Park set aside for residents and their dogs. Their main objective is maintaining the existence and quality of the park. [57]

State government is the next category of stakeholders identified. Within the state government, stakeholders include Larry Hogan, the Governor of Maryland and the USGS Water Resources of Maryland. Governor Hogan is a conservative leader in a liberal state. He states that he hopes to make large steps towards regulations and environmental advancements in communities. In the past, he has funded the money towards environmental policy integration and

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[50] http://extension.umd.edu/prince-georges-county
[51] http://www.ndc-md.org/
[52] http://www.riverdaleparkmd.info/publicworks/index.cfm
[53] http://www.browninsurancegroup.com/Flood_Insuranc.html
[54] Riverdale Park Station. "Discover." http://riverdaleparkstation.com/discover/
[55] http://www.hyattsville.org/180/Community-Economic-Development
[56] http://www.riverdaleparkmd.info/townadministrator/index.cfm
[57] http://www.riverdaleparkmd.info/about/Brochure.pdf

Chesapeake Bay cleanup efforts.[58] The USGS Water Resources of Maryland has a clear missions of maximizing water quality in all of Maryland's waters.

Stakeholders within the Federal Government are another stakeholder category. This includes just the Army Corps of Engineers. The Army Corps of Engineers focuses on ecosystem restoration. Specifically, they have multiple projects within the Chesapeake Bay watershed. Riverdale Park is a potential community for a Corps project. [59]

Stakeholders within the Non-Profit Organization stakeholder group, the final major stakeholder category, include the Chesapeake Bay Foundation and the Anacostia Watershed Society. The Chesapeake Bay Foundation is a non-profit organization, but the Foundation receives funding from several federal agencies, including the Environmental Protection Agency. The Foundations' major objective is fighting for effective, science-based solutions to the pollution degrading the Chesapeake Bay and its rivers and streams, of which Wells Run is included. [60] The Anacostia Watershed Society was focused on protecting and restoring the Anacostia Watershed and all tributaries that filter into it.[61]

Relevant Science

Each stakeholder has a different perspective and vested interest in regard to Riverdale Park and Wells Run; consequently, their specific objectives vary. Scientific data regarding the flood conditions and water quality that currently exists for Wells Run in Riverdale Park is relevant to all the stakeholder groups. Moreover, Wells Run is on the 303 (d) list, so its water quality is severely impacted by a number of factors including: nutrient runoff, urbanization, sedimentation, and fecal matter. This information is essential for each stakeholder group to fully understand the current conditions present in Riverdale Park. Climate change is expected to exacerbate these issues thus acting now is in all stakeholders' interest. Additionally, economic data is important because each stakeholder will have some type of monetary constraint that will influence their perspective. Economic data is also relevant because of the ecosystem services that Riverdale Park is supposed to provide but is not currently.

Voices Not Included

Although we identified a lot of local government and constituents, we cannot identify any specific Riverdale Park residents who does not own a business or does not involve in any community groups. Those residents pay taxes and thus they together form a key player in stakeholder discussion. If this case study would move forward, we would hope to learn about their understandings and opinions on key issues. For example, we would love to learn their understanding on flooding, impervious surfaces, urban green spaces. It also would be beneficial to learn their opinions on the existed neighborhood park, urban development as well as water quality. This case study is tied to each and every Riverdale Park resident, so it would be essential to learn about their perspective.

How to Ensure All Perspectives are Included

As we discussed earlier, we currently do not have any information from Riverdale Park residents regarding this case study. Moving forward it would be beneficial to engage them into

[58] http://governor.maryland.gov/governor-larry-hogan/
[59] http://www.nad.usace.army.mil/Missions/
[60] http://www.cbf.org/about-cbf/our-mission
[61] Anacostia Watershed Society, "Purpose." http://www.anacostiaws.org/about/purpose

the stakeholder conversations. We can either host a local discussion event or send out surveys to local residents. Moreover, we make sure to include stakeholders from all stakeholder categories, although there are more categories to consider, such as local workers, scientists, etc. In the future, we will try to research more about community outreach at Riverdale Park, including but not limited to local government. Thus we can make sure to reach out in most efficient way.

Stakeholder Findings

The Wells Run waterway local to Riverdale Park, MD is a multifaceted and relatively complex issue. The scientific syntheses above determined that Wells Run has a significant role in the Anacostia Watershed streamflow, water quality, and flood conditions, as a tributary that feeds directly into the Northeastern Branch. In addition, upstream development activities change will negatively affect the stream water quality, wildlife in the river and the surrounding area, flooding conditions, and temperature changes. In terms of climate change impacts, water quality in Riverdale Park will be impacted with increased bacteria and pollutants as a result of the increased temperatures and extreme weather events projected for the area. Lastly, activities surrounding Wells Run have an impact on the health and social wellbeing of the community.

The primary stakeholder groups for the Wells Run watershed are local constituents, local businesses, the local government, the state government, the federal government and non-profit organizations. Each of these groups, and the organizations within them have varying vested interests in Wells Run in addition to varying levels of power or influence in the matter. Each perspective is influenced by values as well as science; likewise, some perspectives are more value bases while others more scientific. It is essential for all groups to have a well-rounded understanding of the scientific conclusions listed above. The syntheses findings and stakeholder analysis indicates that stakeholder groups living within a close vicinity to the Riverdale Park portion of Wells Run will be impacted the most by the stream's ecological conditions and structural integrity; however, due to the nature of the waterway, those upstream have a large impact on these issues and those downstream are impacted regardless. In addition, the immediate Riverdale community does not necessarily have as much power as upstream stakeholders, and larger government entities, though their vested interest is greater. Therefore, unified stakeholder coordination is essential to fulfilling science-based problem definition.

V. Policy Options for Stormwater Management in Riverdale Park

Key Statements

1. It is very likely that the Riverdale location in which Wells Run is located in could benefit from the construction of water quality grass swales and the implementation of rain gardens and rain barrels to combat runoff without causing erosion (*high confidence*).
2. The existing Rain Check Program in Prince George's County can cover most of the cost for different types of stormwater management practices. The Riverdale Community would receive up to twenty thousand dollars if they applied this program as an Institutional-Property Owner.
3. A comprehensive municipal green infrastructure implementation plan can address local storm water management problems by utilizing a variety of practices across the entire community in addition to specific priority development sites, but in order for this policy option to be successful, the community needs to cohesively implement these practices in a holistic framework, as opposed to a site-by-site basis.

Policy Option Analysis

Constructing Swales in Riverdale Park to Combat Water Quality Degradation

Riverdale Park is located downstream from the urbanized University Park, with Wells Run stream connecting them both. In University Park, urbanization has been taking place for few years with more to come in the future. Due to the current and future projections for urbanization, the various construction projects taking place will most likely lead to nutrient loading, stormwater runoff, and water quality degradation for the entirety of Wells Run stream. There are many available policy options that can be integrated into the PG County jurisdiction, pertaining to river water quality, and in this particular case, Wells Run.

A water quality swale is described as being a "vegetated open channel designed to treat the required water quality volume and to convey runoff without causing erosion," ("Water Quality Swale"). Usually these channels are vegetated with grass, "flood tolerant, and erosion resident plants," ("Grassed Swales"). By installing these grassed swales, the water will be directed correctly, be flowing at a more controlled and slower rate, and pollutants will be filtered out, creating cleaner water entering the water column ("Grassed Swales"). Differing from drainage channels, swales not only direct the water a certain direction, but they are also "designed to treat the required water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness," ("Water Quality Swale"). According to a swale constructed in Massachusetts to combat stormwater runoff and excess nutrients near a neighborhood community, the swales constructed were able to remove 70% of the suspended solids in the water column, 10-90% of Nitrogen, and 20-90% of Phosphorus.

Swales have many advantages, especially to communities struggling to combat stormwater runoff and erosion problems. Swales with resilient vegetation are an option that is usually inexpensive to fund. Grassed swales "increase stormwater infiltration and add a visually aesthetic component to a site," ("Grassed Swales"). These vegetated pathways allow for stormwater to travel from nearby impervious sources (for example, roadways) and allow for more infiltration into the soils instead of overland flow. Most often, swales are the more environmentally friendly approach to treating stormwater management, and is used all across North America ("Grassed Swales"). Uncertainties regarding the efficiency and the use of swales are dependent on the severity of the pollution happening upstream and the localized pollution levels also happening in Riverdale Park. Swale productivity is also dependent on the plants used in the swale itself and how effective they are at filtering out pollutants, while also posing the question of if they are a species that tend to flourish in our certain geographical location. The implementation of a swale or multiple swales in the Riverdale Park area would be a feasible option due to the cost effectiveness of the entire project as well as the available space that Riverdale Park as a community has. With the correct amount of space and funding, a swale would be a great option in order to reduce flooding as well as the pollution coming from urbanized stormwater runoff upstream.

Implementing Rain Gardens to Decrease Flooding and Stormwater Runoff

Riverdale Park is experiencing increased flooding events because of the increased urbanization occurring upstream of the residential area. The increased urbanization causes increased impervious surfaces. These impervious surfaces lead to flash floods, increased erosion, and pollution of waterways (Walsh et al. 2005). One policy option aimed at returning natural

systems to their pre-industrial characteristics is the use of bioretention, or more commonly known as, rain gardens (Davis et al. 2012). Ran gardens utilize natural processes and decrease impervious surface area by increasing natural vegetation. The natural vegetation and pervious soil allows for increased retention of water during a runoff event, and allows the water to be naturally filtered and evapo-transpirated, rather than being funneled into waterways. Rain gardens have been implemented in many areas to combat the hydrological effects of urbanization. The University of Maryland in College Park has several rain gardens across its campus. For this policy option, the implementation of rain gardens in North Carolina and Maryland were reviewed. In Silver Spring and College Park, Maryland, researchers measured how rain gardens affected soils' bioretention abstraction volume. Rain gardens in these areas substantially delayed and reduced the runoff peak flows, and diminished the runoff volume through infiltration during singular precipitation events. In North Carolina, a study conducted by North Carolina State University evaluated the effectiveness of rain gardens in communities (Woodward et al.) They found that while the rain gardens themselves were effective at mitigating storm runoff, individuals were not always successful at maintaining the gardens on a long-term basis, putting their effectiveness into question. However, the cost of each rain garden was relatively low, at only $50 for both the plants and the mulch. This is an affordable option for many residences, and in many communities, it helps resident's meet there pervious surface requirements. In Riverdale Park, rain gardens could easily be implemented at individual and community levels. It is easy and affordable for residents to establish private rain gardens. Additionally, community rain gardens would be a good way to maximize community ties and raise education and awareness in the community on stormwater management practices.

Implementing Rain Barrels to Decrease Stormwater Runoff

An option for reducing stormwater runoff is through the installation and use of rain barrels in residential yards. Rain barrels are connected to the downspout system of roofs (Jennings et al. 2013). The rain collected can be harvested for later usage. However, in order to be effective, rain barrels must be emptied between rain events so that they do not overflow and defeat their purpose (Litofsky et al. 2014). The use of multiple rain barrels allows for more rainwater collection from roofs. Due to rainwater only being collected from roofs, the design of roof downspouts, and many residents only having one rain barrel, effectiveness of rain barrels is reduced to 25% of roof area (Litofsky et al. 2014). Typically, rain barrel use is constrained to growing months due to the need to protect rain barrels from freeze damage (Litofsky et al. 2014). However, effectiveness of rain barrels is more dependent on precipitation frequency than growing season (Litofsky et al. 2014). This means that for Riverdale Park, rain barrels could be used from April/May – September/October and would need to be emptied after precipitation events in order to be as effective as possible (Steffen et al. 2013). Rain barrels usually cost between $100 - $400 (Davis 2009). In some jurisdiction, collecting rainwater can be considered a crime (Davis 2009). However, this is not the case for Riverdale Park (see next policy option).

As far as effectiveness of rain barrels at maximizing water quality and minimizing flooding, a study in Pennsylvania found a 6.3% reduction in streamflow and 4.9% reduction in sewer overflows (Jennings et al. 2014). A different study conducted in two urban watersheds found a 2-12% reduction in runoff (Ahiablame et al. 2013). Based on data about rain barrel effectiveness in different parts of the U.S., it was found that locations that receive more than 76 inches of precipitation in the Northeast, which would include Riverdale Park, have a storm water runoff reduction rate of about 9% (Litofsky et al. 2014). Rain barrel efficiency increases greatly

combined with other storm water management options; for instance, combined with rain gardens, rain barrels can reduce stormwater runoff 16-28%, however about 90% of that was from rain gardens (Jennings et al. 2014). Regarding maximizing community ties, which is the third objective for Riverdale Park, rain barrels do not have a good track record. The same study in Pennsylvania that found low reductions in streamflow and sewer overflows only had a 40% resident participation rate (Jennings et al. 2014). In order to increase community participation, increase efficiency, and reduce homeowner maintenance the Insurance Bureau of Canada suggests that automatic, slow release discharge valves be installed at the bottom of rain barrels (Jennings et al. 2014).

Implementing a Rebate Program to Incentivize Household Stormwater Management Practices

One example of local funding mechanism is the Prince George County's Rain Check Rebate. This program roots in local partnership between the Chesapeake Bay Trust and Prince George's County. This Rain Check Rebate provides economic incentives for installing practices that "improve stormwater runoff quality, reduce runoff quantity, and improve local streams and rivers" (Chesapeake Bay Trust). It provides possible rebates for installed eligible stormwater management practices. Those eligible practices include rain barrel, cistern, urban tree canopy, rain garden, pavement removal, permeable pavement and green roof. Applicants for this funding mechanism can be residential property owner, business and nonprofit organizations. Residential property owners can receive up to 4,000 dollars for rebate. Businesses and nonprofit organizations can receive up to 20,000 dollars from the Rain Check Rebate. The application of this funding mechanism works as rolling and it is currently open to receive any application (Chesapeake Bay Trust).

In the table below, costs of each practice are listed side by side with different rebates the Rain Check Rebate provided. The rebate of each practice remains the same regardless if the rebate is awarded for individual or institutional property owner. From the table, it is implied that this local funding mechanism can cover most of the cost for all practices.

Table 3. PG County Rain Check Program Breakdown.

	Cost	Rebate[62]
Rain Barrel	$50-$250/ barrel[63]	$2/gallon stored
Cistern	$300-660 for family size cistern $3000 and up for commercial size cistern[64]	$2/gallon stored

[62] "Prince George's County Rain Check Rebate."
[63] "Rain Barrels Fact Sheet."
[64] "Cisterns Fact Sheet."

Urban Tree Canopy	$75-$200/tree[65]	$150/tree
Rain Garden	$4-$35/square foot[66]	$10/square foot
Pavement Removal	Varies Considerably[67]	$6/square foot
Permeable Pavement	$7-$15/square foot[68]	$12/square foot
Green Roof	$10-$30/square foot with $0.75-$1.50 annual maintenance cost/square foot[69]	$10/square foot

The proposed policy option is to actively participate this Rain Check Rebate Program both at individual and community level. For Riverdale Park Community, it can apply to this Rain Check Rebate Program as an Institutional Property-Owner, which includes civic associations. Thus stormwater management practices at Riverdale Park Community can receive up to 20,000 dollars of rebate. In additional to community level effort, Riverdale Park Community can also inform local residents about individual household this local funding mechanism. House owners can implement rain barrels, cistern and urban tree canopy with relatively low cost.

Implementing a Municipal Green Infrastructure Strategy Throughout the Community

Green infrastructure is a relatively broad term that encompasses a wide range of stormwater management practices. Gray stormwater infrastructure refers to conventional piped drainage and water treatment systems designed for the single purpose of moving urban stormwater out and away from communities. Alternatively, green infrastructure works to reduce and treat stormwater at the source. Areas where the natural landscape can absorb and infiltrate rainfall have low levels of flooding and watershed pollution. Green infrastructure mechanisms work to restore these natural processes in the urban landscape in order to sustainably manage water and create healthier urban environments (EPA 2016).This municipal green infrastructure policy option first examines how green infrastructure practices can improve stormwater in a community and then analyzes how they can be implemented using a strategic planning and policy framework.

Green infrastructure practices include land use changes such as swales, rain gardens, green roofs, constructed wetlands, and permeable pavement. These mechanism are proven to have significant reductions in stormwater runoff volumes. For example, permeable pavement can

[65] "Urban Tree Canopy Fact Sheet."
[66] "Rain Garden Fact Sheet."
[67] "Pavement Removal Fact Sheet."
[68] "Permeable Pavement Fact Sheet."
[69] "Green Roof Fact Sheet."

reduce stormwater-runoff volume by 70-90% and vegetated bioswales can reduce average peak flow by 48% during storm events (Foster et al, 2011). As for water quality, green infrastructure mechanisms filter and purify water during rain events, collecting pollutants, chemicals and debris before feeding into waterways. For example, the average home rain garden naturally filters 30,000 gallons of water per year (Rain Gardens 101). Green infrastructure also has positive social impacts. The increase of green spaces and natural vegetation in a community positively impacts human health by improving air quality and increasing opportunities for recreation and exercise. Studies have found general increases of up to 37% in property values associated with the presence of trees and vegetation on a property (Foster et al, 2011). Lastly, the presence of green infrastructure in a community or neighborhood increases residents' awareness of and engagement with watershed issues (EPA 2016).

In general, a municipal green infrastructure plan is a holistic policy option that implements a combination of green stormwater management practices throughout a community watershed, as opposed to at the household level. These types of local policies have been implemented across the country in communities of varying size and geographic locations, including small urban watersheds similar to Riverdale Park (Kim and Park 2016).The most common in trend in successful green infrastructure case studies is the presence of many different policies and programs. However, in order to successfully implement comprehensive stormwater management with green infrastructure, local officials must consider how to protect and preserve existing natural resources. In the case of Riverdale Park, these priority features include the community's extensive old growth tree canopy and community green spaces. This is generally achieved using incentives and ordinance policies. They must also consider where and how to direct future development in the community. This is especially relevant to the new Whole Foods development in Riverdale Park. The surrounding area is a predicted hotspot for future growth in the community. With this in mind, the town can implement a regulatory framework for new development standards that require green infrastructure mechanism (EPA 2010). . Essentially this policy option proposes implementing any number of green infrastructure practices, by using a regulatory and strategic framework guiding these principles.

Policy Option and Objective Evaluation

The table below is a visual representation of the possible policy options for the Wells Run stream in Riverdale. Shown above is the major objectives of the community and how they could be achieved through the policy option of the construction and use of swales, implementation of rain gardens, the use of rain barrels, the implementation of a rain check program, and the creation of a municipal green infrastructure plan.

Table 4. Scientific Evidence and Fundamental Objectives Analysis for Each Policy Option

Policy Option	Minimize Flooding	Maximize Water Quality	Maximize Community Ties
Construction of Grass/Vegetated Swales	It is *highly likely* that the construction of linear swales would reduce the flow of stormwater runoff.[70] Uncertainty associated with amount of urbanization happening upstream.	Water quality is *very likely* to improve when swales are implemented due to its ability to filter incoming water that is polluted by chemicals and debris that are collected throughout its journey to the larger body of water.[71] Uncertainty associated with the amount of incoming polluted waters from Wells Run stream as well as localized pollution from Riverdale communities. Swale efficiency is also dependent on the types of plants that are used in the swale itself.	Swales are *likely* to provide positive aesthetic values along with a more environmentally friendly solution to the problem of stormwater runoff. There is *high confidence* that constructing swales could increase community ties. Since swales can be an alternative to unappealing gutter systems, they have the possibility of enhancing the surrounding community.[72]
Implementation of Rain Gardens	It is *very likely* that rain gardens would minimize flooding from an independent precipitation event. Rain gardens in College Park and Silver Spring, MD exhibited excellent hydrologic performance for small rain events, but results were less successful extreme precipitation events. Authors suggest that a larger media volume: drainage area ratio and greater media depth would likely enhance the performance in large events.[73]	It is *highly likely* that rain gardens would maximize water quality. Rain gardens effectively delay and reduce runoff peak flows, reduce outflow runoff volumes, and promoting infiltration, which promotes higher water quality.[74]	It is *somewhat likely* that rain gardens would promote stronger community ties with the watershed. In North Carolina, self-identifying environmentalists maintained rain gardens to the highest level. Homeowners with flooding issues and rain gardens installed at schools generally received the lowest levels of maintenance and had the highest failure rate.[75]

[70] "Stormwater Management: Swales"
[71] "Stormwater Management: Swales"
[72] "Stormwater Management: Swales"
[73] Li et al. 2009
[74] Li et al. 2009
[75] Li et al. 2009

Rain Barrels	There is *high confidence* that rain barrels are *unlikely* to decrease flooding as a analysis of rain barrel effectiveness for the U.S. as a whole found that the geographic location on Riverdale Park would see a decrease of 9% of runoff if rain barrels are the only storm water management option used.[76]	There is *high confidence* that rain barrels are *unlikely* to increase water quality as a study in Pennsylvania found under a 7% decrease in both stream flow and sewer overflow from the use of rain barrels.[77]	There is *medium confidence* that rain barrels are *unlikely* to maximize community ties as there is usually a low participation rate, but release valves at the bottom of rain barrels might increase homeowner participation.[78]
Local Funding Mechanism (Prince George County Rain Check Program)	It is *very likely* that different practices this Rain Check Program fund will reduce flooding runoff.[79] Uncertainty associated with lack data and information about how well previously funded programs work.	Rain Check Program is *likely* to improve the water quality, especially through three green infrastructure practices. [80] Uncertainty associated with how many green infrastructure practices are funded in comparison how many other practices are funded through the Rain Check Program.	It is *very likely* that Prince George County Rain Check Program can help increase local community ties because it involves local government, nonprofit organizations, local businesses and residents.[81]
Municipal Green Infrastructure Plan	It is *very likely* that green infrastructure mechanisms will reduce neighborhood flood potential[82] Uncertainty associated with climate impacts on precipitation patterns	Green infrastructure mechanisms have a *moderate potential* for purifying and reducing stormwater runoff[83] Uncertainty associated with Wells Run water pollution upstream of Riverdale Park	Green infrastructure has *high potential* for the establishment or retention of aesthetic community amenities[84,85]

Discussion

Stakeholder Preference Analysis

Riverdale Park is a primarily residential area, therefore the stakeholders are primarily concerned with policy options that are cost-effective and flexible. Stakeholders in the local

[76] Litofsky et al. 2014
[77] Jennings et al. 2014
[78] Jennings et al. 2014
[79] "Prince George's County Rain Check Rebate."
[80] "Prince George's County Rain Check Rebate."
[81] "Prince George's County Rain Check Rebate."
[82] Zellner et al. 2016
[83] US Environmental Protection Agency. 2010
[84] ibid
[85] Keeley et al. 2013

government, such as the Prince George's County Department of Environment and Town Council, would also prefer the policy option that allows for the most efficiency and flexibility in its implementation. Thus, they would prefer the municipal green infrastructure plan as it incorporates many different types of stormwater treatment that are cost-effective. Local constituents, such as University Park Elementary School, would also prefer the municipal green infrastructure plan as it would allow them input into what type of stormwater treatment options they can implement and use the various types (rain garden, swales, rain barrels) as educational tools. Non-government organizations, such as the Chesapeake Bay Foundation and Anacostia Watershed Society, would prefer the municipal green infrastructure plan as it would maximize efficiency by reducing flooding and increasing Wells Run water quality. The municipal green infrastructure plan allows for multiple stormwater management options that are tailored to a community's specific needs, thus choosing it over a one specific option would make the most sense in terms of practicality and cooperation.

Gaps in Policy Analysis

If a full policy evaluation were to be conducted for the Riverdale area affected by the Wells Run stream, many aspects would be covered that may have been missing before. The policy options presented above would be studied more in depth, and various other options would be researched and presented as viable solutions to the problems Riverdale citizens face. Along with other policy options, further speculation of the objectives are missing from the policy analysis as well. Although Riverdale's main objectives are identified in the table, including minimizing flooding, maximizing water quality, and maximizing community ties, there are many other objectives that cover more specific topics that are not mentioned. These objectives include the minimizing of monetary costs, which would address the implementation of some of our policy options. Here we would address how we would implement rain gardens, or swales at a low cost to the citizens or to the government. We would debate where the funding would come from whether it would be government grant money or a fundraising mechanism throughout the Riverdale Park community. If a further policy analysis was conducted, many more objectives could be explored and each policy option could be related back to an objective, allowing for more detailed responses and an increased accuracy of the weight of evidence.

VI. Municipal Green Infrastructure Implementation Plan to Address Flood Conditions

Based on the evaluations of the various stormwater management policy options, the best option for Riverdale Park would be the implementation of several green infrastructure mechanisms using a strategic plan that will include both regulatory measures and voluntary options for residents of Riverdale Park. This is an ideal approach for Riverdale Park because it combines aspects from the other policy options that we analyzed and provides an effective framework for implementing them at the community level. Furthermore swales, rain gardens and rain barrels are each types of green infrastructure. When these options are implemented on a singular, household basis they have varying degrees of effectiveness, but when implemented across a community in combination with a rebate program, the impact is significantly stronger in terms of achieving the defined objectives.

In terms of implementation, this strategy includes multiple levels of action. The Riverdale Park local government, as part of a regulatory framework, would issue new development

standards and codes that require any new development projects to use green infrastructure techniques (as opposed to grey infrastructure) for stormwater management. One requirement would be the use of swales in applicable areas. Swales are especially advantageous to communities struggling to combat stormwater runoff and erosion problems. The use of resilient vegetation in rain gardens is usually inexpensive to fund and easily filters stormwater runoff. They are also aesthetically pleasing, which is crucial to community development. Rain gardens also provide an opportunity for community education and engagement. The town could install a rain garden in the local neighborhood park to educate the community on how to install and maintain their own at home. It is recommended that Riverdale Park encourage residents to voluntarily create rain gardens on their private property. Community rain gardens should be established in community spaces to be used as education centers.

The final component of the strategy would be a local funding mechanism that aligns with the Prince George's County Rain Check Rebate program. This is a way for the local government to provide economic incentives along with local partners to residents, businesses and nonprofit organizations for stormwater management. Overall, a residential and community based municipal green infrastructure strategy would be the most effective and feasible approach for Riverdale Park to reduce local flooding and improve Wells Run's water quality, while cultivating strong community watershed ties.

VII. CONCLUSION

As presented in our report, the location of Riverdale Park and the Wells Run stream are both facing stormwater management, flooding, and water quality problems that seek a solution in the form of policy recommendations that are simple to implement, an inexpensive option, and adequately address these problems. In order to recommend viable solutions for the residential neighborhood of Riverdale Park, options needed to be studied that could reduce the impacts from increased flooding events that cause certain public nuisances. Due to the urban development happening upstream of Riverdale Park, and the future climate change scenarios, this community could greatly benefit from polices that specifically address stormwater management and flooding. As a whole, our report studies how Riverdale Park can reduce flooding, increase water quality, and increase community ties with the Anacostia watershed that Wells Run flows into. Our scientific synthesis proved that Wells Run was an important input to the Anacostia watershed, and that pollutants and runoff occurring in Riverdale could overall affect the water quality of the watershed itself. When evaluating this factor, various stakeholders and their perspectives were studied and the community of Riverdale Park had the most interest in a solution to their flooding and pollution issue, while a larger influence may have more power in implementing a possible policy option to combat stormwater management. Based on the policies studied, a holistic green infrastructure plan was developed which was the ideal choice for a small community such as Riverdale Park. This approach included the use of swales, rain gardens, and a rain rebate program which will minimize flooding, maximize water quality, and maximize community ties with not only Wells Run stream, but also the Anacostia watershed. Overall, our integration of the problem, a multi-tiered solution, the incorporation of the stakeholders, and our research has led to the approach that will ideally yield great results, and solve the major problems that Riverdale Park currently faces.

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APPENDIX A: PowerPoint Presentation Slides for *Interdisciplinary Synthesis and Policy Recommendations for the Improvement of Wells Run Stream Quality and Stormwater Flow in Riverdale Park, Maryland*

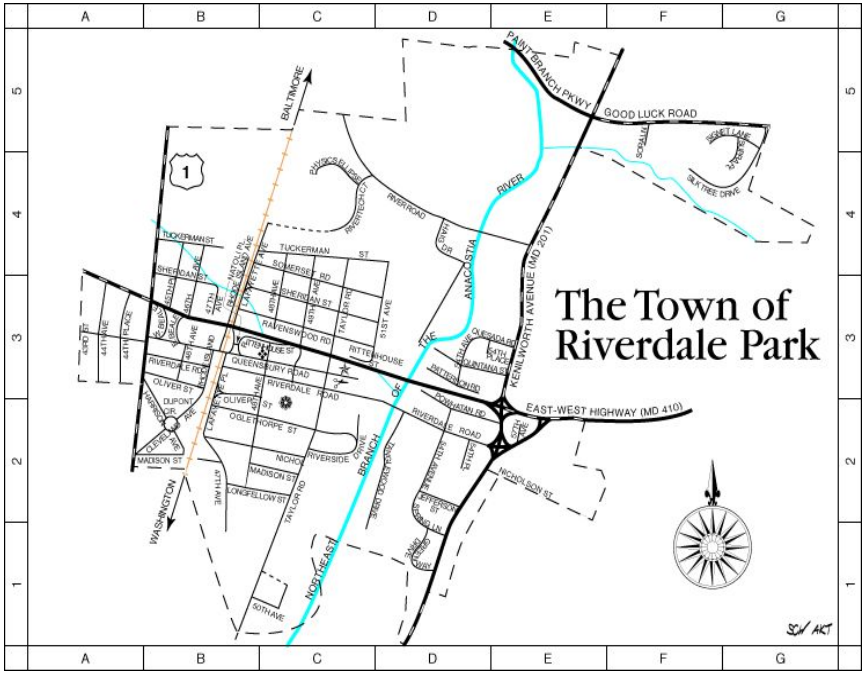
Presented April 28, 2017 in the University of Maryland, College Park, Environmental Science and Policy Capstone Course

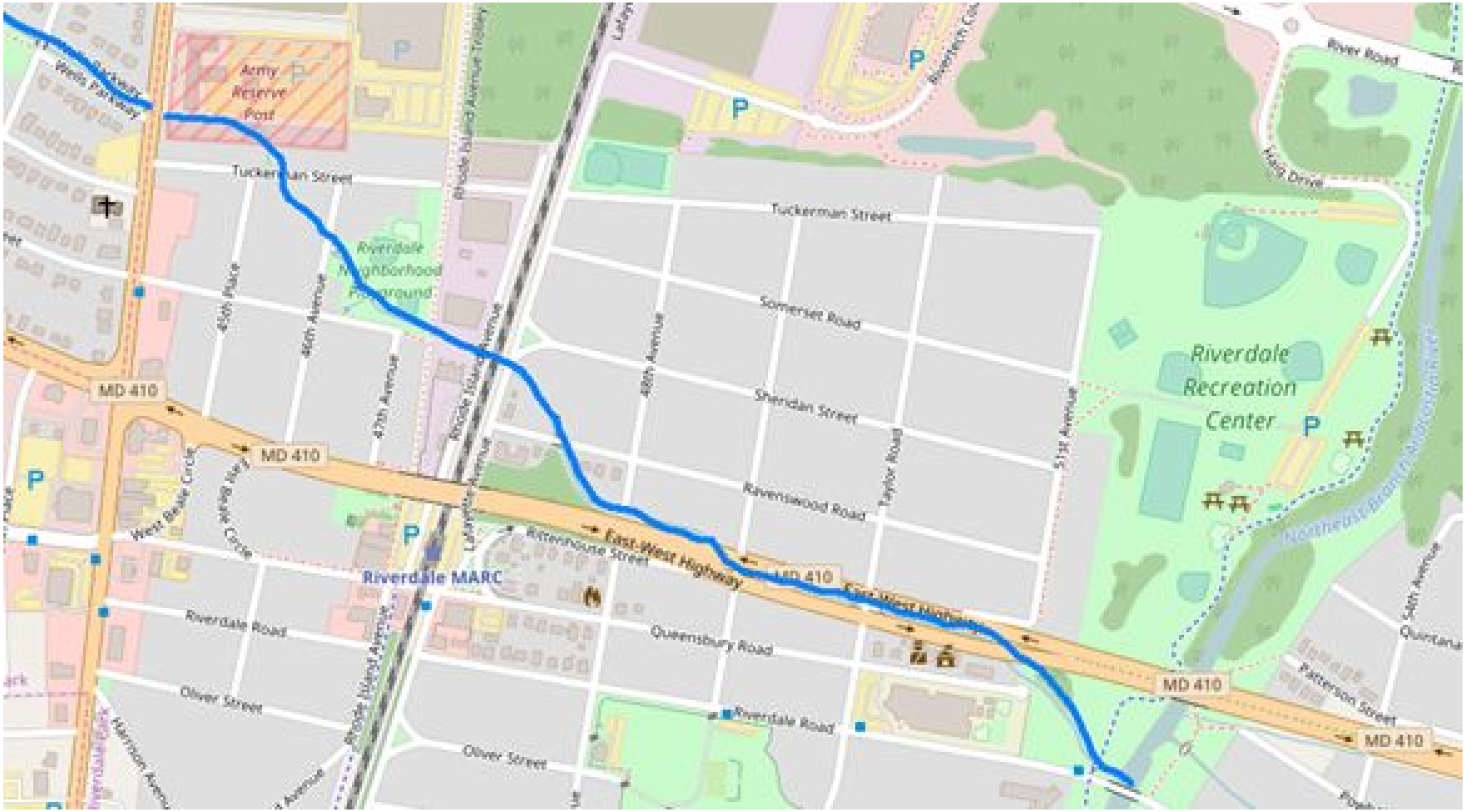
Riverdale Park & Wells Run

Ying Deng, Cara Heilveil, Taylor Hollady, Meghan Loughry, and Audrey Vogel

Geographic Location: Riverdale Park

Wells Run is a small waterway in Prince George's County, Maryland that begins in Hyattsville and passes through University Park and Riverdale Park, ultimately feeding into the Northeast Branch of the Anacostia River.





Basemap Source: EPA EJ Screen 2016

Problem Definition and Objectives

Given the anticipated urban development upstream and predicted climate change impacts, how can Riverdale Park strengthen its community watershed ties, and improve the Wells Run water quality and flood conditions?

Major Objectives:

- Minimize Flooding
- Maximize Water Quality
- Maximize Community Ties

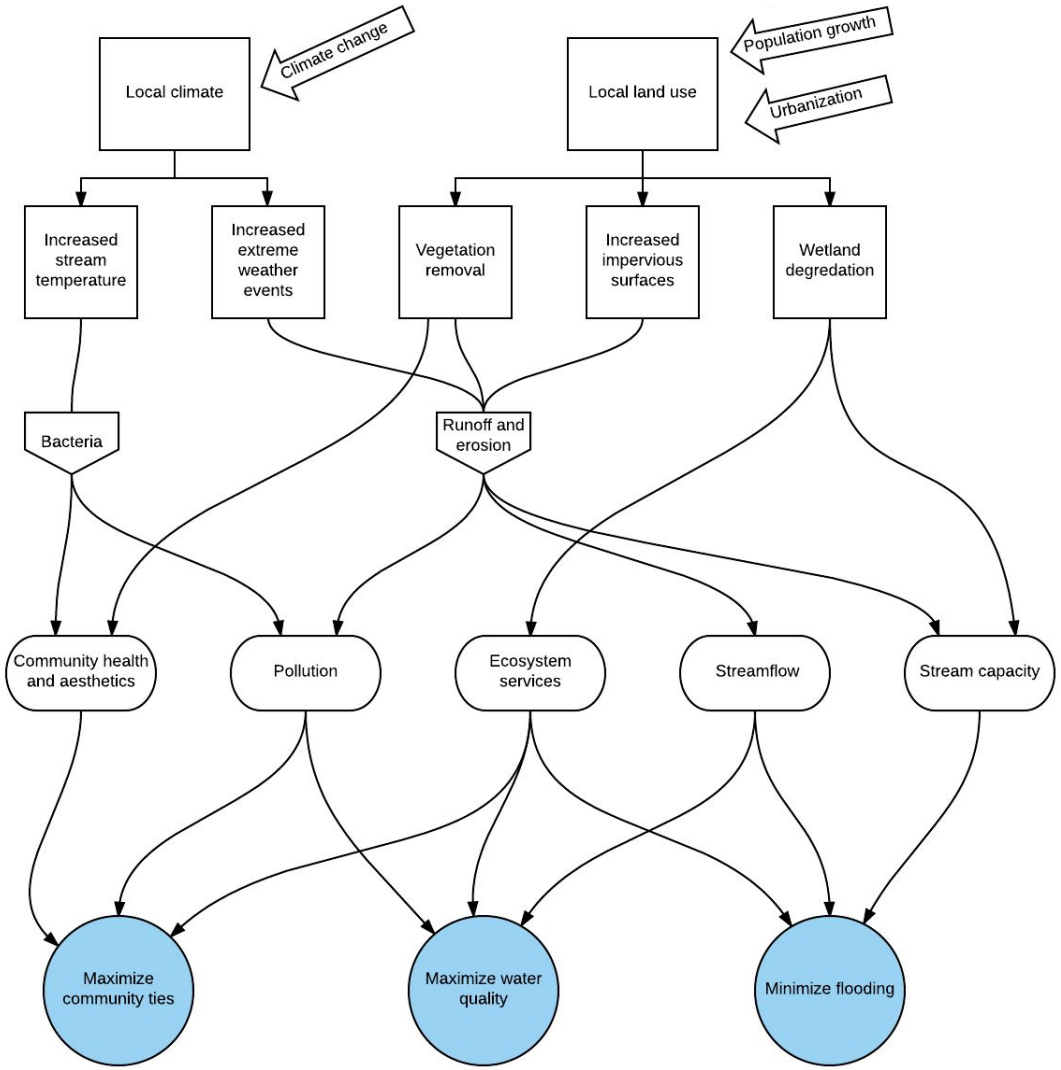
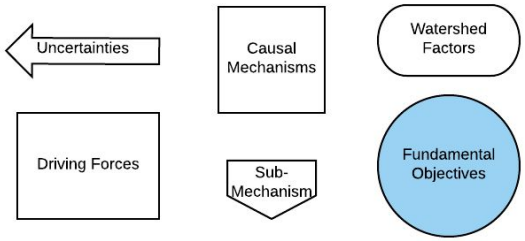

Climate change
Local climate
Population growth
Urbanization
Local land use
Increased stream temperature
Increased extreme weather events
Vegetation removal
Increased impervious surfaces
Wetland degredation
Bacteria
Runoff and erosion
Community health and aesthetics
Pollution
Ecosystem services
Streamflow
Stream capacity
Maximize community ties
Maximize water quality
Minimize flooding

Diagram Key:


Uncertainties
Causal Mechanisms
Watershed Factors
Driving Forces
Sub-Mechanism
Fundamental Objectives

Scientific Synthesis Findings

- Flooding and Urban Development
  - Increased impervious surfaces
  - Increased run off
  - Increased pollution
  - Decreased water quality
- Projected Climate Change
  - Increased major precipitation events
  - Increased stormwater
  - Increased water temperature
- Social Impacts
  - Decreased community health
  - Decreased community investment in watershed

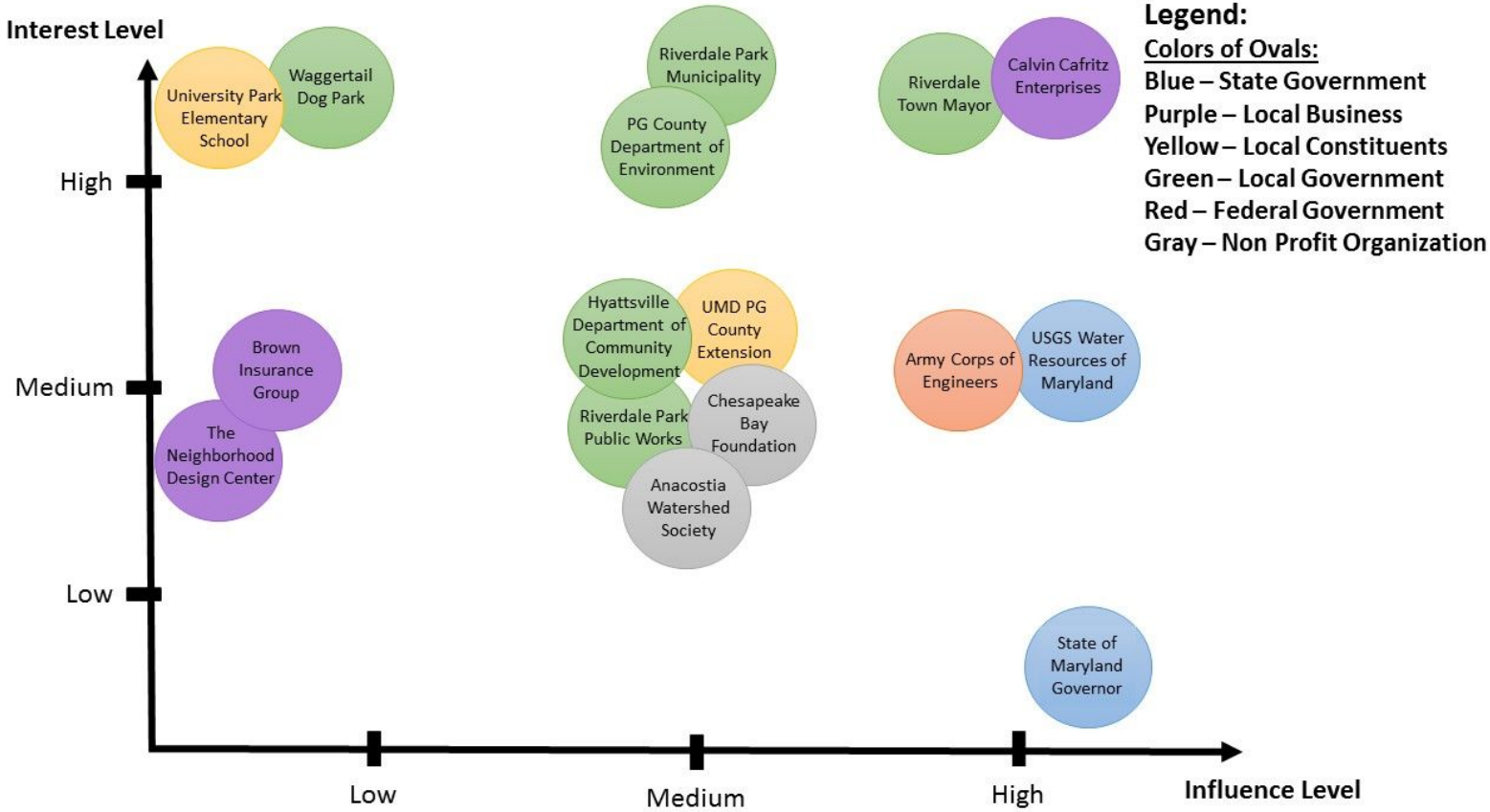
Stakeholders Involved

- Local Constituents
- Local Businesses
- Local Government
- State Government
- Federal Government
- Non-Profit Organization

Stakeholder Needs Findings

Stakeholder Group	Primary Value
Local Constituents	Quality of life and health of watershed
Local Businesses	Maintenance of public resources
Local Government	Cost-effective, sustainable development
State Government	Chesapeake Bay water quality
Federal Government	Ecosystem restoration and flood control
Non-Profit Organization	Protecting the Chesapeake Bay watershed

Stakeholder Diagram



Integration of Problem Definition, Synthesis and Stakeholder Needs

- All stakeholders' in the Wells Run area have an interest in improving the Wells Run watershed quality.

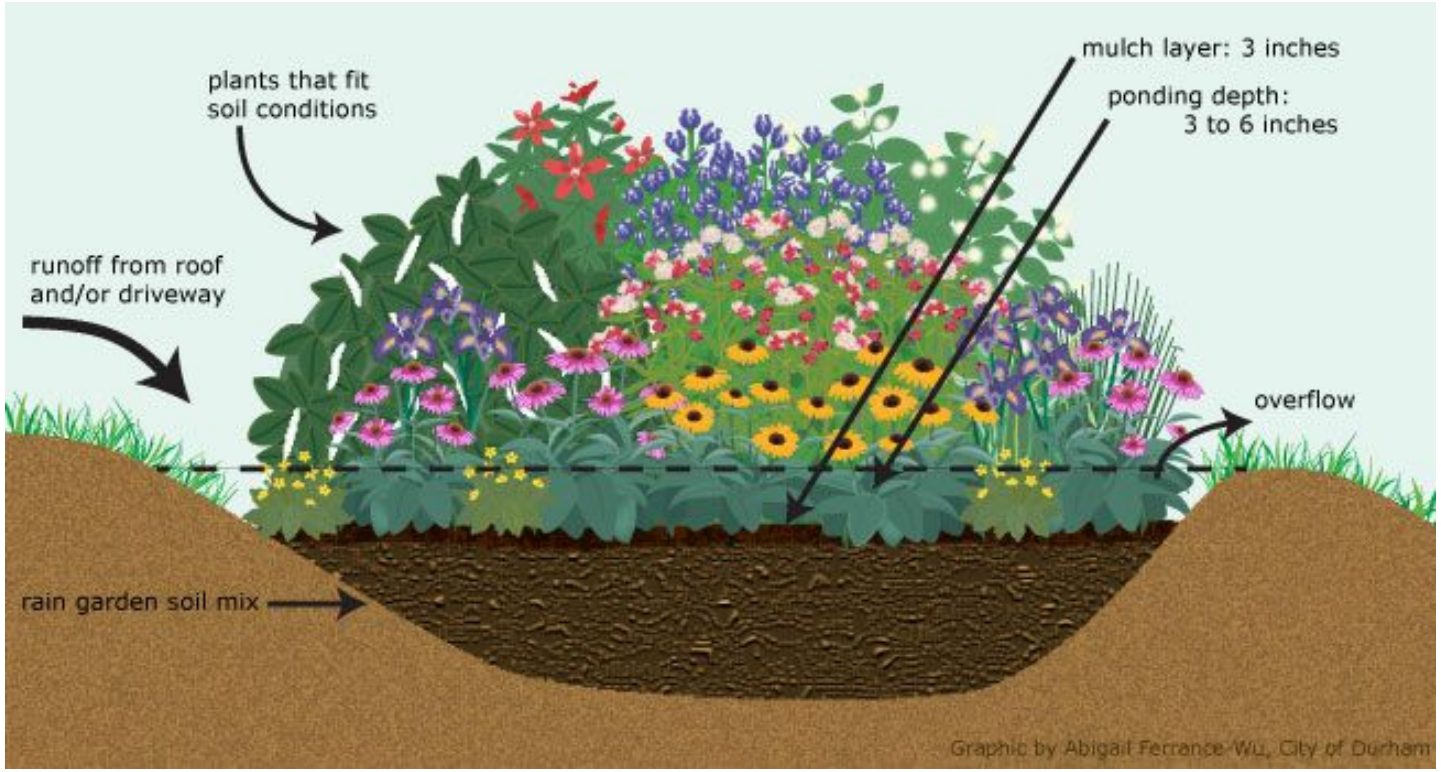
- Policies that focus on involving the community to prevent urban flooding would be the most effective way to address the problem definition and meet the stakeholders' and the watersheds' needs.

Policy Options

1. **Construction of Grass/Vegetated Swales** - *channels that provide stormwater treatment and retention as they move stormwater from one place to another*
2. **Implementation of Rain Gardens** - *shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets*
3. **Use of Rain Barrels** - *Rainwater harvesting systems that collect and store rainfall for later use*
4. **Local Economic Funding Mechanism** - *economic incentives for installing green infrastructure similar to PG County Rain Check Rebate Program*
5. **Municipal Green Infrastructure Plan** - *holistic policy approach that implements a combination of green stormwater management practices at the community level*

Swales

Rain Gardens



Rain Barrels

Rain Check Rebate Program

	Cost	Rebate (maximum for each practise)
Rain Barrel	$50-$250/ barrel	$2/gallon stored
Cistern	$300-660 for family size cistern $3000 and up for commercial size cistern	$2/gallon stored
Urban Tree Canopy	$75-$200/tree	$150/tree
Rain Garden	$4-$35/square foot	$10/square foot
Pavement Removal	Varies Considerably	$6/square foot
Permeable Pavement	$7-$15/square foot	$12/square foot
Green Roof	$10-$30/square foot with $0.75-$1.50 annual maintenance cost/square foot	$10/square foot

Municipal Green Infrastructure Plan

Benefit	Reduces Stormwater Runoff				Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice											
Green Roofs	●	●	●	●	●	◒	●	◒	◒	●	●
Tree Planting	●	●	●	●	●	●	●	●	◒	●	●
Bioretention & Infiltration	●	●	●	●	●	●	◒	◒	○	●	●
Permeable Pavement	●	●	●	●	○	○	●	○	○	○	●
Water Harvesting	●	●	●	●	○	○	○	○	○	○	●

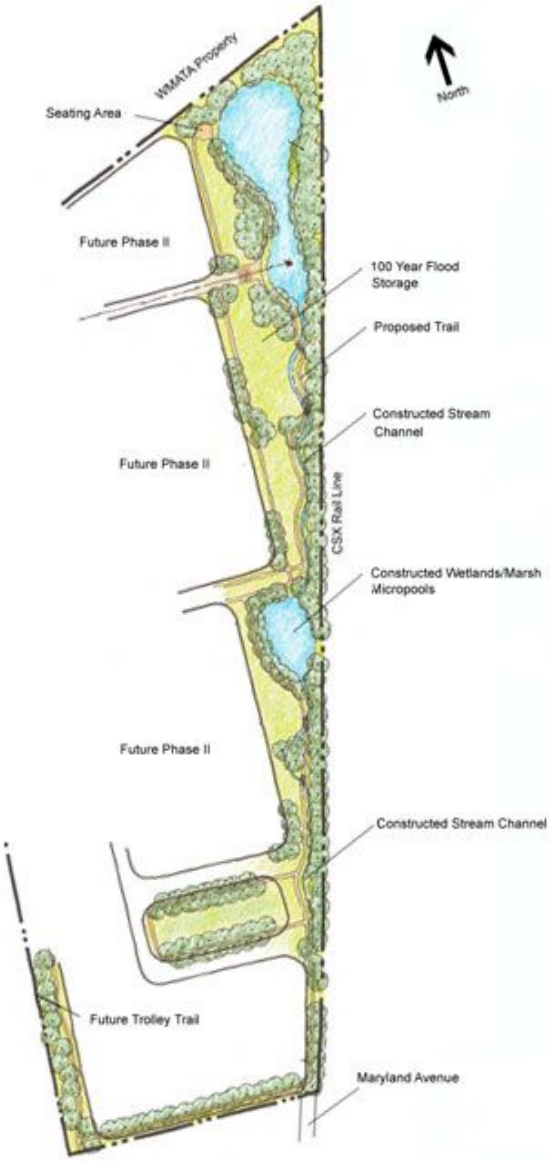
	Minimize Flooding	Maximize Water Quality	Maximize Community Ties
Construction of Grass/Vegetated Swales	*Highly likely*	*Highly likely*	*Somewhat Likely*
Implementation of Rain Gardens	*Highly likely*	*Highly likely*	*Somewhat likely*
Rain Barrels	*Unlikely*	*Unlikely*	*Unlikely*
Local Funding Mechanism (PG County Rain Check Program)	*Highly likely*	*Somewhat likely*	*Highly likely*
Municipal Green Infrastructure Plan	*Highly likely*	*Highly likely*	*Highly likely*

Recommendations

Three-Tiered Municipal Green Infrastructure Implementation Strategy

Tier 1. Local Land Use Standards and Development Regulations

- Local policies that extend beyond the PG County Stormwater Management Regulations
  - Considerations for smaller development projects
  - Formal protections for urban tree canopy and interconnected green spaces



Tier 2. Participate in the PG County Rain Check program

- Incentive for homeowners, business and nonprofit entities to install green infrastructure
- Funding mechanism
- Site level practices implemented across a neighborhood

Tier 3. Community Rain Garden Initiative

- Install a rain garden in the local neighborhood park
- Opportunity to learn about proper maintenance
- Strengthen community ties and aesthetics

Take Home Messages

- It is *very likely* that projected climate change and urbanization patterns will negatively impact the stream water quality and flooding conditions in Riverdale Park

- Despite having different needs and long-term goals, all stakeholders in Riverdale Park will benefit from improving the Wells Run watershed quality.

Take Home Messages

- We recommend a holistic approach to restore community watershed ties, and improve the Wells Run water quality and flood conditions.

- Policies that can be implemented at multiple levels have the highest potential for success.

  → Community, Neighborhood, and Household/Site

  → Public and Private Property

  → Voluntary and Regulatory

Any Questions?