Watts Branch Resiliency Masterplan

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Watts Branch Resiliency Masterplan
Master's Project Report

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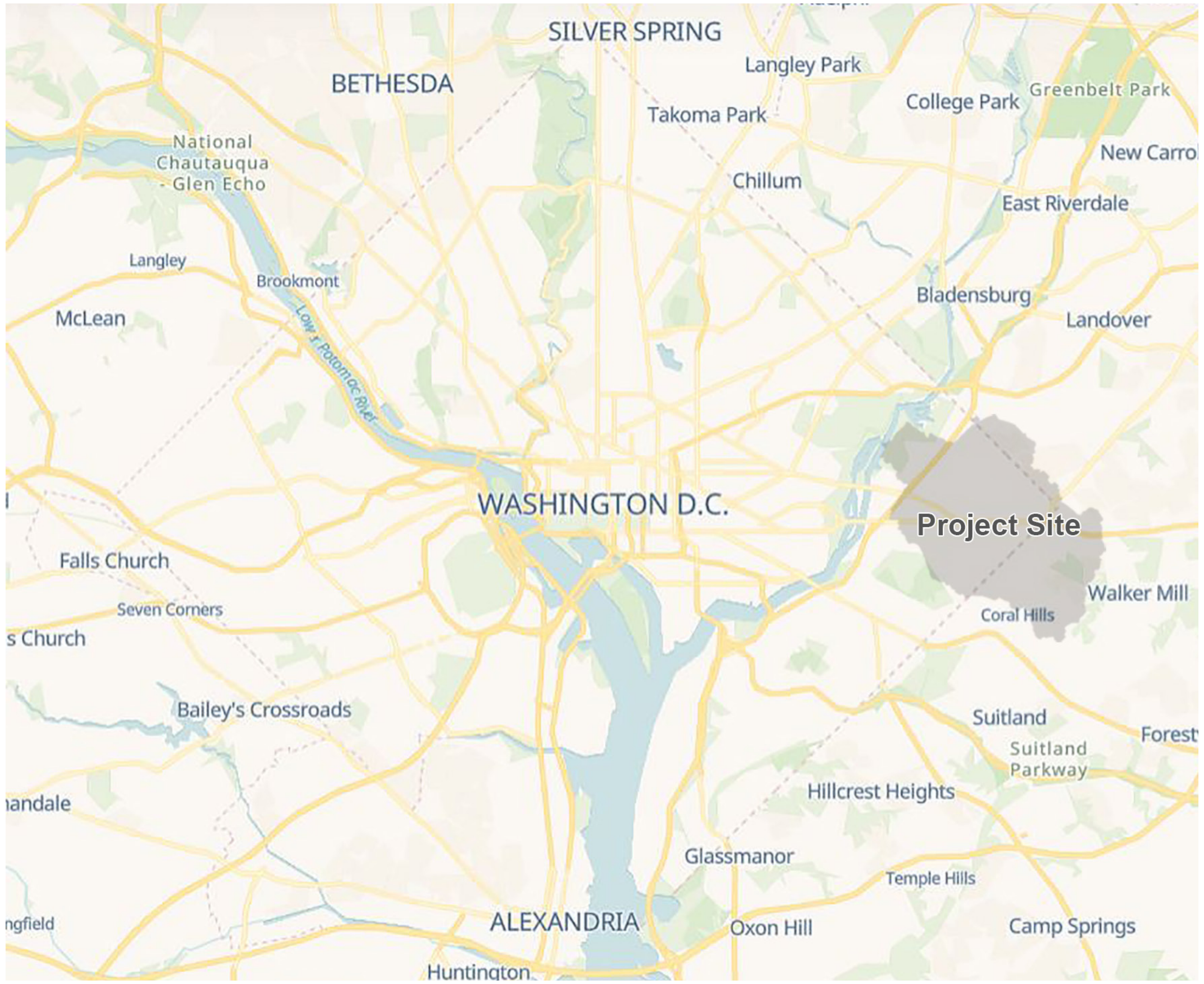
Introduction

Urban areas are major concentrations of culture, acting as centers of trade, industry, innovation, and daily living. Since the industrial revolution, cities have continuously developed and further concentrated human capital. Urban areas face a multitude of challenges, from efficient transportation to resource distribution to public safety and crime prevention. Today, the number of people who reside in cities outnumbers the number of people who reside outside of cities, and the proportion of the population that lives in urban areas is expected to increase to nearly 70% by 2050.[1] As this occurs, we must make sure our cities can effectively

A park in the Fort Circle Park/Mayfair airea of the Watts Branch Watershed, Washington, D.C.



The Watts Branch watershed (shown in grey) falls across the northeast corner of the Washington, D.C./ Maryland border.

provide residents with the resources and services they need not just to live but to thrive.

Meanwhile, climate change threatens the health and safety of all our living spaces, especially in cities. In the near future, our cities will not only have to accommodate more people, they will also have to adapt and respond to the effects of climate change in order to maintain conditions that are safe, healthy, and liveable. The effects of climate change are far-reaching. They include increased precipitation and other extreme weather events—which result in a heightened risk of flooding and the endangerment of lives and property—and the increased fragility of ecosystems and biodiversity as they also attempt to adapt to changing living conditions. Urban environments are especially vulnerable due to large amounts of impervious surfaces, which prevent rain water infiltration and absorb heat, and limited space for ecosystems that can help mitigate these effects.

This project is located in the watershed of the Watts Branch, a tributary of the Anacostia River, and spans parts of both Prince George's County, Maryland, and the District of Columbia. It crosses densely populated urban neighborhoods, some of which are home to socially and economically vulnerable populations. Some of its residents are low-income families or live in affordable housing communities. Washington, D.C. and the State of Maryland have both experienced catastrophic flooding events in the last several years, largely driven by precipitation. Flooding in the Federal Triangle has threatened not just homes and businesses but also irreplaceable national historical documents and artifacts. Similarly, catastrophic and fatal flash flooding suffered in Ellicott City, MD, in 2018, disrupted that city's leading industry, tourism.[2] These events are devastating—as they will occur more frequently as climate change continues to have greater impacts, it is thus essential to ensure that this community is protected against these impacts.

One way to address multiple challenges within an urban environment is through planning and designing urban spaces to manage stormwater, provide recreation opportunities, increase biodiversity, and reduce local surface temperatures. A multifaceted process incorporates demographic information, local habitat and biodiversity considerations, and hydrology and terrain analysis to create an urban design that functions better for its residents. These designs prioritize "blue-green" infrastructure in conjunction with traditional "gray" infrastructure.

Ramboll, a Danish engineering and design consulting firm, consulting for District of Columbia Department of Energy & Environment (DOEE), and in collaboration with the Army Corps of Engineers (USACE), assembled the first phases of a community resiliency masterplan for the Watts Branch catchment in 2019. Ramboll has conducted a variety of similar projects across the world. Most prominent is a flagship project in Copenhagen, Denmark, in which Ramboll created a resiliency plan to protect the city from flooding caused by significant precipitation events. Similar projects have been conducted in New York City and Singapore. Elements from these projects are used to inform this project.

Continuing Ramboll's work, we identified further areas of concern and analyzed the social and ecological dynamics of the space. With those results, we identified opportunities to improve the site and created a watershed-level masterplan focused on prioritizing areas of concern. We then designed three conceptual "pilot projects" in representative areas of the watershed to highlight the possible infrastructure solutions that could be implemented throughout the watershed. Our infrastructure solutions and pilot projects are sensitive to the ecology of Watts Branch, respectful of its culture and history, and aesthetically responsive to the needs of the space. As urban ecosystems like that of Watts Branch present a unique intersection of ecological and social needs, it is especially important that we deliberately design such spaces to be responsive to this variety of needs for both their current and future populations.

Project Objectives

To create an ecologically based landscape design, informed by hydrological and spatial analyses. We set three goals for the outcome of this project that would respond to both social and environmental needs of the watershed to enhance its resilience.

Kenilworth Park, in the northwestern end of the branch close to where Watts Branch meets the Anacostia River.

Reduce the risk of flooding for homes and businesses within the watershed.

- Improve upon the existing stormwater management system and reduce residents' exposure to flood water hazards.
- Decrease impervious surface to promote water management and water quality

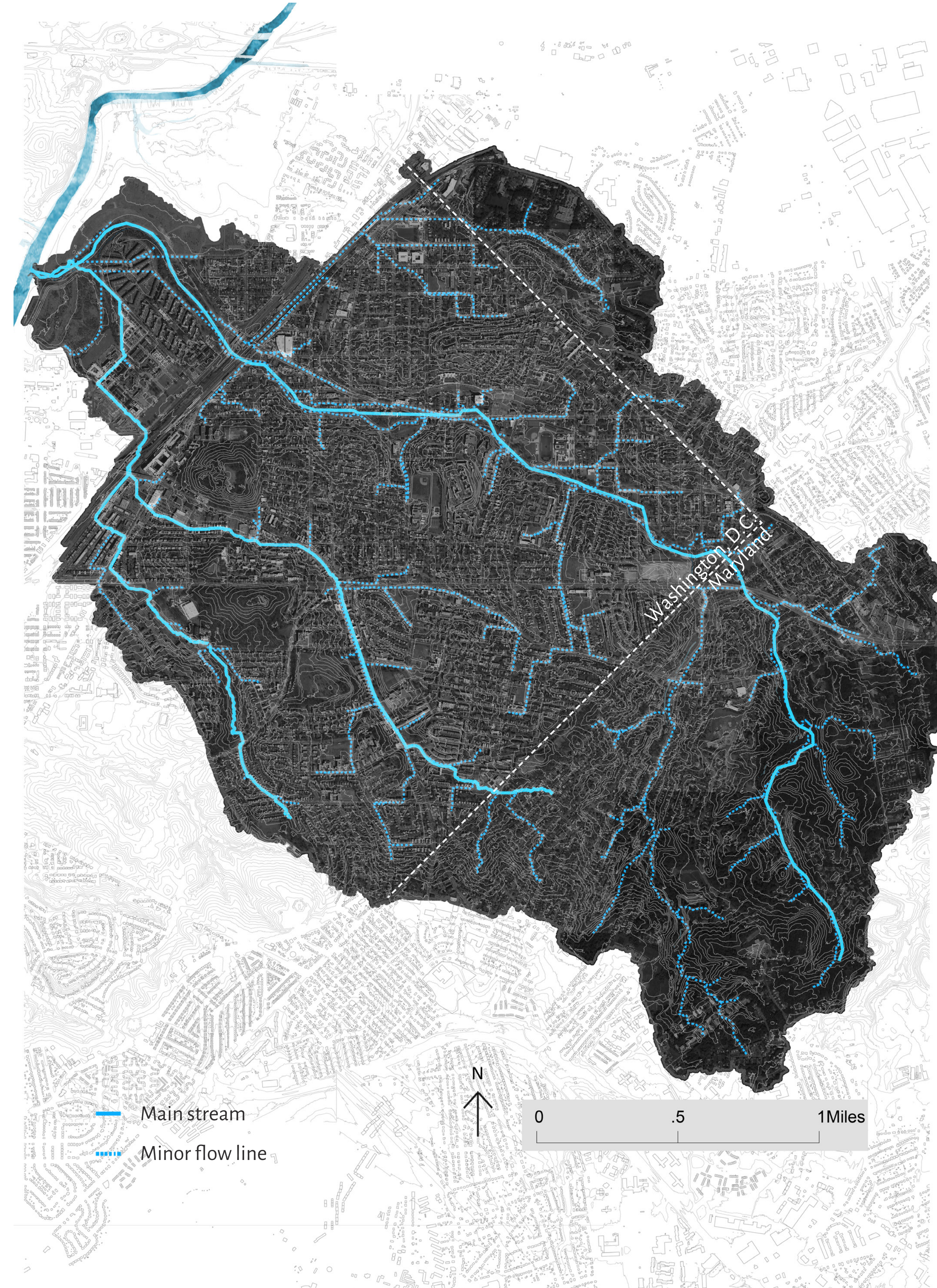
Improve quality of water and habitat

- Increase local residents' access to thoughtfully designed space in their urban neighborhood
- Decrease stream bank erosion through appropriate vegetation choice

Enhance social and economic benefits—such as recreation, education, and sense of community—and enhance human accessibility to the water.

- Increase access to green space
- Increase the capacity of the neighborhood to cope with climate-related hazards, including urban heat and flooding
- Add value to the community
- Reduce climate-related costs and infrastructure damage

The Watts Branch watershed. Two primary streams (shown in solid blue) flow into the Anacostia River in the north. A multitude of other flows likely run along streets.



Definitions

This project includes several broad concepts. As a result, we have found it useful to define these concepts for the development of our own thoughts as well as for added clarification for readers.

Mayfair neighborhood near the Cesar Chavez Public Charter School, in the northwestern end of the branch.

Blue Infrastructure and Green Infrastructure
Blue infrastructure and green infrastructure are both terms used to describe networks that provide the "ingredients" for solving urban and climatic challenges by building with nature. Many of the design interventions we suggest in this masterplan fall into this category. This approach improves many core ecological functions such as stormwater management, climate adaptation, heat stress reduction, biodiversity enrichment, food production, air quality improvement, sustainable energy production, clean water and healthy soils. Blue-green infrastructure also helps meet human needs such as increased quality of life, increased recreational or property value, added shade and shelter, avoided costs associated with flood risk, and enhanced aesthetics. Blue-green infrastructure solutions are often used along with or in place of grey infrastructure, which encompasses existing solutions such as pipes and drainage systems.

Cloudburst
A cloudburst is an extreme weather event that produces a large amount of precipitation in a short period of time, usually 4 inches or more per hour. Cloudburst events can threaten life and property. During a cloudburst, rain falls too quickly for it to infiltrate into the soil, leading to flash floods and severe erosion. A cloudburst in an urban area is likely to flood more severely due to high levels of impervious surfaces, which further prevent infiltration.

Liveable City
A liveable city is an urban area for which the design and planning strategically maximize social well-being. As an increasing proportion of people begin to reside in cities, thoughtful urban design becomes increasingly important. Livable cities are equitable and affordable, provide all residents easy access to opportunities and amenities, and are good stewards of their residents' health. Cities should be comfortable, safe, and attractive to all residents. They are places in which people can not just survive but flourish. These outcomes can be improved through the optimization of all aspects of city life - transportation, recreation, entertainment, work, governance, and climate adaptation.

Living Shoreline
The concept refers to habitat created along rivers that serves as a way to stabilize riverbanks and prevent coastal flooding while providing habitat to local wildlife.[3] This is one of the primary concepts utilized in our masterplan. While most of the current academic literature on Living Shorelines is primarily focused on the establishment of marshes along riverbanks, Ramboll uses their Living Shorelines as a platform for a more holistic approach to waterfront restoration. In addition to increasing riverbank stability, Ramboll's Living Shorelines include a liveability component, which overlays social, cultural, and policy considerations onto the ecological and hydrological ones.[4] As a result, Living Shoreline projects are beneficial to the natural environment of a site as well as to its social context. They are responsive to a variety of both short-term and long-term uses. The concept is especially useful in working to create spaces that are thoughtful and durable. As landscape ecologists, we want to make sure the spaces we are creating are multifunctional and sensitive to all ecological and social processes that are taking place there.

Masterplan
A masterplan is a high-level, long-term overview of intended outcomes for a given spatial area. A masterplan contains a series of objectives and applies those objectives across the area. Masterplans can be created for any aspect of a community's development; this masterplan outlines methods to make Watts Branch more resilient. They are usually not prescriptive; they create a vision for the area that will guide future development.

Resiliency
Our project seeks to mitigate the impacts of climate change in this watershed and help the community in this watershed adapt to the effects of climate change they do experience. The UNFCCC defines climate adaptation as "changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change."[5] Resiliency is made possible by these changes to processes and practices and is an essential part in assessing a community's adaptation to climate change effects. Resilient communities, both human and otherwise, are able to quickly recover from the difficulties climate change might cause. They have systems in place that will handle many of these impacts in a way that causes minimal harm to the community, and reduce the most devastating impacts.

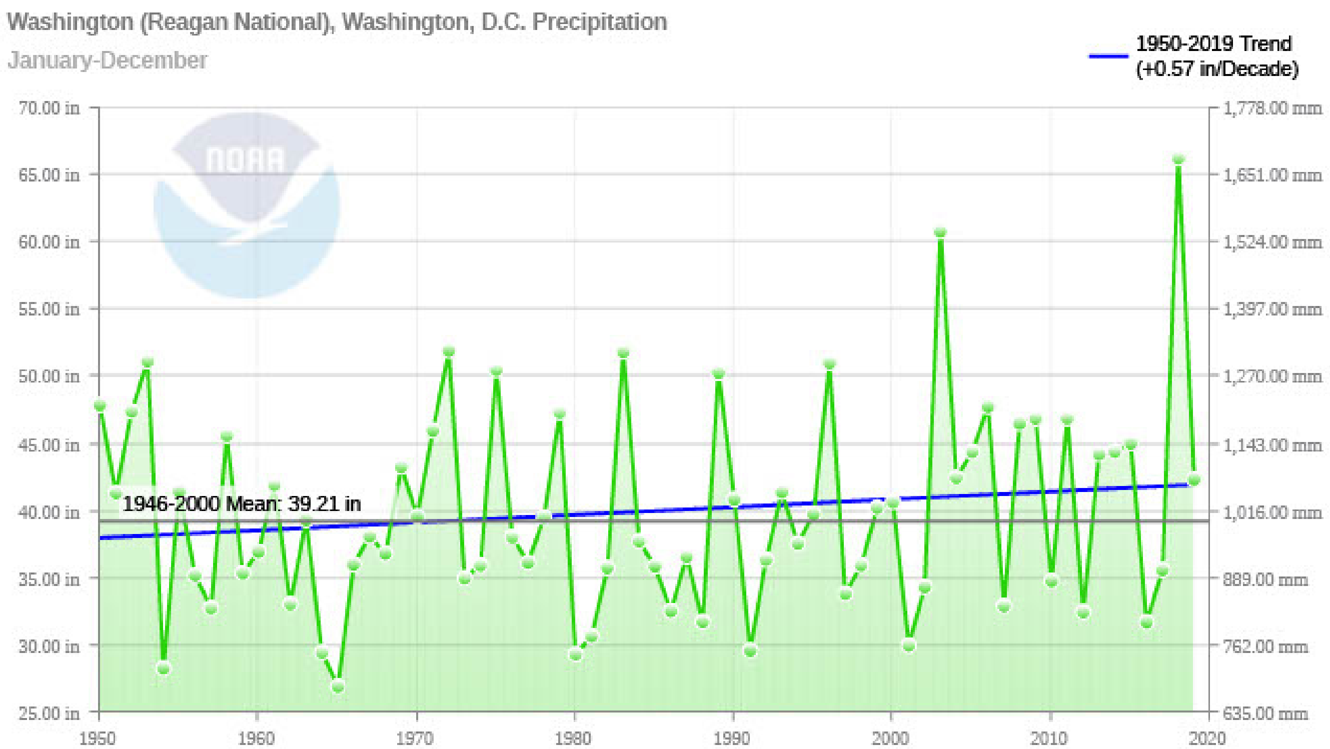
History and Current Conditions

Our team conducted a site visit in late August 2019. We toured the entire watershed and viewed representative sections of the Watts Branch from its headwaters in Prince George's County, MD, to where the branch meets the Anacostia River in Kenilworth Park, Washington, D.C.

We identified three main issues within the watershed:

- Flooding and water management
- Poor water and habitat quality
- Lack of human connection to the water and social ecosystem services

A residential neighborhood adjacent to Watts Branch near Marvin Gaye Park, Washington. D.C.



Each individual issue is not only complex and individually significant but is also closely interconnected with the others, magnifying their collective impact throughout the watershed. The interrelatedness of each issue further contributes to overall limited ecological and social health within the watershed.

Precipitation in the Washington, D.C. area has increased over the past several decades. Increased flooding as a result of this trend could cause harm to many residents and businesses in the watershed.

Flooding and Water Management

Flooding problems throughout the world have been increasing and are expected to continue to have increasing negative impacts on communities. One contributing factor for this is climate change. Climate change is caused by increasing greenhouse gas emissions, which trap heat in the atmosphere and raise global temperature. Climate change will have manifold effects on our living environments.[6] Specifically, in the Washington, D.C and Maryland area, where the Watts Branch is located, climate change is expected to make weather hotter throughout the year, endanger wetland habitat for birds and fish, worsen human health, and increase the frequency of heavy rains.[7] Global temperature rise has been melting ice sheets and glaciers which empty into the oceans and raise sea levels.[8] Increased temperature levels also cause water to expand, compounding sea level rise.[9] This leaves coastal areas such as the Watts Branch incredibly vulnerable to major and minor temporary flooding, as well as permanent inundation.

Moreover, tidal rivers like the Anacostia, into which the Watts Branch empties, are directly influenced by the ocean. This means the Anacostia River watershed is subject to three types of flooding:

1. Interior flooding, which occurs when heavy storms produce more rain than the piped stormwater infrastructure system can handle.
2. Riverine flooding, which occurs when high flows from upstream flood downstream areas.
3. Tidal flooding, which occurs when coastal water is pushed up the river from the ocean or a large bay (in this case, the Chesapeake Bay), often during a storm.[10]

Heavy flooding accumulated in the Federal Triangle because of its location in a topographic low spot. Several portions of Watts Branch are in similar low areas, posing a flooding hazard for those who live and work in those areas.

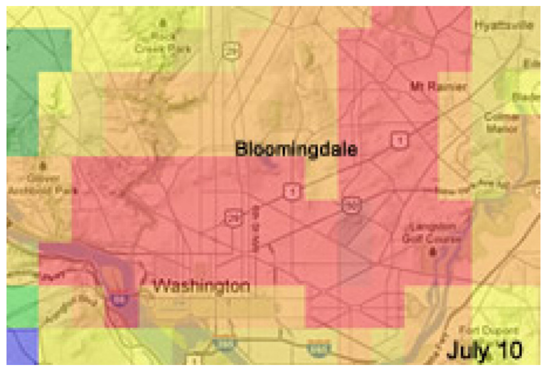
Climate change is making large storm events more frequent, which will increase the likelihood of interior flooding. Meanwhile, sea level rise makes riverine and tidal flooding more of a risk.[11]

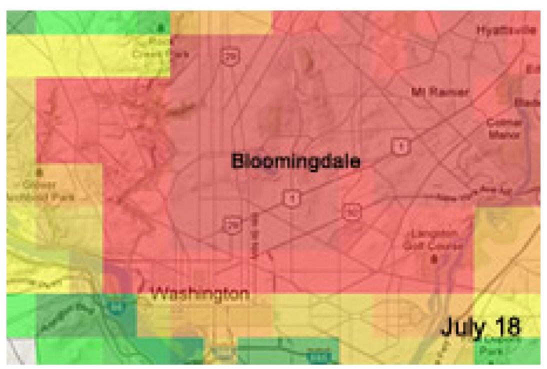
Precipitation

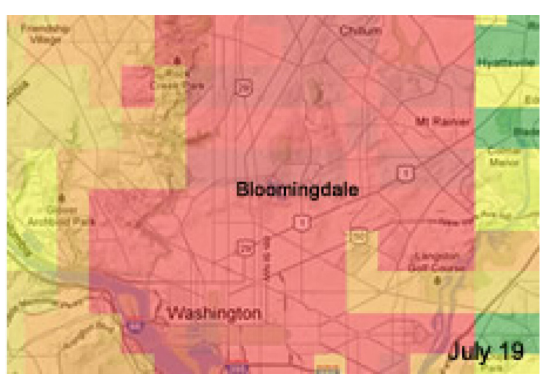
Over the past 50 years, local water levels have risen by 6-7" and may increase further to anywhere between 16" and 4' in the future.[12] Local precipitation shows a general increase over the past few decades.[13] Specifically, precipitation has increased significantly during the summer but decreased slightly during all other seasons. In addition, FEMA floodplain maps may underestimate the risks, as they do not account for the effects of drainage systems that aren't able to handle the added water.[14] Exacerbating the issue is that the land around Washington, D.C. is also sinking, helping make the rate of sea level rise twice as fast as the global average.[15] All this leads to the endangerment of several portions of the Anacostia watershed, including areas in the Watts Branch watershed.[16]

Previous Flooding Events

The concern about flooding for the Watts Branch watershed is not unwarranted. The branch, as well as Washington, D.C. has a history of flooding. Recently, the Watts Branch watershed has faced three major storms. These storms overwhelm the area's infrastructure, damage property, and pose health risks for the community. For example, while the Maryland portion of Watts Branch, located in Prince George's County, and the Washington, D.C. portion of Watts Branch both have separate storm sewer systems, the portions of Washington, D.C. between the Potomac and the Anacostia Rivers do not. These have combined sewer systems, making those areas far more vulnerable to overflows than a separated system. Such flooding events have led to significant loss to the economic and social aspects of the community. It is vital for researchers to further study the flood events around the area to prevent such harm from occurring in the future.







Top: Heavy flooding such as that in the National Archives poses both safety and economic risks to those who live and work in the area.

Bottom: Radar images of the 2012 Bloomingdale floods show the intensity and extended duration of the rain.

There have been many recorded floods throughout the history of the District of Columbia. They can be categorized into the three main types mentioned above: riverine floods, tidal floods, and interior floods. In this review, we will mainly focus on recent interior flooding events. More specifically, we will look into three relatively recent flooding events: the Federal Triangle in 2006, the Bloomingdale neighborhood in 2012, and Cleveland Park in 2016.

2006, Federal Triangle

In 2006, a major precipitation event in Washington, D.C. led to water accumulation on Constitution Avenue and 9th Street.[17] The water poured down into the basement and theater of the National Archives building. It also caused over $13 million in damage to IRS buildings.

It could not have been prevented by strengthening the nearby Potomac River levees because the water did not come from the river. The Federal Triangle happens to be the bottom of a "bowl" formed by the surrounding topography. During a large rain event, water quickly runs down into the Federal Triangle. Unless these conditions are changed, this area will remain at risk. A similar volume of precipitation could quickly cause another flood.[18]

2012, Bloomingdale neighborhood

In 2012, 3 major rainfall events happened in the Bloomingdale neighborhood within 2 weeks: July 10th, 18th, and 19th. The first event brought the most water, while the second and third precipitation events passed quickly but still brought a large amount of precipitation to the neighborhood. The government passed out sandbags to residents, but there were still complaints that the agencies did not respond quickly enough. This area did not expect this volume of water in such a short time as it was unusual for the neighborhood to experience this kind of rainfall.[19]

2016, Cleveland Park

Similar to the flooding events in Federal Triangle and Bloomingdale neighborhoods, during a large thunderstorm, Washington, D.C.'s Cleveland Park metro station flooded so badly that the Metro station ended up closing for nearly two hours.

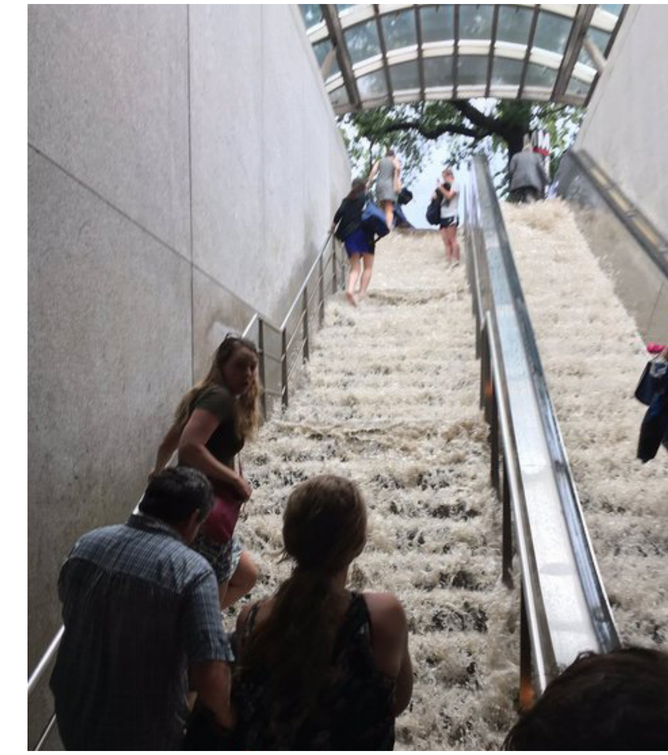
In the previous two cases, the flooding locations were mostly low in elevation, which caused all the water to run down into basements or streets. However, in Cleveland Park, impervious surfaces were the major driver of the flooding rather than topography. Instead of draining into the ground, the water can only flow over the surface and thus accumulates greater volume as it runs over paved surfaces. The metro station has parking lots on both sides, which drain to the city's storm water system. During a heavy rain event, the stormwater system can overflow and breach the height of street curbs; from there, water will flow to the lowest point. In this case, the metro station proved to be an easy outlet. Possible solutions to prevent this from happening again include building up a sandbag wall in front of the station entrance or raising the level of the metro station gate.[20] However, a more sustainable and more long-term plan could include a well-designed landscape plan as well as flood control analysis to further address the problem.

Poor Water and Habitat Quality

Poor Water Quality

Water quality is often an issue in dense urban areas and the Watts Branch is no different. Chemical pollutants, sediment overload, and solid waste all contribute a significant load on the stream.[21]

The Anacostia River, for example, contains 58 pieces of trash per 100 feet of the river. Trash collectors and litter traps have ameliorated the situation, but the Watts Branch is still listed as impaired.



Top: Flooding in the Washington, D.C. Cleveland Park Metro station shut down the station and inconvenienced many.

Middle: Much of the river experiences poor water quality, including the presence of trash.

Bottom: The stream at Marvin Gaye Park is hidden by canopy trees and shrubs.

Use Information		
	Attainment Status	**Uses**
Assessed:	Not Supporting	Primary Contact Recreation Protection and Propagation of Fish, Shellfish and Wildlife Protection of Human Health related to Consumption of Fish and Shellfish Secondary Contact Recreation and Aesthetic Enjoyment

Cause Information

Causes	Associated Uses	Pollutant?	Confidence
Alterations in wetland habitats	Protection and Propagation of Fish, Shellfish and Wildlife	Yes	
Combination Benthic/Fishes Bioassessments	Protection and Propagation of Fish, Shellfish and Wildlife	Yes	
Combined Biota/Habitat Bioassessments	Protection and Propagation of Fish, Shellfish and Wildlife	Yes	
Debris/Floatables/Trash	Protection and Propagation of Fish, Shellfish and Wildlife	Yes	

Due to trash dumping, stormwater discharges, and sewer leaks, Watts Branch currently supports neither aquatic life nor human recreational use.

Much of the Watts Branch's natural floodplain has been replaced with impervious surfaces, like asphalt and concrete. Impervious surfaces prevent precipitation from infiltrating the soil. Water from rain events flows instead through the city's stormwater infrastructure (flowing to either a treatment center or into the waterway) or flow directly into streams and rivers. Pollutants on impervious surfaces are washed into the water as well. Pollutants like PCBs, PAHs, pesticides and trash debris have been a big problem for the species living nearby, according to an assessment investigation conducted by Ecology and Environmental, Inc.

Rapid rainfall with minimal infiltration causes flash flooding, which occurs when a large amount of rain falls in a short period of time. Flash flooding produces fast flowing water that erodes streambanks. The water cuts down into the streambank, changing the shape of the channel. This is also the most significant source of sediment in the river, which doesn't settle and clouds the water. Channel shape and water clarity affect the type of habitat available in the river for aquatic animals and can have detrimental impacts on the survival of native species.

Pollution per se is detrimental to human health and safety. Polluted water can increase health issues. Although modern drinking water systems can provide safe drinking water from other sources, pollution makes it impossible for communities to use water sources local to their neighborhoods. It also eliminates the stream as a recreational or economic resource for a

community and is harmful to wildlife.

Not only is the branch unsuitable habitat for flora and fauna that live in riparian areas, it is also unsuitable for human use. The water is not safe to drink, and that means it is also not the safest for recreation. As stated above, if people cannot use the water, it produces a disconnect between the residents in the branch and the water that flows through their neighborhood. Watts Branch is a beautiful resource, but without care it can't fulfill its potential as an attraction for residents and as a source of community as well as community pride.

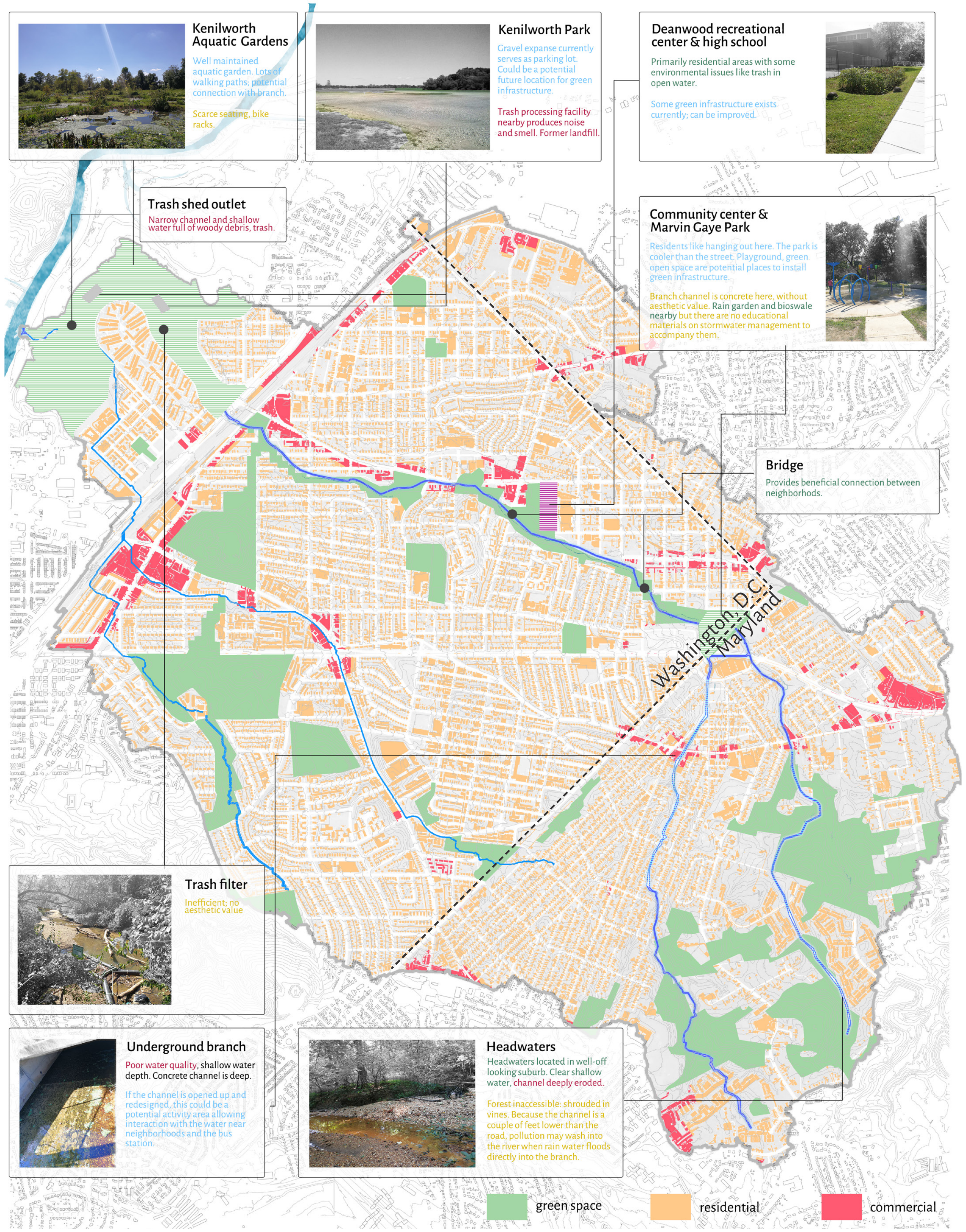
Lack of Habitat

Ideal riparian habitat provides organisms with their basic necessities: food, water, and safety. Typically, that means water free of industrial chemicals and solid waste, diverse and productive plants, and varied sediment structure. In an urban area, the concept of a riparian buffer becomes additionally important. A riparian buffer provides a relatively untouched area with intact vegetation a certain distance from the stream channel. A vegetated buffer prevents erosion, provides shade refuge and regulates temperature. The Watts Branch has very limited and poor quality available habitat. This is due to channelization (the replacement of natural soil or vegetated stream beds with concrete sides and bottoms, piping (routing the stream through a pipe underground) and the high percentage of impervious surfaces in the catchment area. The erosion problem has been a long-term problem for the Watts Branch.

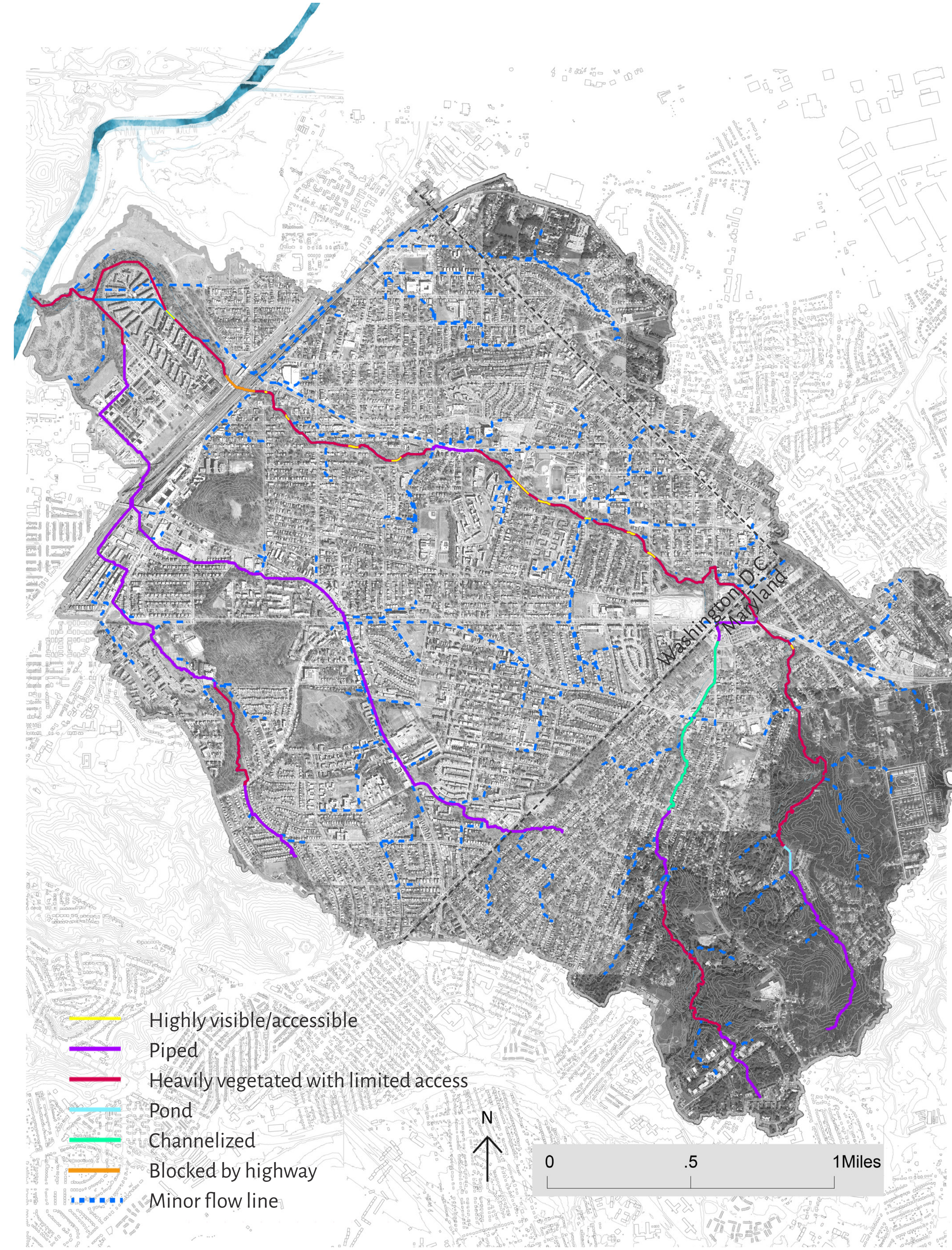
Lack of Ecosystem Services

People derive a multitude of benefits from the natural spaces around them. These ecosystem services include food, water, energy, recreation, spiritual health, nutrient cycling, and pollutant filtration, as well as others. In the Watts Branch watershed, a heavily urbanized environment and significant modification of the stream's natural flow pattern and channel shape have reduced

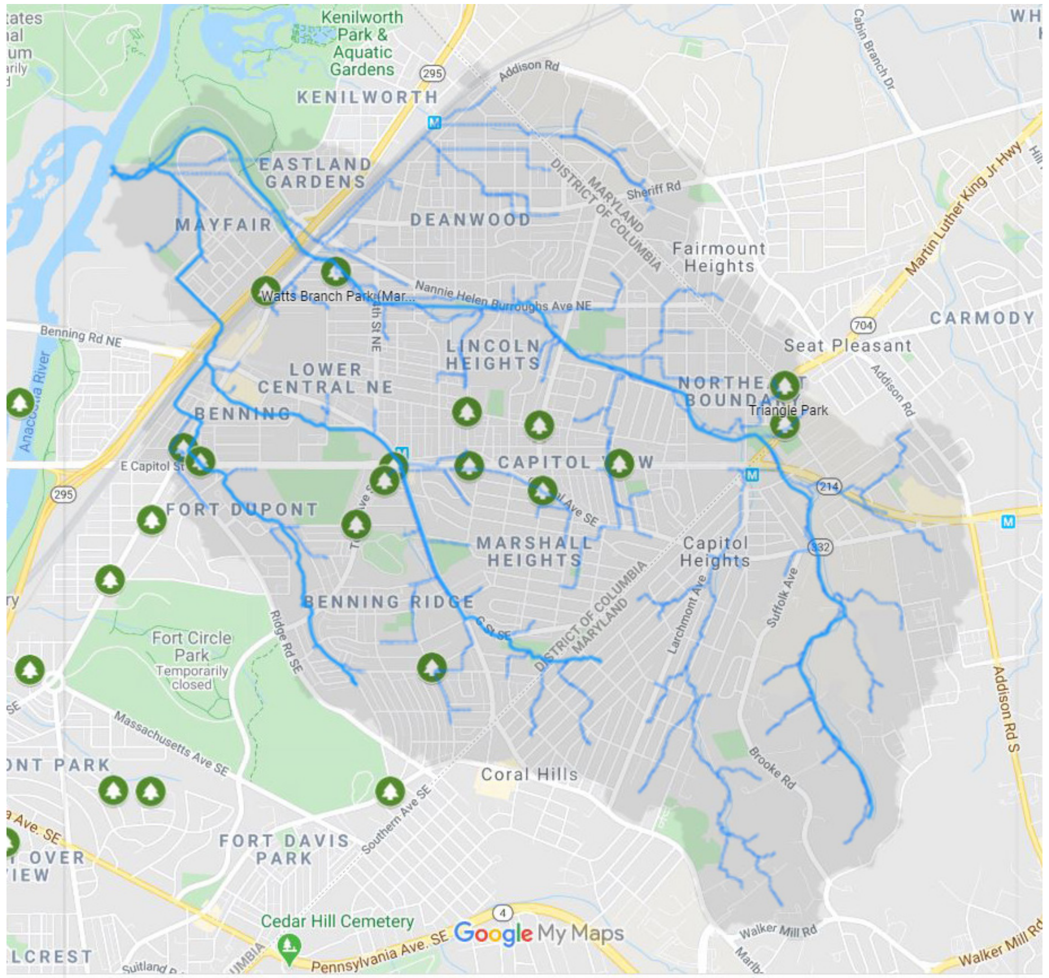
From top to bottom: At the MTA station, the stream is channelized below the ground and is mostly invisible from the sidewalk unless people are close enough to look down into it. In the Mayfair neighborhood, the river is obscured by vegetation. Near the Anacostia River, the stream is similarly covered by heavy vegetation. Meanwhile, by the headwaters of the stream, the channel is severely eroded.



This map, created after our site visit, illustrates some of the locations we saw, and our summaries of the strengths, weaknesses, opportunities, and threats each presents.



In many places, the Watts Branch river channel is blocked or inaccessible in some way, making it difficult for residents to interact with the water and benefit from its nearness.



While there are some existing parks around Watts Branch, none provide opportunities to interact with the river.

the stream's capacity to provide important ecosystem services for the people who live in the area. Ideally, a waterway running through a neighborhood would provide clean drinking water and an opportunity for education and recreation, in addition to things that are not as easily quantified, such as a sense of place and identity.

Residents in the Watts Branch watershed lack connection to their waterways. There are noticeably few places that allow clear visibility and physical access to Watts Branch. Much of the branch is underground, flowing through pipes or concrete channels, so it's not even visible. When not piped underground, the stream branches are often hidden by other elements like heavy vegetation, vast empty lots, fencing, and other barriers.

Where the water does see daylight, the streambed is often incised and the banks too steep and unstable for people to gain direct access to the water. And where the water is visible, there is no celebration of Watts Branch. Many residences, schools, and recreation and community centers located near the stream have few opportunities to interact with the water.

Almost none of these example locations have pleasurable aesthetics or access for people, making it hard for residents to even realize that they are living very close to a water channel. This leads to a lack of awareness both about how they are affecting water (for example, through detrimental anthropogenic activities such as trash dumping) and how they are affected by the water (for example, by poor water quality and flooding).

It might result in missing many advantages of living close to the water bodies, including establishing strong environmental stewardship of a place with community bonding, having educational opportunities for water-related ecosystems for residents and students, and creating recreational spaces related to the water bodies. It is important to establish a strong human connection to water both physically and psychologically.

Education Potential

Education centers that structure their curriculum around a local natural feature are common. In Washington D.C., there is an educational center called The Aquatic Resources Education Center (AREC) located in Anacostia Park about 2 miles away from our project site. It provides environmental education programs and tours for people to learn about water-related topics such as aquatic resources, wildlife habitats, and ecological relationships.[22] This type of center could be made more effective if residents had visual and physical access to the water body outside of a structured educational program. Making the channel more visible to residents and establishing pleasurable connections will increase their encounters with nearby water channels in their daily lives, providing casual but more effective and regular opportunities to observe and learn what is happening in their local watershed.

According to the Trust for Public Land's 2017 City Park Facts report in 2017, Washington, D.C. is ranked number one in parkland percentage and parkland per 1,000 residents. This fact is significant, but as the map on the previous page shows,[23] the residents in our project area (highlighted in gray) do not have walkable or easily reachable access to a pleasant and high quality of parks and outdoor spaces which are particularly interactive with Watts Branch. As mentioned earlier, places near the water channel can provide great opportunities not just for education but also for recreation such as playgrounds, parks, and gardens where people can appreciate and enjoy the water. Also according to our site visit, few of the outdoor green spaces near Watts Branch included water-related design elements, and people barely either noticed or appreciated the existence of the water channel.[24]

For all these reasons, it is important to encourage having natural spaces within urban environments. They can help us improve our quality of life in many of these ways at once.

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Intervention Analysis

To determine how best to achieve our three objectives within the Watts Branch watershed, we first conducted a geospatial analysis to investigate land use and hydrological conditions within the watershed. Concurrently, we researched design interventions that would most effectively contribute to achieving our objectives. We combined these two elements to determine what interventions would be appropriate for each land use context in the watershed.

Rock dam in the Watts Branch channel at Marvin Gaye Park, Washington, D.C.

GIS Analysis

We analyzed a variety of site conditions, including topography, soil, and land use. The purpose and intent of the site analysis was to gain insight and form a technical foundation for the masterplan. Most of the data was obtained from open-source, government-maintained data portals, particularly Open Data DC and Maryland's GIS Portal. Satellite imagery obtained via Google Maps was also heavily utilized to verify individual lot conditions.

Using high resolution lidar DTM data, we were able to identify not just the main channel of the Watts Branch, but also likely auxiliary flow lines that show where water will begin to flow first along with identifying areas that may flood during heavy precipitation events.

We primarily used ESRI ArcMap and its Spatial Analyst toolbox and conducted several analyses to form a foundation for our masterplan.

Cloudburst Analysis—Identification of Low Spots

Using the technique developed by Ramboll in response to major precipitation in Copenhagen, we identified areas of the watershed that would pool and accumulate water first if the soil and existing stormwater system were at capacity. Using the high resolution DTM, we applied the Spatial Analyst toolbox's Fill tool, once with standard parameters and once with a z-value of 0.05—the error of the DTM lidar input. Then, we used the Raster Calculator to find the difference between these two rasters. This final output showed the areas of the watershed that are lower than the rest of the surrounding watershed. These "sinks" are likely to fill first in the event of a cloudburst event. In order to identify low spots that would be meaningful to our analysis, we eliminated single pixels and used the Region Group tool to combine adjacent low spot cells. To produce a final visualization, we reclassified the remaining pixels to show the variation in elevation within each sink.

Site Conditions

To further understand the primary factors influencing the future flooding potential of Watts Branch, we investigated several additional variables as well. Soils in the watershed are primarily sandy or silty, with some areas of clay and mixed soils. Although these are heavily urbanized soils and therefore function slightly differently than natural soils of these same types, increasing the infiltration of water is easier in sandier soils, while clay-heavy soils hold water more easily and therefore are more susceptible to flooding.

The existing land use of a site influence what changes or additions can be made there. We generalized existing land use and land cover data into four major categories: residential, commercial, parks and open space, developed areas used for various industrial and institutional purposes, and streets and other impervious surfaces. The interventions we proposed had to be feasible and appropriate for the surrounding land uses. In particular, understanding the extent of the impervious area in a watershed is essential. Water sheets off impervious surfaces straight into drainage systems and thus reaches rivers extremely quickly, which can contribute to flash flooding. Relatively small amounts of impervious surface can cause enough damage to impair a river.

Variable	Data Source
Digital Terrain Model	Open Data DC; Maryland's GIS Data Catalog
Soils	
Land Use/ Land Cover	
Demographics	US Census

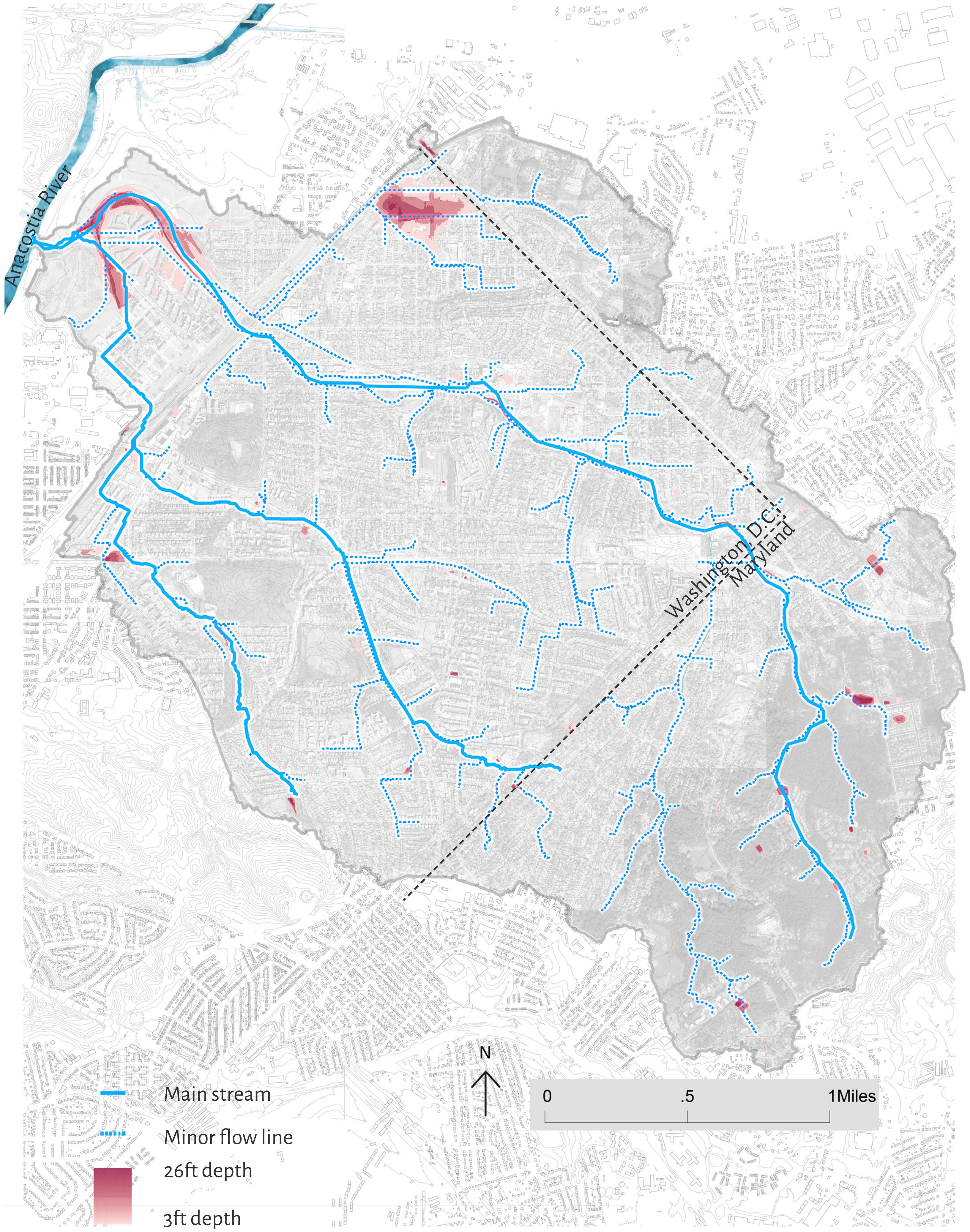
Site variable data and respective data sources. These variables were used as inputs for overall site analysis. Most data was obtained from government GIS catalogs.

Tool	Input	Output
Flow Direction	DTM 1 meter	Flow Direction raster
Flow Accumulation	Flow Direction	Flow Accumulation raster
Reclass	Flow Accumulation; Accumulation Threshold	Stream
Watershed	Flow Direction; Pour Point	Watershed

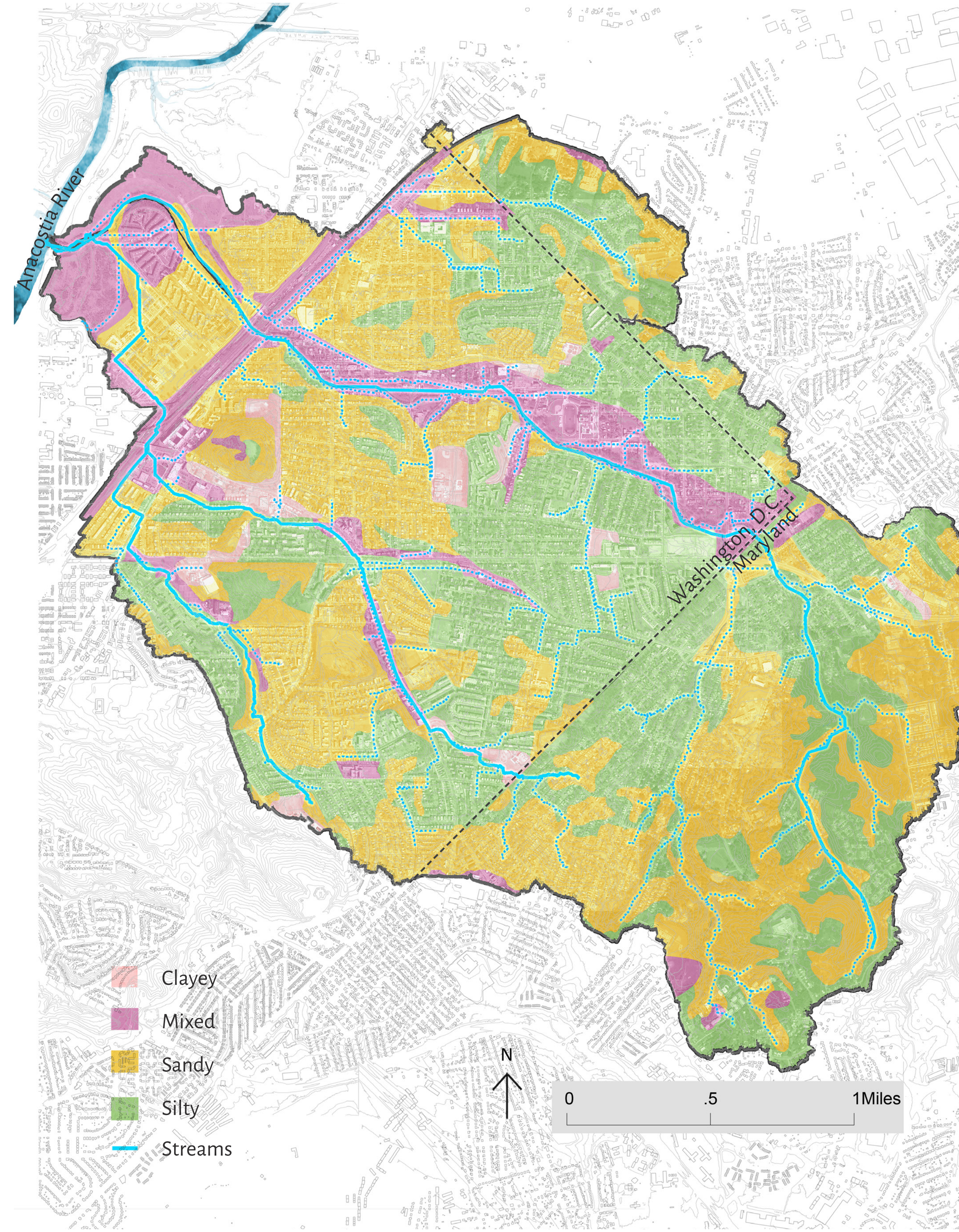
Spatial analysis workflow used to delineate hydrological features of the Watts Branch. All the tools are found in ArcGIS's Spatial Analyst Hydrology Toolbox.

Tool	Input	Output
Fill	DTM 1 meter	Filled DTM
Fill	DTM 1 meter; 0.05m error	DTM filled to LiDAR error
Minus	Filled DTM; DTM Filled to LiDAR error	Difference surface raster
Con	Difference surface raster	Conditional raster
Region Group	Value > 0, IFTRUE = 1 Conditional raster	Low spots

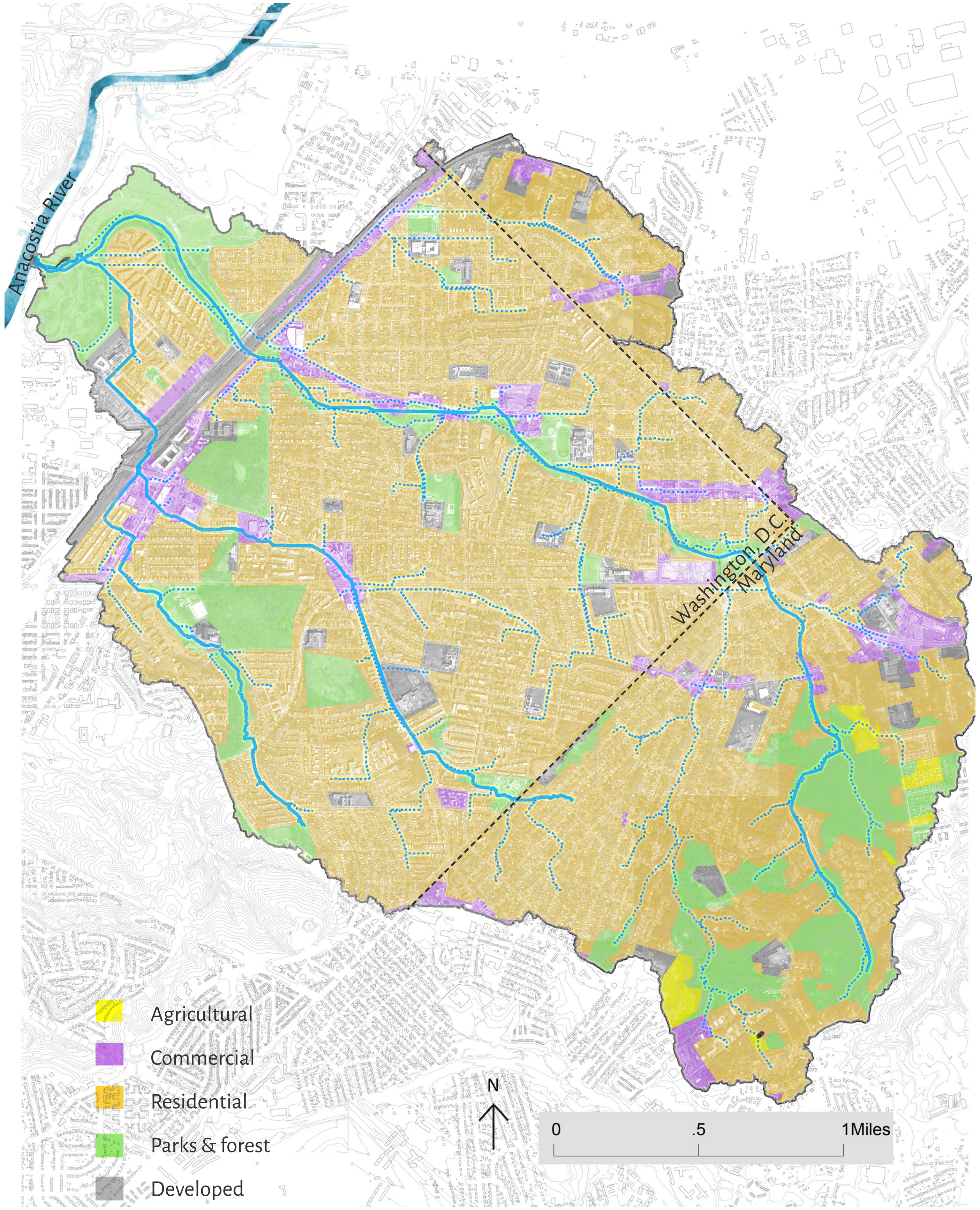
Cloudburst analysis workflow used to identify low-lying sinks in the Watts Branch area.



Low elevation areas in the watershed. Highlighted by our cloudburst analysis, these areas are the most susceptible to future flooding.



Soil texture in the watershed. Much of the soil is sandy or silty, which allows for infiltration of stormwater. Clayey soils experience more issues with pooling water.



Land cover in the watershed. Most of Watts Branch is residential. Developed land includes industrial, institutional, and transportation land that function similarly in their water infiltration and level of development.

Impervious surfaces in the watershed. Much of the watershed is paved, which can make the area more susceptible to flooding.

Landscape Interventions

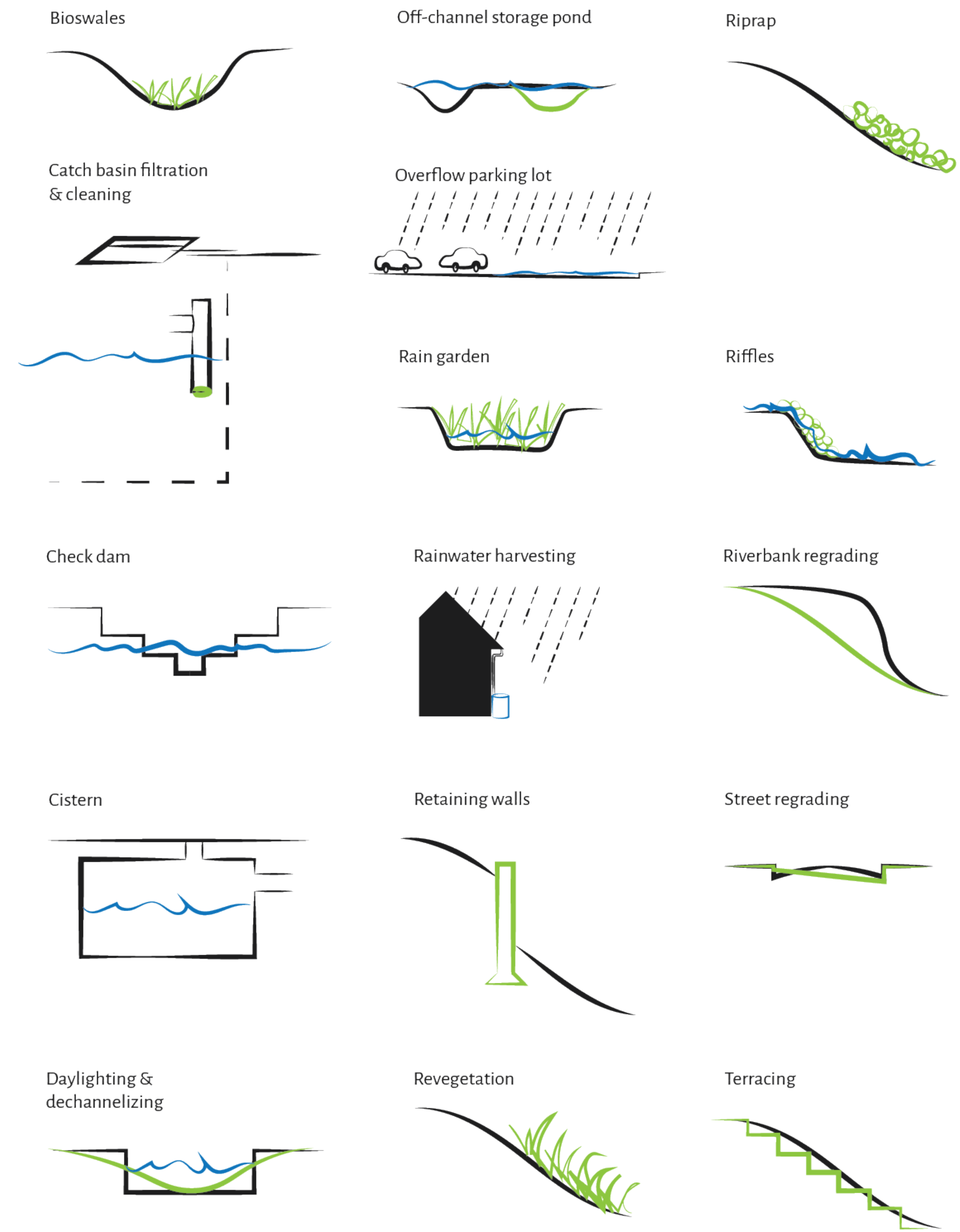
Based on research of the best practices and existing technology for streambank restoration, we devised a list of interventions that are appropriate for this watershed.

Then, referencing the project objectives, we devised a matrix that illustrates the potential of each intervention to improve each objective. The interventions were also identified based on their performance in four major land use types: residential, commercial, parks and open space, and streets and impervious surfaces.

It should be noted that this list of interventions is not intended to be exhaustive. However, it does incorporate many frequently used solutions that span a variety of scales and applications, and are representative of the major types and functions of blue and green infrastructure options.

Once the set of applicable interventions were established, we constructed a set of decision trees.[25] Like the intervention tables, these trees allowed us to begin with one of our major project objectives in mind, and, for each area within the watershed, choose an appropriate intervention based on the characteristics of the space. The decision trees begin with our objectives so that the interventions and project objectives can be scaled based on community goals and resources. A project can be very small or very widespread. The tool can be used across differing spatial and temporal scales. A decision-maker can identify a community need (i.e. flood control, habitat improvement, or human access/connection) and then use the decision trees to determine appropriate landscape intervention(s) that can help meet that goal.

After identifying the major objective, the next step is to choose the land use category for the project area. There are four main categories of land use generalized within the watershed and some interventions are not appropriate for certain land uses. From there, decision-makers can narrow down specific interventions by identifying sub-goals and project-specific constraints.



These interventions are commonly used to prevent flooding. They can be applied across many spatial scales and in a variety of land uses.

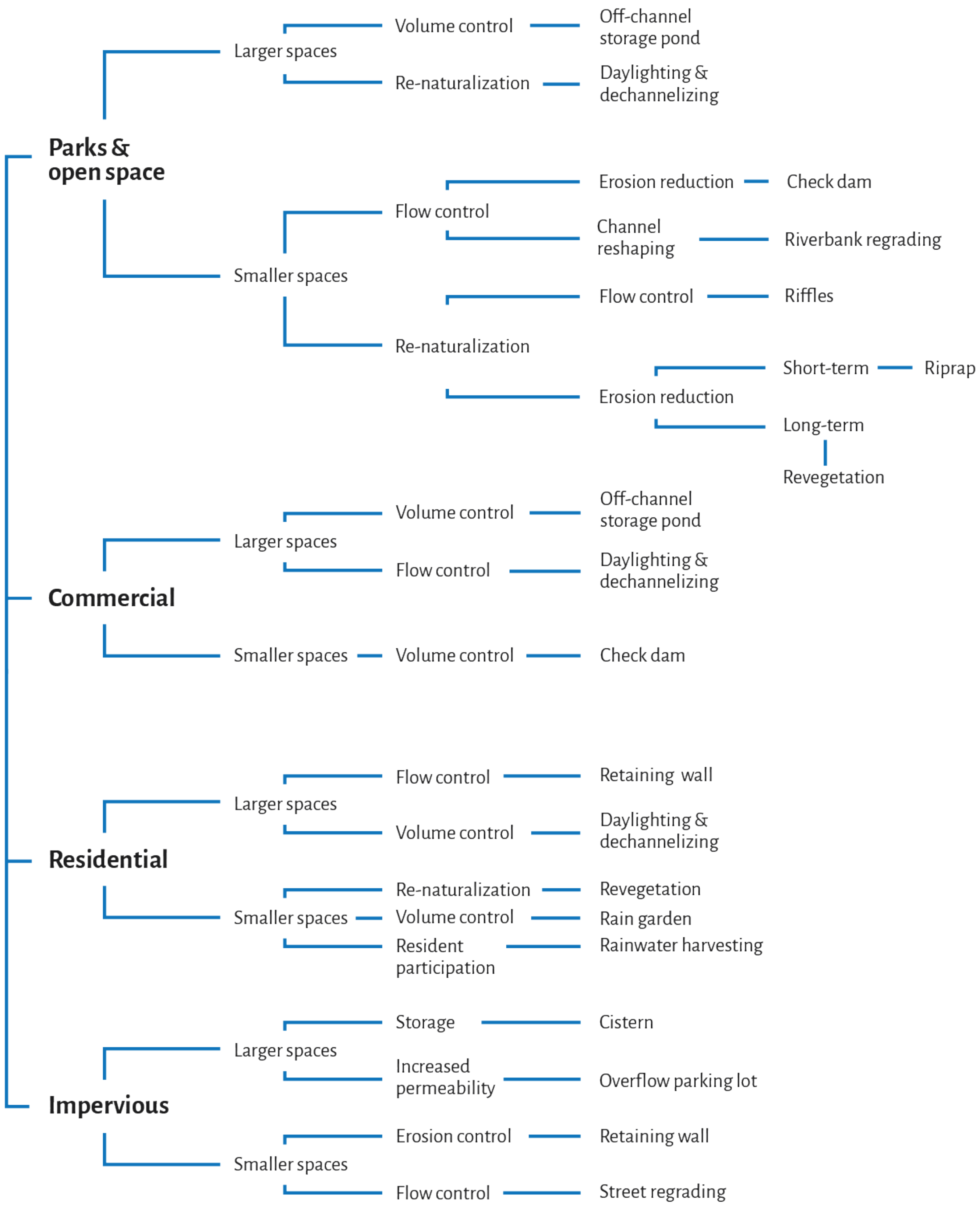
	Parks & open space	Commercial	Residential	Impervious
Bioswales				■
Catch basin filtration & cleaning		■		■
Check dam	■	■		
Cistern		■		■
Daylighting & dechannelizing	■	■	■	
Overflow parking lot				■
Off-channel storage pond	■			
Rain garden			■	
Rainwater harvesting			■	
Riverbank regrading	■			
Retaining wall		■		■
Revegetation	■		■	
Riffles	■			
Riprap	■			
Street regrading				■
Terracing		■		

Each proposed interventions is applicable in at least one of the four primary land uses in the watershed. Many are applicable in more than one land use.

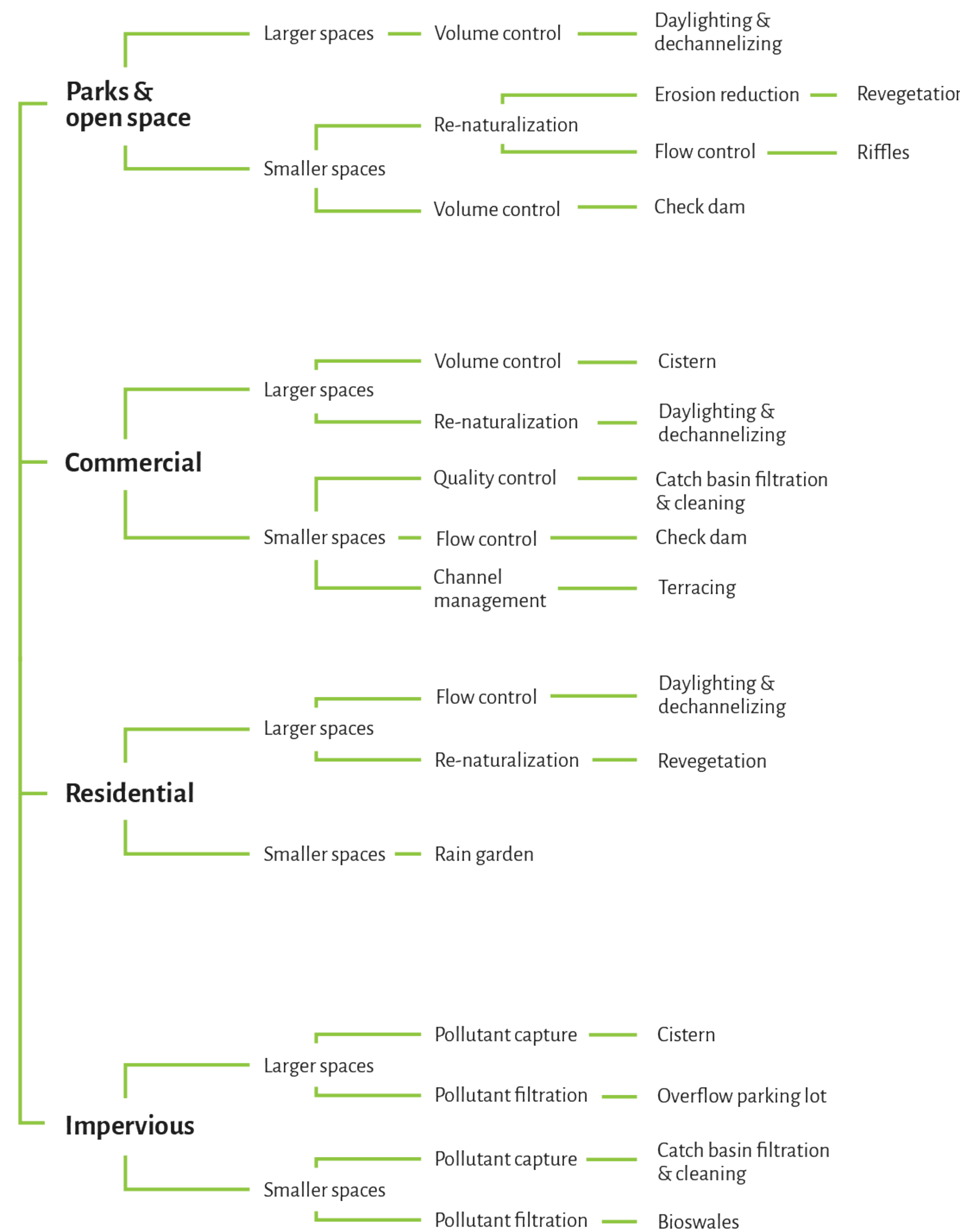
	Flooding control	Habitat & water quality	Social ecosystem services
Bioswale		■	■
Catch basin filtration & cleaning		■	
Check dam	■	■	
Cistern	■	■	
Daylighting & dechannelizing	■	■	■
Overflow parking lot	■		
Off-channel storage pond	■		■
Rain garden	■	■	■
Rainwater harvesting	■		■
Riverbank regrading	■		
Retaining wall	■		
Revegetation	■	■	■
Riffles	■	■	
Riprap	■		
Street regrading	■		
Terracing		■	■

Each proposed intervention can be used to achieve at least one of the three objectives of this project. Many of them can be used to achieve more than one objective.

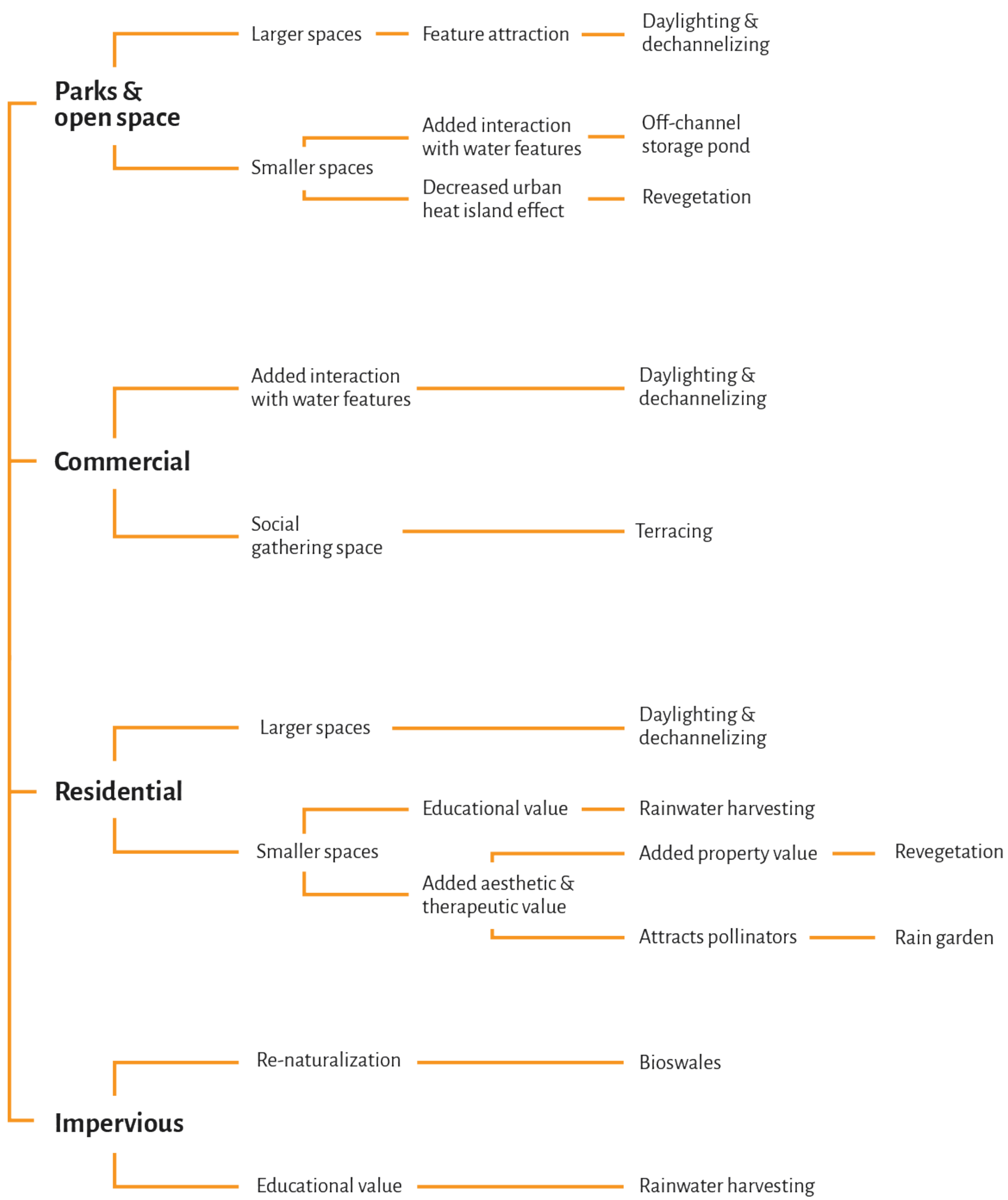
Primary objective: Flooding control



Primary objective: Habitat and water quality improvement



Primary objective: Social ecosystem services



Masterplan

The masterplan is a flexible, dynamic document that represents the diversity and adaptability of the solutions within the watershed. It identifies, analyzes, and proposes both blue-green and grey infrastructure improvements to address three major issues within the catchment: increased risk of flooding due to climate change, poor water and habitat quality, and limited social resources and human connection to the water.

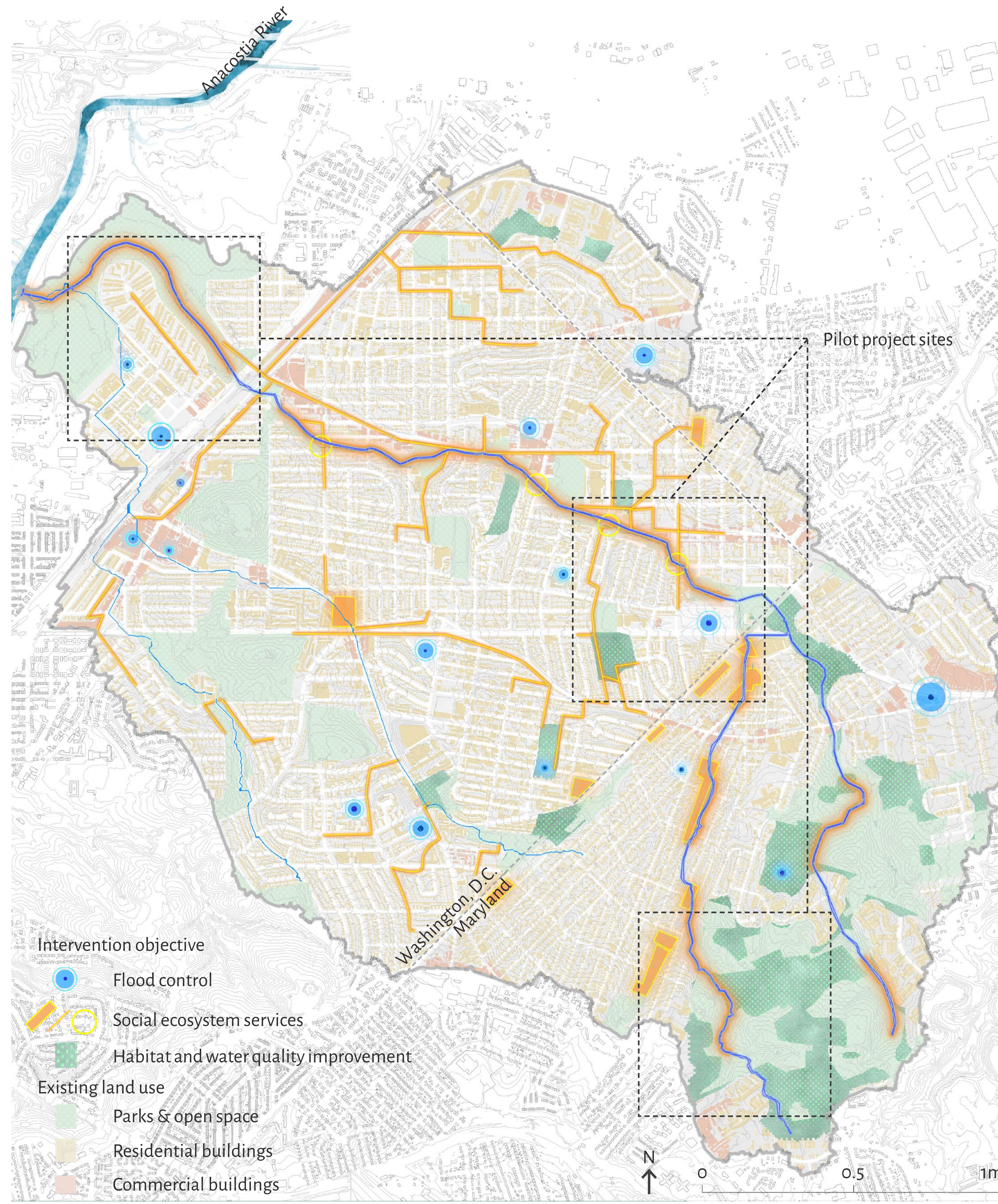
In areas like the Coral Hills neighborhood, the heavy vegetation obscuring the river can be opened up and the riverbanks terraced to form an attractive amphitheater, serving as a gathering space and educational opportunity.

After considering the variables and watershed conditions, along with our objectives and intervention list, we selected areas within the watershed that would make significant progress toward improving performance for a given objective. Each colored area represents an area with high potential to progress toward achieving the identified objective. While the entire watershed could likely see improvements for any or all of the three objectives, the chosen objective for each area was prioritized based on a variety of factors such as proximity to the branch, proximity to existing parks and open areas, and proximity to community areas (like schools and recreation centers). Blue-green infrastructure in areas that have existing community activity have more potential to add social value to the areas than areas without community activity. However, each of our objectives is highly transmutable and interconnected with one another. Focusing on one objective will not exclude the possibility of improved performance for any of the other objectives—on the contrary, multifunctional design is capable of achieving all three objectives at once.

Our three main objectives are continually served throughout this masterplan. We seek to increase access to the branch by prioritizing social benefits close to the main channel. Removing visual obstacles and enhancing connectivity with the existing park infrastructure will allow residents of the neighborhood to enjoy the branch as a neighborhood asset. Connectivity in these areas will also support biodiversity and wildlife by creating a corridor through which species will be able to move without the typical disruptions of urban life. Water management and flood control are managed through existing open areas- parking lots, parks, and empty lots. These areas are locations for retention ponds, catch basins, and other types of off -stream storage. Specific locations for these storage areas was determined by the elevation and flow lines, capturing the watershed's natural shape to keep water away from homes. We also utilize existing transportation infrastructure, residential and commercial streets, to serve both the stormwater management and social benefit objectives. Streets are used to convey stormwater to water storage installations during high precipitation events and interventions like bioswales and rain gardens along the same routes serve to enhance and beautify the neighborhood.

In the upstream area, the existing open areas allow for a focus on social enhancement, with a special emphasis on education and community engagement. In the downstream area, flood control, while still maintaining an aesthetic environment for area residents, is the focus. Kenilworth Park and neighboring housing complexes are within the 100-year floodplain, making flood management a key concern. Newly constructed spaces allow for controlled inundation while doubling as community parks.

Our masterplan for the watershed. This highlights at a high level priority areas for interventions that will accomplish our three goals: increasing flooding resilience, habitat and water quality, and quality of life. While we have chosen only one priority objective for each highlighted area, a multifunctional design will allow for all three objectives to be accomplished in any area. ▶



Pilot Projects

We selected three areas from the watershed-level masterplan for which to design a conceptual pilot project. The three pilot projects are representative of the watershed as a whole, featuring a mix of residential, commercial, and park areas, each with a different neighborhood dynamic. There is a pilot project in upstream, mid-stream, and downstream sections of the Branch.

Downstream – Mayfair

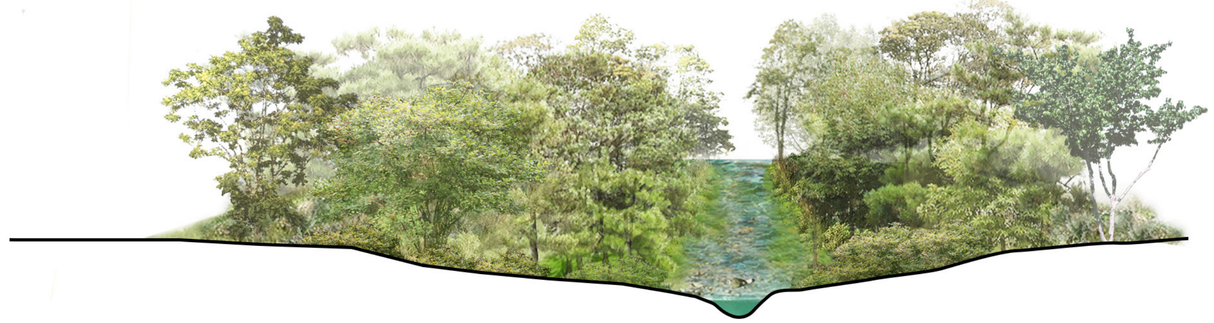
The first pilot project is located in the downstream area of Watts Branch. A primarily residential area, it is located in the floodplain of the stream and thus it is important to provide it with added resilience. The Mayfair neighborhood has a high risk of flooding issues caused by rainfall, similar to the Federal Triangle floods of 2006. This project has three components:

1. Reshaping the channel of the Watts Branch will create a larger capacity and allow a larger quantity of flow, helping to avoid flood issues in the nearby neighborhoods.
2. Installing green infrastructure, including bioswales and an eco-parking lot, will catch the water from impervious surfaces in the neighborhood, diverting water from homes.
3. Re-designing green space as an off-channel storage pond park will function as a community amenity during dry periods. When flooded, it will add stormwater storage capacity, reducing heavy flows, preventing bank erosion, and protecting property.

Bioswales or rain gardens adjoining impervious surfaces like streets or parking lots can help capture and infiltrate stormwater runoff.

Site plan for Mayfair neighborhood. Overflow parking lots collect water runoff from the neighborhood. An added park does the same while also providing residents with a recreational space.

Before

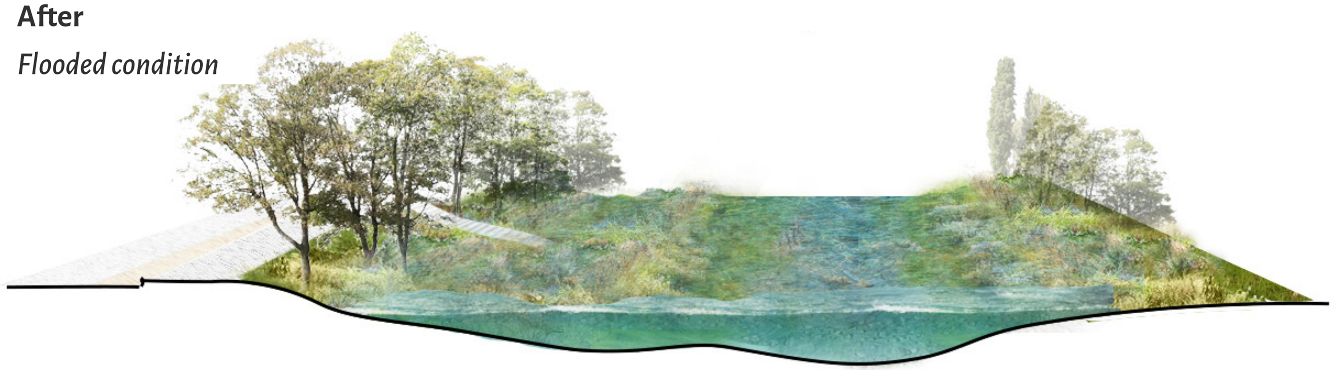


After

Typical condition

After

Flooded condition



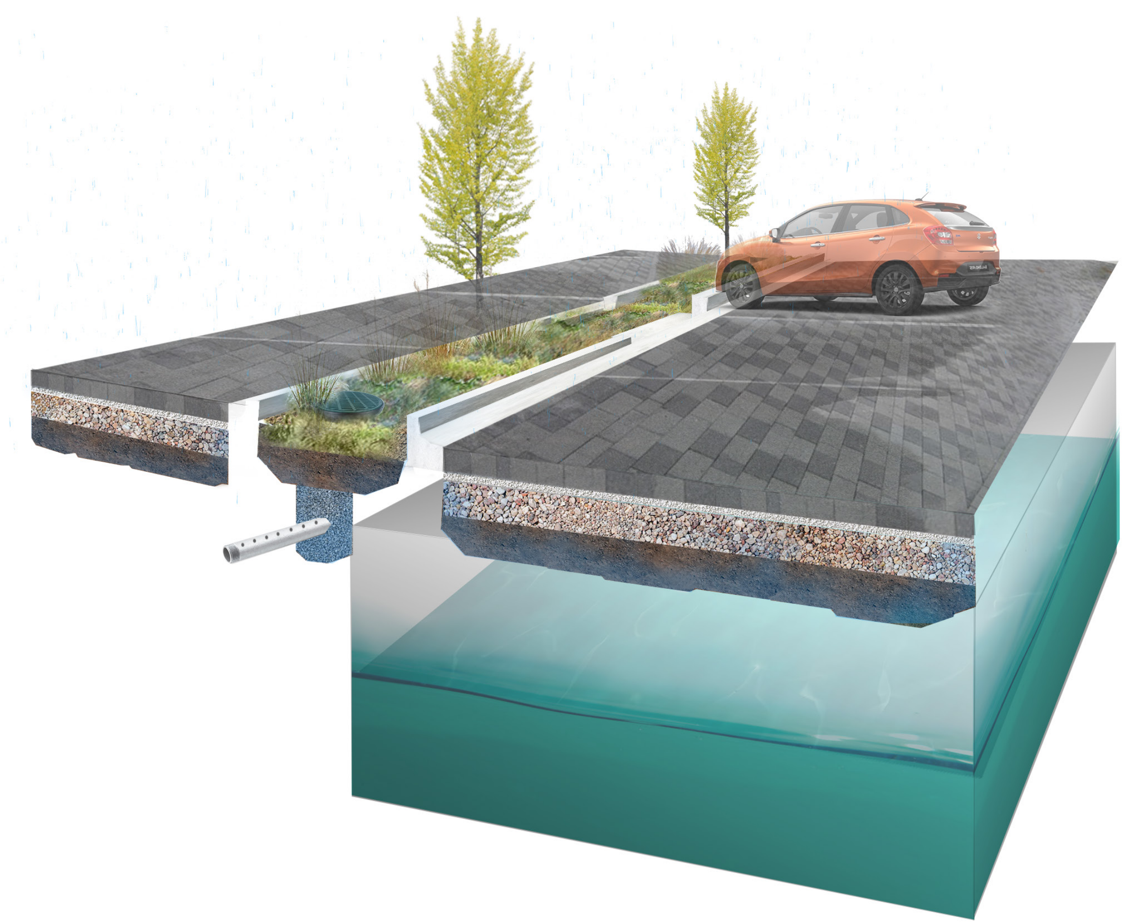
▲ *Regrading the riverbank gives the channel a less incised shape, reducing erosion and providing additional wildlife habitat. Removing some of the riverbank vegetation allows people to see past it through to the river.*

The added park at the southern end of the site provides a recreational space for Mayfair residents while capturing water runoff: off-channel storage ponds are typically dry but fill with water during a cloudburst event. ▶

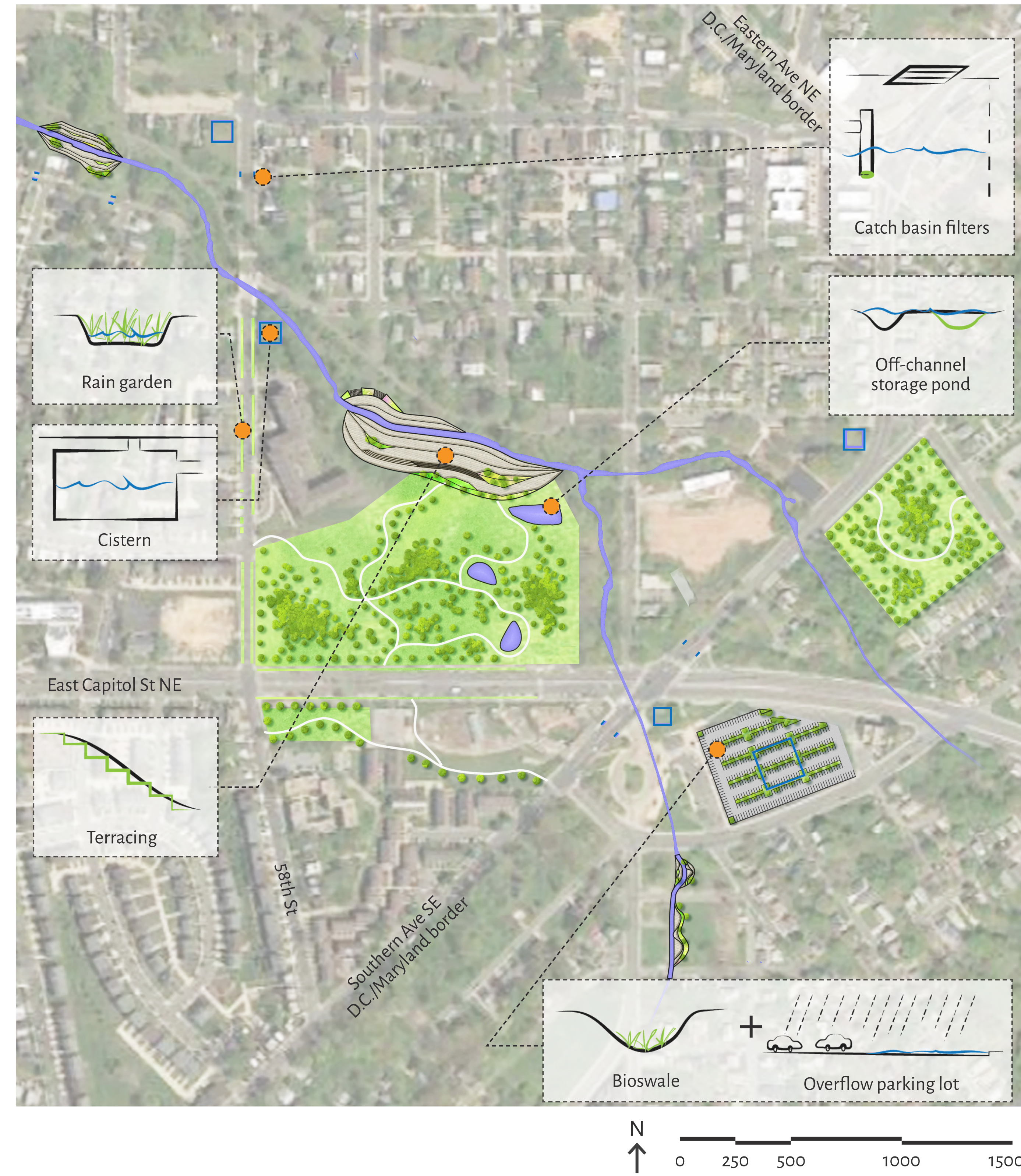
Midstream – Grant Park

Located in the middle of the branch in the northeast corner of the site, a mix of residential and commercial properties comprises this area. Several major roads and intersections also cross the site. This provides an opportunity to demonstrate how interventions in different land uses might be used together to achieve our three objectives.

Increased greenspace and removed paved surface provide more area in which water can infiltrate. These greenspaces can also be connected to allow freer movement of both animals and humans. Along the branch itself, terraced portions of the river keep the river in a controlled channel, reducing the flooding risk. However, they also increase the interaction that people can have with the water by opening up the channel. Plantings on the terraced areas create native plant habitat and allow users to have easy, everyday interactions with greenspace. Additional pedestrian walkways further activate the space and increase its accessibility. Lastly, underground cisterns placed along major road intersections reduce water runoff by holding it in place. Filters fitted to catch basins along roads close to the channel clean water runoff before it gets into the branch.



Overflow parking lots fitted with permeable pavement and rain gardens infiltrate water instead of allowing it to run off. An underground cistern captures additional water, while trees in rain gardens provide shade to the heat-absorbing pavement.



Site plan for Grant Park neighborhood. Three portions of the river are opened up and terraced to form an attractive gathering space. Catch basin filters and underground cisterns placed along main roads clean and retain stormwater runoff respectively.

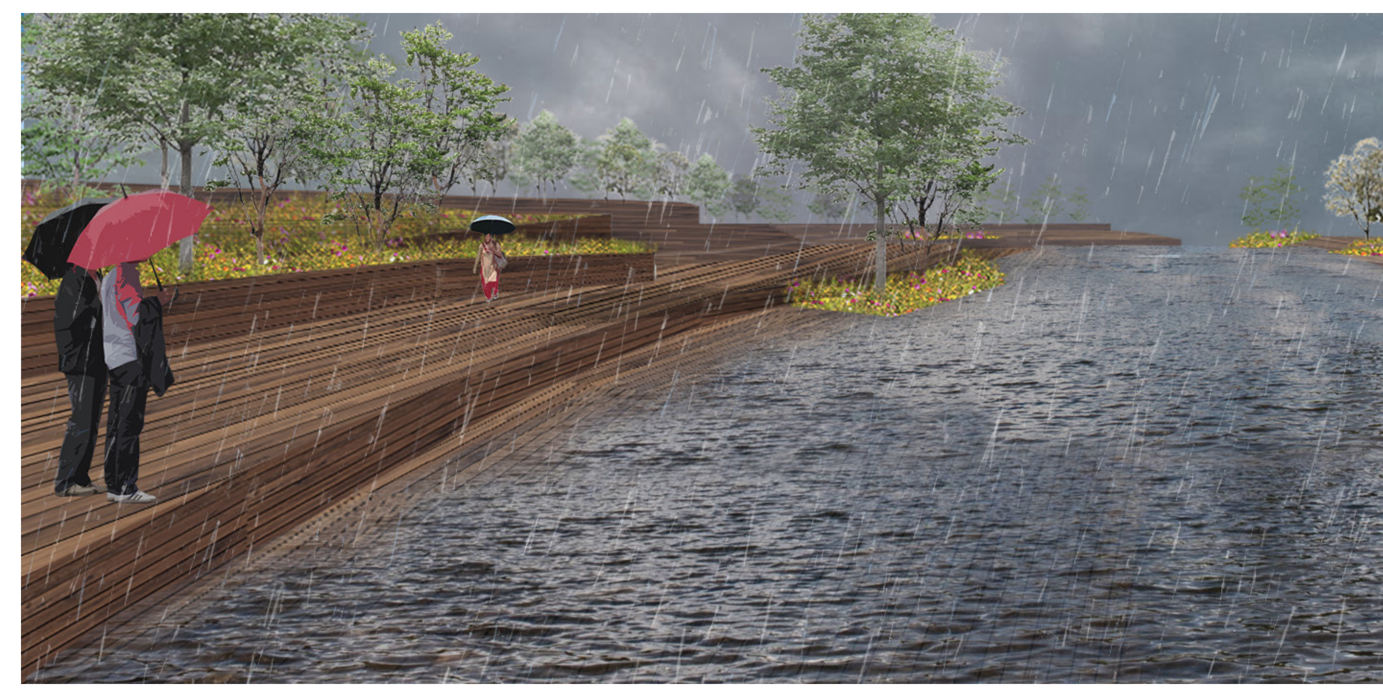
Before

After

Typical condition

After

Flooded condition



Rain gardens capture the stormwater runoff from streets and allow it to infiltrate. They also add aesthetic value to the streets, and can be used to narrow the road as well.

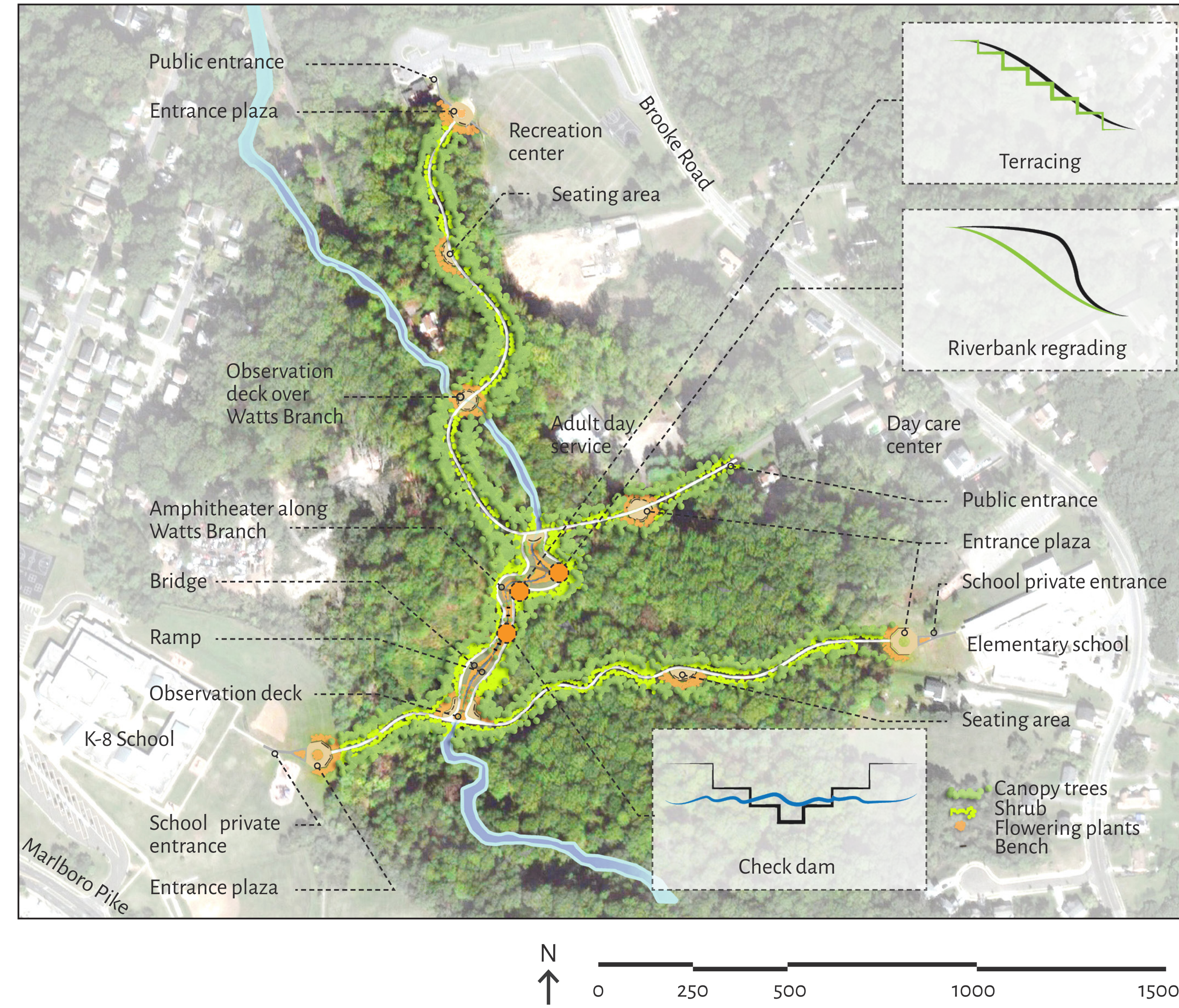
Terraced portions of the river allow people to spend time by the river. Plantings along the terrace provide wildlife habitat , aesthetic value, and shade. During a cloudburst event, the controlled terraced shape floods without over-flowing into the nearby residential or commercial areas.

Upstream – Coral Hills

This site, located in the upstream portion of Watts Branch, is surrounded by nearby two public schools, an adult care, a daycare center, a recreational center, and housing units farther away, which likely contribute to a wide range of ages, abilities, social status, etc. in the expected primary users of this area. Currently, it is a heavily wooded area without any park facilities such as an entrance and walking trail. In the light of proximity to schools and aforementioned facilities, this area has a great opportunity to be transformed into a park where people can have clear visibility and physical access to Watts Branch for recreational and educational purposes. However, since the branch is now hidden by heavy vegetation, this requires opening up some portion of the existing vegetated areas, but only to the extent that the habitats are not negatively impacted by the new development. The existing canopy trees within this project boundary will be replaced with turf, native grass, and shrubs.

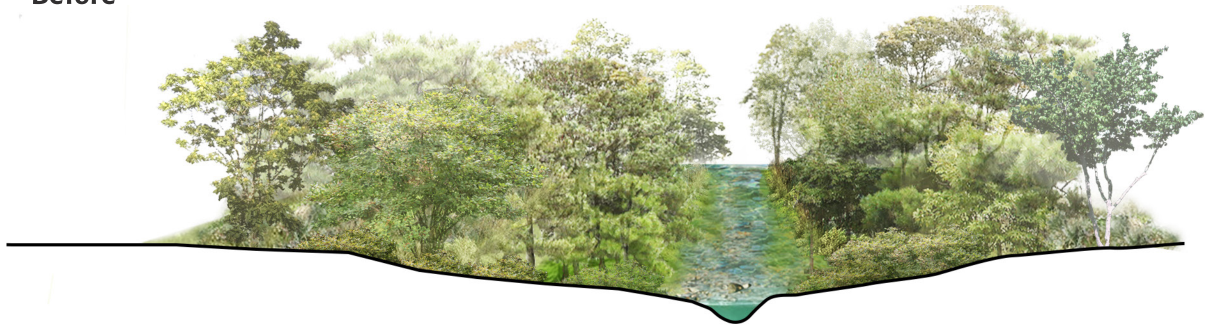
There are four different entrances into this project site based on the expected main users. Two entrances are for students in each school, one for the public from a recreation center, and one for those from an adult care/daycare center. Walking trails from the entrances lead to a main hub along Watts Branch while in between a few wooden docks with benches cross over the river to give a peek of Watts Branch.

The main hub is composed of an amphitheatre, check dams, terraced stone blocks and boardwalk to encourage social gathering and educational activities. In a small amphitheatre overlooking the branch, students and faculty can hold outdoor classes, extracurricular activities, and, importantly, water-related educational activities on site. They can directly observe, analyze, and study what is happening in Watts Branch in their neighborhood and further understand the whole water system in Washington, D.C. Check dams in the hub are installed to create different aqua-habitats for organisms, slow down a peak flow, and also add pleasurable aesthetics. On both sides of the branch shoreline, terraced stone blocks are placed not only as seating but also as a natural sculptural element to see a changing water level in different seasons for aesthetic and educational purposes. Lastly, a boardwalk along the branch is equipped with benches and a few bridges surrounded by native grass and shrubs to allow a walk closer to the branch.



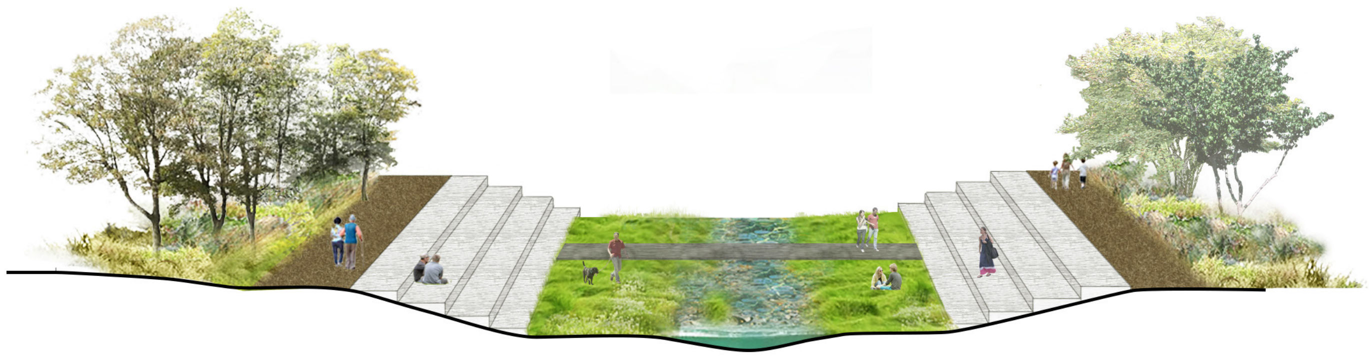
Widening and terracing the river channel allows for added access to the river, while removing some vegetation provides better views of the water. Four entrances to the site give easy access to students and residents, turning the river into not just a recreational spot but an educational opportunity.

Before



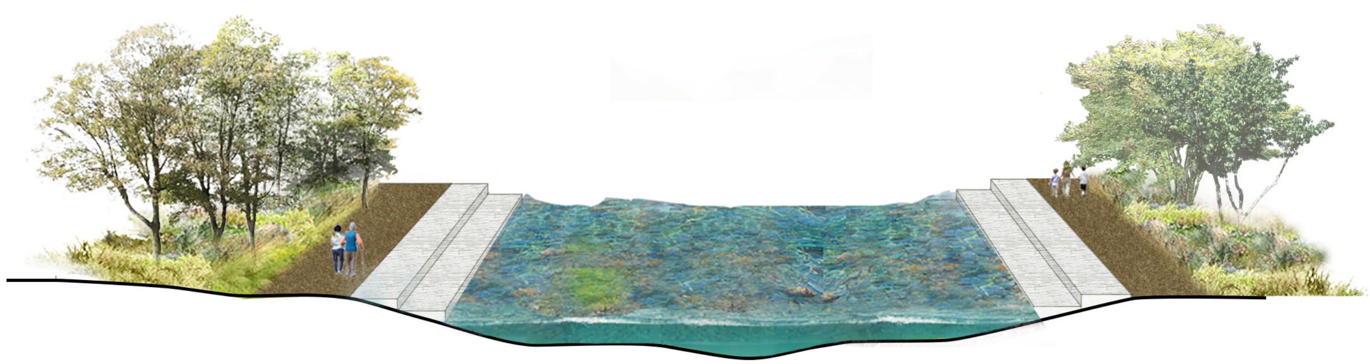
After

Typical condition



After

Flooded condition



Widening the river channel reduces erosion and increases wildlife habitat. Thinning the riverbank vegetation allows for better views of the channel, augmented by a terrace that serves as a gathering spot as well as a safe space for the river to flood during a cloudburst event.

The terraced river is an attractive place to spend the day, and a perfect educational opportunity for students and residents alike to learn more about stream ecology and climate change. During a cloudburst event, the terrace remains aesthetically attractive while flooded.

Conclusions

The masterplan serves to highlight priority areas that are well-positioned within the watershed to make an impact toward achieving masterplan objectives. The masterplan can be implemented incrementally in order to allow for community engagement processes, planning reviews, and budget considerations. This plan exists as a high-level conceptual plan. Specific and technical surveys will need to be completed before implementing it. In addition, the plan should undergo a robust community engagement process, testing the concepts with neighborhood residents.

A park in the Mayfair neighborhood is a space to recreate and spend time for people of all ages.

There are many aspects of this project on the way to effective implementation that are important but nonetheless beyond the scope of this master's project.

Community Engagement

As this design is intended to serve the community and meet the specific needs of the neighborhoods in the watershed, the design should not be constructed without feedback and engagement from the community. Through the community engagement process, benefits and costs of the design will also be understood as specific priorities of each neighborhood are defined.

Performance Evaluation

Advanced modelling and simulations would provide more insight into specific performance of the design plan under different conditions and interventions. Additional simulations could help predict the costs and benefits associated with varying climate conditions and could compare the current, status quo conditions with our design plan.

Phased Construction Proposal

In order to accommodate time, budgets, and community needs, construction and implementation could be phased over time. Some lower cost interventions could be constructed or installed immediately, allowing the community to begin to enjoy the positive benefits of newly designed neighborhood spaces. The more costly, higher impact construction, such as street regrading and reprofiling and installation of in-street storage capacity could be advanced further into the future to allow for proper community engagement, planning, and budget considerations. A comprehensive construction phasing plan would require more direct community engagement to establish a timeline that works best for the needs of each neighborhood.

Adaptive Management Plan

Economic and social conditions in the watershed will change over time. The needs and capacity of each neighborhood will change and this will necessitate ongoing evaluation of the function and structure of the landscape design. Like any infrastructure installation, the interventions will require regular maintenance efforts to keep them functioning optimally. Ideally, the adaptive management plan would include a comprehensive data collection and analysis program that would allow the function of the interventions to be evaluated over time. Over time, management decisions could be altered in response to changing conditions.

Future Resilience

As the global climate continues to change, urban areas will be particularly vulnerable to its effects due to the density of development and high percentage of impervious surfaces. Threats from water hazards, such as sea level rise and catastrophic precipitation events require infrastructure interventions to mitigate threats in vulnerable areas. Washington, D.C. is particularly vulnerable to the effects of climate change due to its dense urbanization, low elevation, and relatively high rate of precipitation. While adaptation and mitigation efforts can be daunting, their necessity provides a significant opportunity to improve neighborhood conditions and enhance residents' quality of life. Through the use of blue-green infrastructure, stormwater management interventions can simultaneously serve as beautiful recreation areas, community and educational spaces, and biodiversity support areas. Our plan for the Watts Branch watershed supports stormwater management, provides amenities to residents, and improves habitat quality. The combination of these effects makes for a more resilient city.

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Even in the rain, the terraced stream in the Grant Park neighborhood is an attractive place to walk through.

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