GREEN INFRASTRUCTURE IN THE PUBLIC REALM: REIMAGINING STORMWATER AND THE URBAN FABRIC OF FALLS CHURCH, VIRGINIA

Abstract

Impervious surfaces are the greatest contributors to degradation of water quality and large volumes of stormwater runoff. Green infrastructure is the holistic solution to this problem which not only reduces flooding but also actively moves towards achievement of larger environmental goals like lowering the water temperature, restoration of hydrological processes and stream base flows, replenishment of groundwater supplies, diminishing the heat island effect, suppressing erosion, downstream flood control, and improving surface water quality, among several others. Furthermore, when green infrastructure is actively applied to cities in the form of green streets, it boosts economic value, beautifies the surroundings, increases pedestrian safety, creates pedestrian friendly environments, and improves the overall public realm.

This paper seeks to find solutions for the city of Falls Church, which faced catastrophic flooding incidents in 2011 and 2019. The paper identifies the most critical locations to intervene in the city to address the issue of stormwater runoff and pollution. Subsequently, design solutions are explored with the ultimate goal of reimagining stormwater as green infrastructure which can form an integral part of the public realm.

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Keywords

Green infrastructure, infiltration, public realm, stormwater, watersheds

Introduction

The city of Falls Church is deeply concerned with the pressing matter of flood control due to the threats to human life and property in recent flooding events. However, the environmental impacts of large quantities of polluted runoff is often relegated to be secondary. It is impending to bring to notice that the polluted waters of Falls Church contribute to a highly impaired watershed — the Chesapeake Bay. The Chesapeake Bay is a 64,000-square-mile watershed constituting six states, including Virginia. This paper recognizes the environmental crisis caused by polluted runoff and places equal emphasis upon reducing runoff as well as improving water quality.

The city to date has used several methods to prioritize stormwater projects including focusing upon areas which face extreme flooding risks, availability of public land, daylighting opportunities, and locations for demonstration projects. This paper instead presents a new method of attenuating flooding issues and instead searches for the cause of the problem. The study contends that in order to significantly improve stormwater management in a city, one must first identify the watersheds which produce a disproportionately large amount of pollutants and runoff. These areas must be tackled first as they are the most detrimental.

Methodology

The research finds solutions for Falls Church to mitigate the effects of inundation through the following steps:

1. IDENTIFYING LOCATIONS WHICH ARE CRITICAL TO INTERVENE

This paper seeks to intervene at the *source* of the problem, i.e., locations which are responsible for the greatest amount of pollution and runoff. This was assessed using the Rational Method and SCS Method of stormwater calculation using two studies.

A. THE IMPACT OF LAND USE UPON STORMWATER MANAGEMENT

The Rational Method and SCS Method of Stormwater Calculation are used to compare the impervious cover and runoff volume between two adjacent blocks of similar area and gradient but which differ in land uses — one commercial and the other single-family residential.

Rational Method

The evaluation of these blocks highlighted the stark difference in the amount of impervious surface cover based on land use. The commercial plot had 84 percent impervious surface area while the residential had only 24 percent. Furthermore, the commercial block produced 68 percent more runoff than the residential. A large impact can thus be created by intervening at a single commercial site instead of multiple residential plots.

SCS Method

The first set of calculations takes into consideration the entire watershed while the second set of calculations eliminates the commercial zone. This helps to assess the overall impact of the commercial zone. Even after the elimination of the commercial area, the watershed remains a connected watershed. Reducing the impervious area in commercial zones is insufficient to restore water quality. Streets can thus become an important place of intervention to reduce runoff in all kinds of zones — ranging from residential to commercial.

According to Ferguson (1998, p.70), "unconnected" impervious surfaces are those from which runoff spreads as sheet flow over previous areas before entering the drainage system, so that it can be slowed down and reabsorbed into the soil before continuing to the watershed's outlet. Consequently, "connected" impervious surfaces will be those from which runoff directly moves into stormwater drains without getting a chance to percolate into the ground.

Rational Method Calculations	Plots				
	Commercial Plot A				Residential Plot B
Drainage Areas	Drainage Area 1	Drainage Area 2	Drainage Area 3	Drainage Area 4	Drainage Area
Design storm (year)	10	10	10	10	10
Drainage area A(d) (in acres)	1.61	0.98	0.88	1.81	5.2
Cover factor A(d)	0.9	0.9	0.9	0.9	0.55
Slope along hydraulic length (%)	3.97	2.5	2.83	3.54	2.27
Time of concentration factor	0.23	0.29	0.26	0.24	0.65
Hydraulic length (feet)	352	239	211	395	701
Time of concentration (depends upon slope and cover factor) (mins)	4.31	4.48	3.7	5.16	15.9
Time of rainfall (equated for comparison) (mins)	16	16	16	16	16
Rainfall intensity (inches/hr)	7	7	7	7	7
Peak rate of flow (acre-foot-hr)	0.85	0.51	0.46	0.95	1.66
Volume of water in time of rainfall (acre-foot)	.22	.13	.12	.25	.44
Total volume of water (acre-foot after 16 mins)	0.74				0.44
Volume (cu/sqft)	0.13				0.08

Table 1: Rational Method Calculations. (Source: Author.)

Figure 1: Rational Method Landcover (left), Waterflow (right) diagram. (Source: Author.)

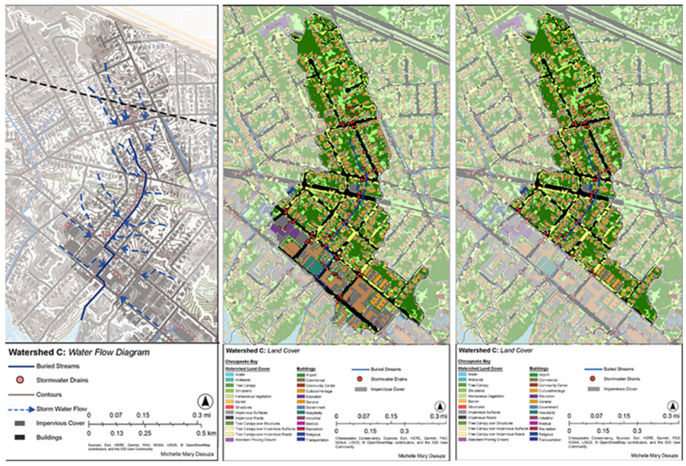

Figure 2: Coe Branch Watershed Waterflow (left), Landcover 1 (center), and Landcover (right) diagram. (Source: Author.)

B. THE STUDY OF RUNOFF VOLUMES FROM SUB WATERSHEDS WITH THE HIGHEST LEVELS OF IMPERVIOUS SURFACES

The SCS method of stormwater calculation is used to prove the relationship between impervious cover, disconnection, and runoff volumes. Three watersheds with high levels of impervious surfaces were studied using the SCS method. Watershed A, which contains the downtown area of Falls Church, emerged as the one with the highest volume of runoff as well as the greatest impervious cover at 64 percent. A staggeringly low 2.4 percent of rainfall soaks into the ground before runoff. Watershed A is also the largest watershed among the three compared which means that it has a relatively larger impact upon the health of the stream too. Watershed B and C both constitute equally high impervious surface areas of around 40 percent. However, Watershed C infiltrates 5.2 percent of the rainfall in contrast to Watershed B which only infiltrates 3.4 percent of rainfall. These stark differences are an indication of the potency of infiltration or disconnection in reducing the amount of runoff in a storm event.

2. DEFINING THE SITE OF INTERVENTION

Factors like the topography of the land, locations of buried streams, stormwater drains, impervious surfaces, and water flow are used to determine the locations of intervention for stormwater management. Subsequently, factors like great street policies, zoning patterns, property ownership, local landmarks, traffic flow, and future development plans were considered while developing a street program for this pair of streets.

The paper identifies the two intersecting streets of S. Maple Avenue and Annandale Road as the location of intervention after tabulating a confluence of 'stormwater' and 'public realm' factors in selected Watershed A. S. Maple Avenue is a part of the Falls Church bike network and is also designated to become a civic great street. Meanwhile, Annandale Road has the potential to play an active role in collection and management of stormwater. A part of it runs along the watershed boundary as well as crosses several tributaries which are low points in the watershed. Furthermore, there is a dynamic urban character to the street as it transitions from a business to a mixed-use zone and finally terminates into a residential zone. Both streets present excellent possibilities for road diets, pedestrianization, and traffic calming, which would bolster the implementation of green streets. This would help Falls Church achieve its goal of becoming a 'Walk Friendly Community' as well as a part of the 'Bike League.'

3. OUTLINING A DESIGN PROPOSAL AS A DEMONSTRATION PROJECT FOR GREEN INFRASTRUCTURE

The implementation of green infrastructure in a city needs to place equal emphasis upon 'stormwater management' as well as the city's 'urban development plan.' This strategy tries to solve the issue of inundation and achieve environmental benefits by also pushing forward the future development plan of Falls Church.

A. URBAN DESIGN PLAN

In the new urban design plan, S. Maple Avenue is designed as a 'Civic Great Street' keeping in mind the future goals of Falls Church. It is relatively monotonous in comparison with Annandale Road with a strong defined building line and mixed-use activities on either side. Annandale Road will act as a neighborhood link which will actively be used by locals to access downtown. Due to the lower traffic volume on the street and the connectivity to Big Chimneys Park and Church Branch Plaza, Annandale Road would become popular for children and adults alike and shall be a green street.

SCS Calculations	Watersheds		
	Watershed A	Watershed B	Watershed C
Watershed Area (acres)	121	40	115
Impervious Surface Area (acres)	78	16	49
%	64	41	42
Connected Watershed Area (acres)	72	16	32
%	60	39	27
Composite Curve Number	93	91	87
Infiltration (%) (considering a 10-year storm)	2.4	3.4	5.2
Runoff Volume (cuft/sqft)	0.39	0.37	0.33

Table 2: SCS Method Calculations (Source: Author.)

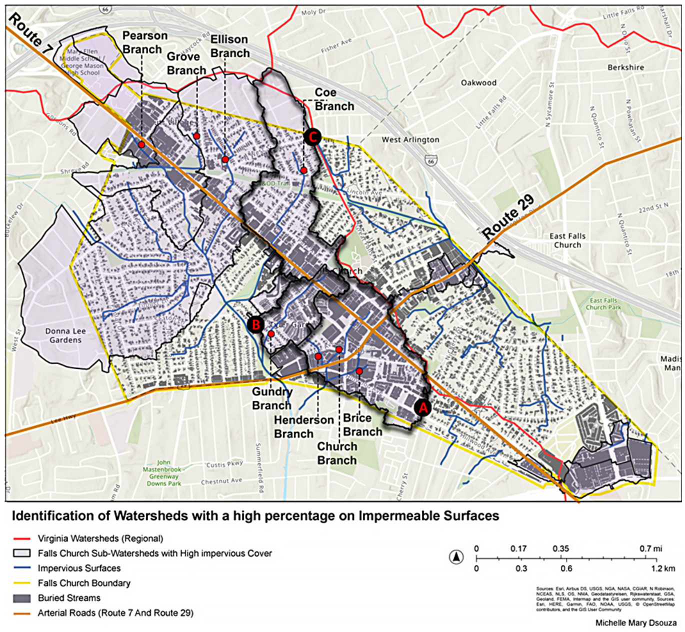

Figure 3: Impervious Cover in subwatersheds of Falls Church. (Source: Author.)

The urban design plan of S. Maple Avenue and Annandale Road was constituted to identify historical places of importance, placemaking opportunities, important links, and neighborhood communities which would augment the presence of these two streets within the public realm in Falls Church.

The characteristics of the future plan consists of urban street zones, plazas, and nodes. The urban street zones will give a sense of place to each street zone which are reflective of the building uses and activities along the street. The plazas are raised intersections which increase safety for pedestrians and provide ease of access to city parks. They also indicate a change of traffic pattern in the upcoming street thus warning vehicles to slow down before merging into the street. Nodes are smaller pause points and places of interest where placemaking strategies can be implemented. Historical nodes contain historical markers placed by the city of Falls Church. These are recognizable and well known by locals. Water features are located at buried stream crossings in the public right of way. The water features are designed to increase the salience of buried streams and highlight the natural movement of water within the city while educating the public on stormwater.

B. STORMWATER MANAGEMENT PLAN

The aim of the stormwater management plan for the proposed design is as follows: "Infiltrate runoff at the point that it hits the ground." Roads that are topographically downhill of an urban block should be designed to infiltrate at least one inch of rainfall of the estimated runoff from the block uphill and the corresponding street with the understanding that the first one inch of rainfall carries the maximum pollution.

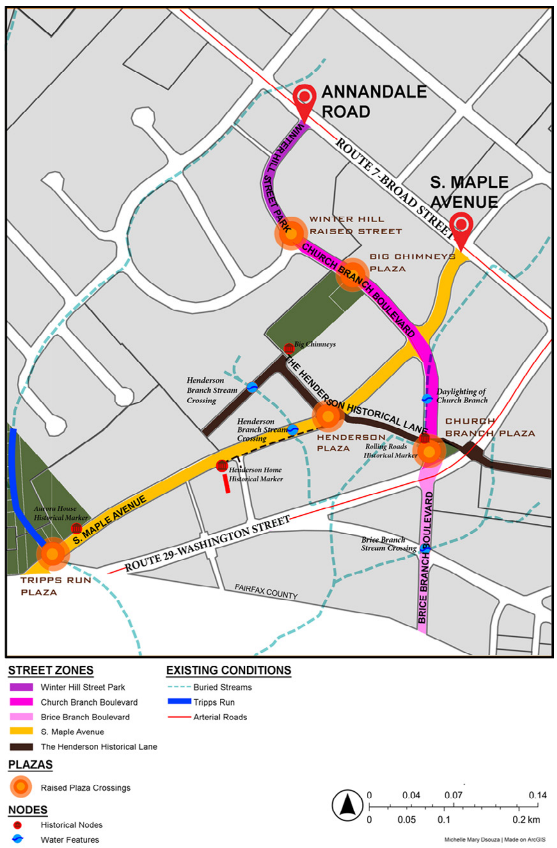

Figure 4: Proposed Urban Design Plan. (Source: Author.)

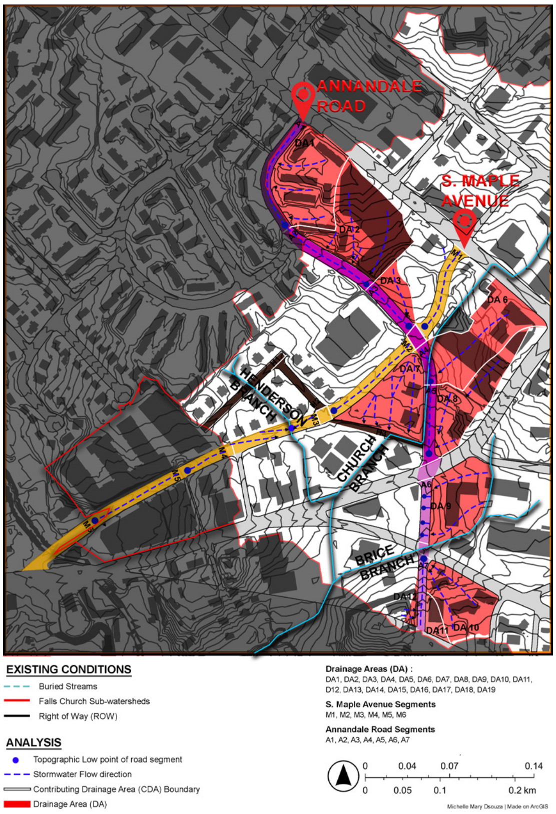

Figure 5: Annandale Road Stormwater Management Plan. (Source: Author.)

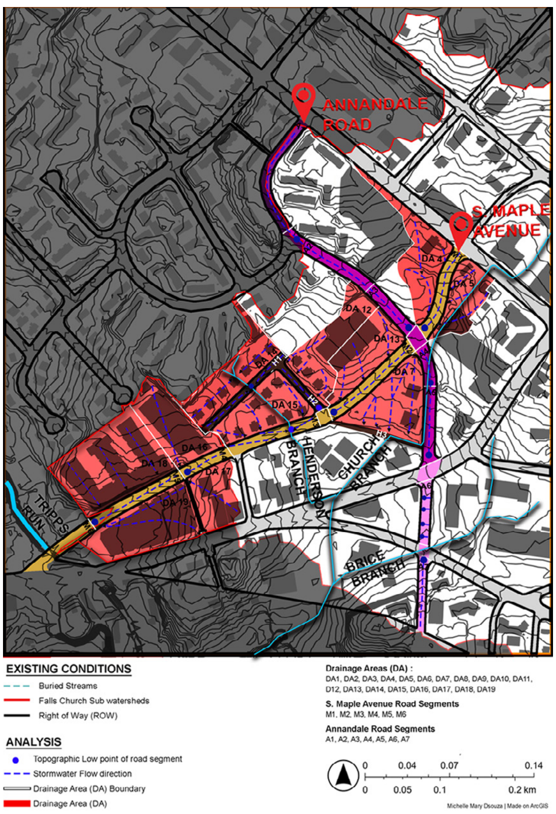

Figure 6: S. Maple Avenue Stormwater Management Plan. (Source: Author.)

The road is divided into road segments. Each road segment will attempt to infiltrate one inch of runoff from the plot which drains onto the road segment. Instead of allowing the runoff from the plots to be directed into the storm drains, the green infrastructure additions on the road segment will try to capture the water. The low point in each road segment is likely to have the greatest quantity of stormwater runoff. The aim of the design would be to intensify green infrastructure and reduce impervious surfaces moving towards the low point of each road segment. Street parking will be located at higher elevations within the road segment which gives an opportunity to infiltrate the water and reduce pollutants in pervious surfaces downhill. When the road runs parallel to the direction of the contours, basins can be designed to hold back the water and prevent it from flowing downstream. When the road runs perpendicular to the contours, bioswales can be designed which infiltrate water as it moves downhill to the next swale. A single overflow at the low point of the road segment will ensure that water moves into the storm drains only after the capacity of all the bioswales in the series is completely utilized.

To evaluate the efficiency of S. Maple Avenue and Annandale Road in managing stormwater through green infrastructure, stormwater calculations are carried out for each road segment after the redesigning of the street.

C. DESIGN PROCESS

Each road segment was designed by understanding the water flow within the area, the surrounding landcover which affects water infiltration and the function of the street as a part of the larger urban setting.

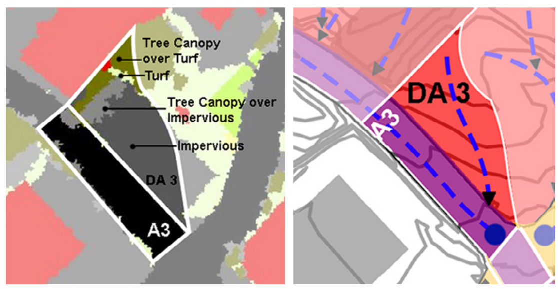

Figure 7: Landcover (left) and Waterflow (right) diagram for Road Segment A3. (Source: Author.)

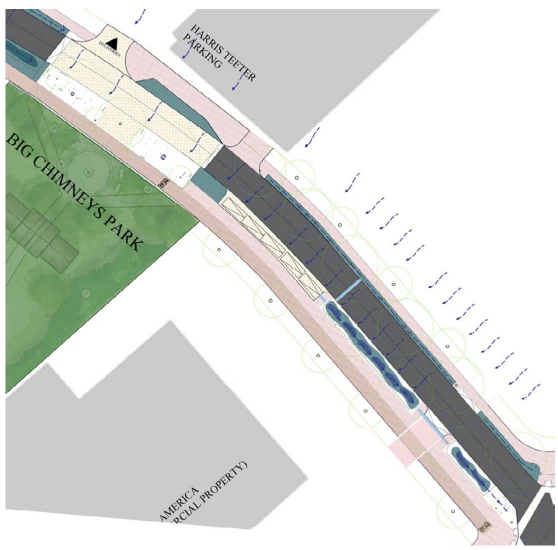

Figure 8: Proposed Plan for Road Segment A3. (Source: Author.)

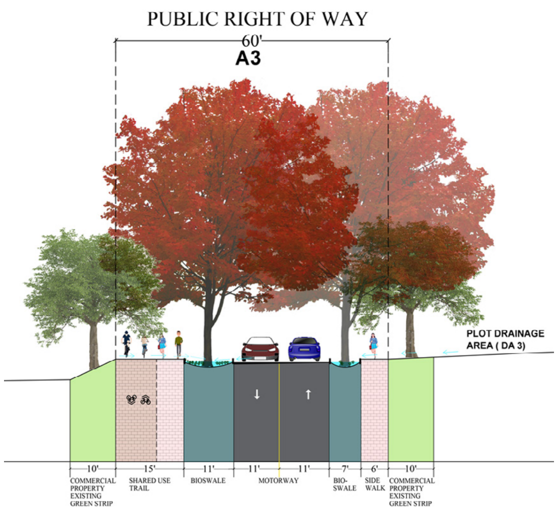

Figure 9: Proposed Section for Road Segment A3. (Source: Author.)

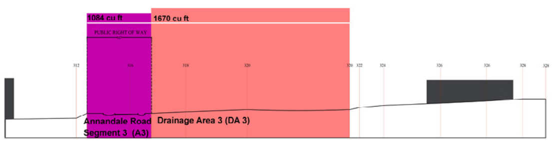

Figure 10: Stormwater Catchment for Road Segment A3. (Source: Author.)

Results

The capacity of the individual road segments along Annandale road to manage stormwater runoff from the catchment areas is as follows:

- Runoff volume from the plot (DA1) and the proposed road segment (A1) is 9,270 cu ft. The bioswales occupy 7.2 percent of the total drainage area and can hold 9,327 cu ft which is 100 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA2) and the proposed road segment (A2) is 5,073 cu ft. The bioswales occupy 3.5% percent of the total drainage area and can hold 4,322 cu ft which is 85 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA3) and the proposed road segment (A3) is 2,754 cu ft. The bioswales occupy 12 percent of the total drainage area and can hold 3,984 cu ft which is 144 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA6) and the proposed road segment (A4) is 8,157 cu ft. The bioswales occupy 3 percent of the total drainage area and can hold 2,828 cu ft which is 35 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA8) and the proposed road segment (A5) is 6,572 cu ft. The bioswales and stream occupy 6 percent of the total drainage area and can hold 5,380 cu ft which is 81 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA9) and the proposed road segment (A6) is 5,652 cu ft. The bioswales occupy 4.4 percent of the total drainage area and can hold 2,943 cu ft which is 52 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA10, DA11, DA12) and the proposed road segment (A7) is 7,157 cu ft. The bioswales occupy 3.1 percent of the total drainage area and can hold 3,000 cu ft which is 41 percent of the first 1 inch of runoff.

The capacity of the individual road segments along S. Maple Avenue to manage stormwater runoff from the catchment areas is as follows:

- Runoff volume from the plot (DA4 and DA5) and the proposed road segment (M1) is 10,166 cu ft. The bioswales occupy 5 percent of the total drainage area and can hold 6,002 cu ft which is 59 percent of the first 1 inch of runoff.
- Runoff volume from the plot (DA13) is 7,341 cu ft. The bioswales occupy 6.2 percent of the total drainage area and can hold 5,958 cu ft which is 81 percent of the first 1 inch of runoff.
- Runoff volume from the plots (DA 16 and DA 17) is 6,389 cu ft. The bioswales occupy 1.8 percent of the total drainage area and can hold 1,268 cu ft which is 20 percent of the first 1 inch of runoff.

Conclusion

This paper establishes that in order to mitigate the effects of inundation, it is most critical to 'intervene at the source' of locations which create the most runoff and pollution and provides a systematic methodology of identifying such areas and intervening in them.

Streets are large contributors to stormwater runoff but also provide the best opportunity to solve the problem of polluted runoff in publicly owned land. They are the most extensive network of public-owned property, which are intertwined in the urban fabric and provide the best opportunity to act as 'disconnectors.' The City of Falls Church has the agency to manage stormwater in this area. The implementation of green infrastructure in a city needs to place equal emphasis upon 'stormwater management' as well as the city's 'urban development plan.'

"Stormwater is not a mechanical system. It is an environmental process, joining the atmosphere, the soil, vegetation, land use, and streams, and sustaining landscapes," (Ferguson, 1998, p.1).

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