London Borough of Camden

Sustainable Urban Drainage System (SuDS) in Camden

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Sustainable Urban Drainage System in Camden

Sponsored by London Borough of Camden

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Report Submitted to

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Abstract

The London Borough of Camden has had two major flood events in 1975 and 2002 that caused disruption to business and transportation. The Council is concerned that such flood events will become more common in the future as climate change brings more intense storms with increasing frequency to U.K. The project goal was to determine a strategy to mainstream Sustainable urban Drainage Systems (SuDS) into the public realm work of the Highway and Transport Strategy Teams. We conducted desk-based research, interviews, and site visits to identify the actual and perceived benefits and barriers to the adoption of SuDS and potential strategies to promote their adoption in the borough's public highways.

Acknowledgement

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Executive Summary

In the London borough of Camden (LBC), there have been two major floods in 1975 and 2002, and in the coming years, climate change is projected to cause more frequent and severe storms. The LBC has created policies that encourage the implementation of sustainable developments, specifically sustainable urban drainage systems (SuDS). The primary purpose of this report was to outline a strategy to mainstream SuDS into Camden's public realm's highways and streetscapes projects. We developed the following five objectives to reach our goal:

1. Identified the policies encourage the incorporation of SuDS into the public realm projects.
2. Examined the extent to which the current engineering and transport strategy projects reduce the risk of flooding.
3. Assessed the benefits of the adoption of SuDS.
4. Evaluated the barriers preventing the adoption of SuDS and identified potential solutions to overcome them.
5. Identified opportunities for incorporating SuDS in Camden's public realm projects.

Through desk based research and discussions with the Camden council staff and advocates of SuDS from other boroughs, we found that flooding from rapid runoff due to impermeable surfaces poses a substantial risk for Camden. The combined drainage and sewer system is already overtaxed and is likely to be stressed further as the population grows and climate change leads to more frequent and intense storms. Many policies in place at the national, regional, and local level encourage SuDS. The many benefits of SuDS, besides reducing flood risk, include reduced stress on the storm water system, increased recharge of aquifers, and amenity values. Camden council has not yet implemented any SuDS schemes although some private SuDS projects have been implemented in the borough. Lack of knowledge about the range of benefits associated with SuDS technologies and concerns and misperceptions about costs of construction and maintenance have impeded the adoption of SuDS schemes

in the borough. Other barriers to the implementation of SuDS in the borough include employee resistance to the adoption of new technologies that they fear are unproven, or may be irrelevant to the goals that they are trying to achieve. Staff were also concerned about the conflict caused by potential SuDS schemes displacing parking spots that are at a premium in the borough. Finally, staff were concerned about funding opportunities.

Conclusion and Recommendations

Camden is at risk of surface water flooding, an obstacle that can be overcome through the implementation of SuDS. SuDS offer many benefits beyond flood risk reduction but they have not been implemented in Camden due to a number of barriers. Many planned streetscape and highway projects offer opportunities for the incorporation of SuDS. The main barriers to the adoption are lack of awareness about the range of SuDS technologies available and a lack of knowledge about the true costs and benefits. Contrary to expectations, the costs of installing and maintaining SuDS are often less than the costs of conventional drainage schemes, and they offer many additional benefits over conventional schemes, such as reduced flood risk, increased amenity values, improved air and water quality, the promotion of biodiversity, and reduction in climate impacts. The team identified several proposed transport projects that Camden is considering and explored the possibility of integrating SuDS components in the highway schemes. Based on the findings from the interviews and background research the project team recommends that the Camden Council:

- Revise the “Camden Transport Strategy” to clearly emphasize the need to include SuDS in future streetscape and highway projects.
- Provide more information to staff regarding the costs and benefits of SuDS schemes through various means such as:
    - Guidance documents and other resources;
    - Site visits to schemes implemented in neighboring boroughs;

    - Lectures and workshops by SuDS experts/organizations, such as John Bryden of Thames 21, TfL, George Warren of Hammersmith and Fullham, and Ian Russel of Enfield Council.
- Develop pilot schemes based on the projects identified and evaluate the success of the pilot schemes according to various stakeholders, including council staff, residents near the schemes and other users, such as cyclists.
- Collaborate with Georgie Street of Camden Town, who has expressed interest in working with the Council to implement SuDS in that district

Adopting SuDS in Camden is appears to be a feasible goal for the borough and options for integrating SuDS should be considered in the design phase of all future highway and streetscape projects.

Authorship

	Initial Author	Revision 1	Revision 2	Revision 3
Abstract	O.L.	B.A. and C.A.	C.A.	
Acknowledgements	O.L.	B.A. and C.A.		
Executive Summary	C.A.	A.G.	C.A.	
Introduction	B.A., C.A., A.G.	B.A.		
Policy Drivers	B.A., C.A., A.G., and O.L.	B.A., A.G., and C.A.	B.A. A.G. and C.A.	B.A., C.A., A.G.
Flood Mitigation Projects and Missed Opportunities	C.A. and A.G.	B.A., C.A., A.G. and O.L.	C.A. and A.G.	
Barriers	C.A. and A.G.	C.A., A.G., B.A.		
Potential Opportunities	B.A. and O.L.	C.A. and B.A.		
Benefits	C.A. and A.G.	C.A.	A.G.	
Cost	B.A. and A.G.	C.A.		
Case Studies	B.A and A.G.	B.A. and A.G.	B.A. and A.G.	B.A., A.G., and O.L.
Conclusion & Recommendations	B.A.and C.A.	C.A.		

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1. Introduction

The London Borough of Camden has suffered two major flood events since 1975 that caused disruption to residents, businesses and transportation. The Council is concerned that such flood events will become more burdensome in the future as climate change brings more frequent and severe storms to the UK. Flooding in Camden is a result of runoff from impermeable surfaces during storms rather than riverine, or fluvial, flooding. Excessive runoff exceeds the capacity of the drainage system and pools in low-lying areas, such as underpasses, that become impassable to traffic. Under the Flood and Water Management Act 2010, the London Borough of Camden, like other Local Authorities, was appointed as Lead Local Flood Authority, taking responsibility for managing flood risk at a local level. Many Lead Local Flood Authorities (LLFAs), including Camden, are beginning to adopt new approaches to the construction of highways and streetscapes that incorporate Sustainable Urban Drainage Systems or SuDS. SuDS entail the innovative use of technologies, such as permeable paving and green components, to reduce runoff. The main priority of SuDS is reducing the likelihood of flooding, but they also support tree growth, increase biodiversity, ameliorate the effects of climate change, and reduce the load on the combined storm water and sewer system. Unfortunately, many of those responsible for designing and building streetscape improvement and highway engineering projects are skeptical of the benefits and costs of SuDS. They are hesitant to adopt new technologies because the approaches are not well understood and may entail additional uncertain costs of maintenance.

As a result, many boroughs, like Camden, have been slow to adopt these technologies. The goal of this project was to explore what are the perceived barriers to the adoption of SuDS and propose a way to mainstream SuDS into the highway projects. Through desk-based research, site visits, and interviews with council staff, infrastructural experts, and other stakeholders, the team clarified the main policy drivers, examined the extent to which the current highway projects mitigate the risk of flooding and identified the main benefits, and the major barriers to the adoption of SuDS. The team reviewed proposed projects in Camden to identify opportunities for incorporating SuDS into the public realm, and developed detailed proposals for the implementation of SuDS in several key locations. This report recommends how Camden can best encourage the adoption of SuDS as a standard practice in highway and streetscape projects and identified avenues for further research.

2. Policy Drivers

In this section we review the policies and policy drivers pushing the implementation of sustainable urban drainage systems at three government levels; national, regional, and local (Figure 1). Through extensive interviews with staff members of the London Borough of Camden, the London Borough of Enfield, Thames 21, Thames Water, and Transport for London (TfL) we determined that the three main factors driving current policies are concerns about flooding and climate change, and the desire to promote more sustainable development.

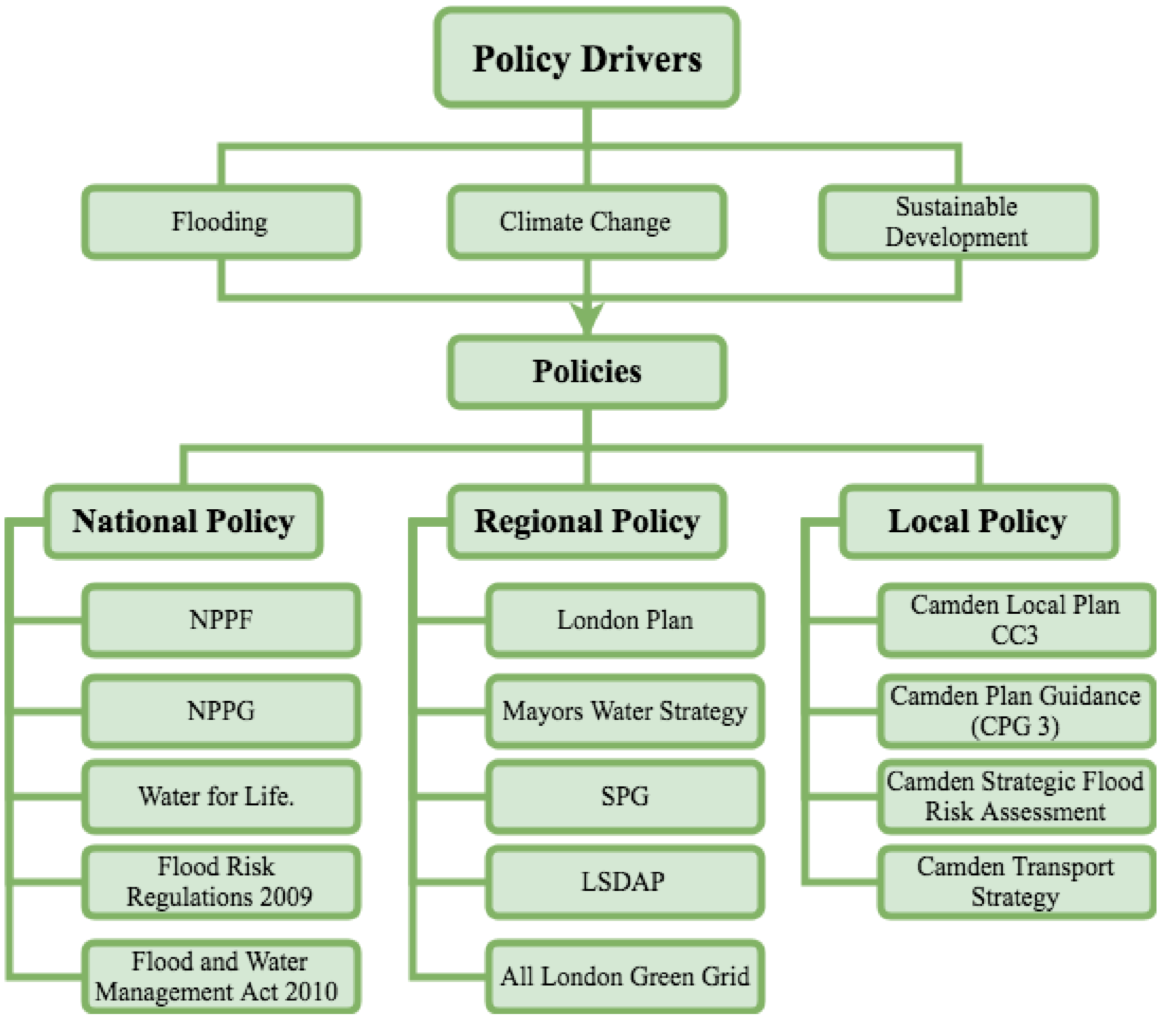

Figure 1: Policies and policy drivers promoting SuDS in London.

2.1 National Level

The key pieces of legislation and policy guidance driving the adoption of SuDS at the national level are presented in Figure 2 and discussed briefly below.

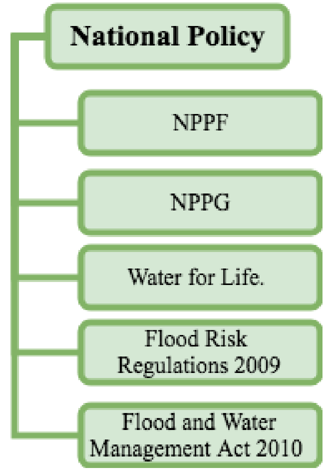

Figure 2: National policies on SuDS.

2.1.1 NPPF (National Planning Policy Framework)

"The National Planning Policy Framework" (NPPF) clearly states the government's expectations for each individual Council to create plans and implement them with the purpose of improving their communities. The NPPF has two main policies that drive the adoption of SuDS: (1) "Local Plans should take account of climate change over a longer term, including factors such as flood risk" (DCLG 2012,23), and (2) "When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through planning of green infrastructure" (23). The policy drivers and policies addressed in this document are climate change, flood risk, and green infrastructure. The NPPF is one of the most significant policies pushing the implementation of SuDS because it creates the framework for how policies at all levels should be designed.

2.1.2 Flood and Water Management Act 2010

"The Flood and Water Management Act" is, "An Act to make provision about water, including provision about the management of risks in connection with flooding and coastal erosions," (Crown, 2010). The document first defines sustainable drainage as "a structure designed to receive rainwater except—(a) a public sewer, or (b) a natural watercourse." (Crown, 2010, schedule 3).

The policy requires strategies to monitor flood risk on a local level in England. The document states that the lead local flood authorities, "must aim to make a contribution towards the achievement of sustainable development" (Crown, 2010). "The Flood and Water Management Act" is an influential document that has shaped many of the policies at the local level in Camden by addressing the policy drivers of sustainable developments and flooding.

2.1.3 National Policy Planning Guidance (NPPG)

"The National Policy Planning Guidance" (NPPG) is a guide to accompany the policies addressed in the NPPF. This document recommends that local flooding authorities implement a Strategic Flood Risk Assessment (SFRA) to develop a full understanding of the flood risk in the borough. This guidance recommends that local authorities take measures to reduce flood risk factors and flooding impacts through the installation of infrastructure such as SuDS. Local authorities are required to implement policies that reduce the impact of climate change in local plans.

2.1.4 Flood Risk Regulations 2009

"The Flood Risk Regulations 2009" assign responsibility to the Lead Local Flood Authority (LLFA) for surface water flooding and the Environment Agency for fluvial flooding. The LLFAs are required to assess flood risk and create maps showing areas that are at risk of surface water flooding. Once these areas are determined, the local flood authority must develop a plan of action to reduce flood risk. The Local Flood Risk Management Plan is required to "take account of the likely impact of climate change on the occurrence of floods" (Crown, 2009). The significance of the "Flood Risk Regulations 2009" is that this document gives responsibility to the LLFA to address surface water flooding and climate change, two of the most prominent policy drivers pushing for the implementation of SuDS.

2.1.5 Water For Life

"Water for Life", written by the Secretary of State for Environment, Food and Rural Affairs, was designed to explain current stresses on England's water supply caused excessive withdrawal and lay out possible steps to help replenish the water bodies. SuDS are linked to water replenishment, as seen in paragraph 4.28 that states, "we want to encourage the use of Sustainable Drainage Systems (SuDS) wherever they will be affective. SuDS are a range of measures designed to mimic as closely as possible natural drainage, and its advantages in providing habitat, filtering pollutants, recharging groundwater –particularly important in water stressed areas, and in slowing water down – thus reducing flood risk" (DEFRA 2011, 62). While the main focus is in flood risk management, "Water for Life" discusses the importance of water replenishment and emphasizes that many SuDS designs allow water to infiltrate underground to replenish aquifers rather than being drained off through the combined sewer network.

2.2 Regional Level

The regional policies are influenced by the policies at the national level and in turn shape policies at a local level. Figure 3 illustrates the major policies pertinent to the implementation of SuDS in the Greater London region and these are discussed in more detail below.

Figure 3: Regional policies on SuDS.

2.2.1 The London Plan

Chapter Five of "The London Plan" discusses London's response to climate change and emphasizes the use of SuDS in several places, such as: "The Mayor will work with all relevant agencies including the Environment Agency to address current and future flood issues and minimize risks in a sustainable and cost effective way" (Khan, 2016, 5.12) and "A development should utilize sustainable urban drainage systems (SUDS) unless there are practical reasons for not doing so" (Khan, 2016, 5.13). The London Plan's drainage hierarchy (as stated in section 5.13) stipulates the parameters that a SuDS scheme should meet when incorporated into a development:

- Store rainwater for later use;
- Use infiltration techniques, such as porous surfaces in non-clay areas;
- Attenuate rainwater in ponds or open water features for gradual release;
- Attenuate rainwater by storing in tanks or sealed water features for gradual release;
- Discharge rainwater direct to a watercourse;

- Discharge rainwater to a surface water sewer and/or drain
- Discharge rainwater to the combined sewer.

The Plan also references "The Flood and Water Management Act of 2010" that places more responsibility on the borough councils to manage their surface water and defines what is meant by sustainable drainage in Schedule 3. Further, it makes references to "The Drain London Forum", which brings together several London-wide agencies, such as GLA, Thames Water and the Environment Agency, as well as London's 33 councils to coordinate surface water management plans in the different boroughs throughout London, including Camden. The London Plan also emphasizes that drainage projects should be designed to promote other policy objectives, such as water use efficiency and quality, biodiversity, amenity, and recreation.

2.2.2 All London Green Grid

The "All London Green Grid" (ALGG) is a policy framework document designed to encourage the creation and delivery of "green infrastructure" across London. The main policies that shape this document are the NPPF and Policy 2.18 of "The London Plan". In Section 4 of ALGG, the plan shows SuDS as an opportunity for greening that brings many other benefits. It states, "For example, incorporating Sustainable Drainage Systems (SUDS) can reduce surface water runoff in a more natural way as well as providing amenity value and benefits for wildlife" (GLA 2012, 64). Section 5.4 of the ALGG planning guidance lists various opportunities across London where greening is possible. One opportunity that incorporates SuDS is to "[i]ntegrate green infrastructure as part of the regeneration of Barking Riverside with particular emphasis on incorporating flood management/SUDs, conserving and enhancing biodiversity and creating a network of accessible green spaces" (GLA 2012, 86). The importance of the ALGG is that it links the necessary need for greening London with the reduction of surface water flooding, one of the main policy drivers.

2.2.3 London Sustainable Drainage Action Plan 2016

"The London Sustainable Drainage Action Plan", or LDSAP, explains the reasons for sustainable drainage in the first place. It states, "The combined challenges of London's growing population, changing land uses and changing climate mean that if we continue to rely on our current drains and sewers, we face an increasing risk of flooding" (GLA, 2016, 2). After reviewing the problems, the Plan describes how to implement sustainable drainage into current buildings, lands, and infrastructures. Figure 4 is a visual representation of how the London Sustainable Action Plan relates to SuDS. The basic plan clarifies to all boroughs in London "the key to identify when and where other planned maintenance, repair or improvement works are scheduled and then to identify opportunities to retrofit sustainable drainage as part of those works" (GLA, 2016, 2).

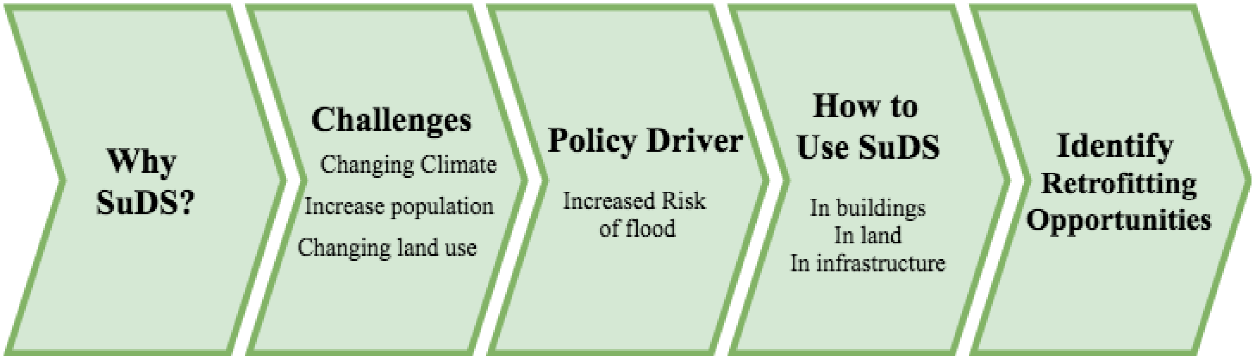

Figure 4: LSDAP representation of SuDS implementation process.

2.2.4 Mayors Sustainability Planning Guidance

"The Supplementary Planning Guidance (SPG)" developed by the GLA states "It is important to incorporate sustainable drainage in all developments to prevent the increasing volume of surface water runoff during heavy rainfall" (GLA, 2014, 3.4.2). The document references the policy drivers of flooding and sustainable developments but does not take into consideration highway and transport strategy projects, the basis of this report.

2.2.5 The Mayor's Water Strategy

"The Mayor's Water Strategy" explains how London needs to better manage its water. Rainfall intensity in London is increasing as a result of climate change and the current drainage system struggles to cope with the surface water runoff. "The Mayor's Water Strategy" emphasizes that the city needs to "Adopt a more creative approach to managing flood risk from rainfall in London, taking opportunities to slow the progress of water from 'rain to drain' and using rainwater for non-potable uses to reduce demands for treated mains water" (GLA 2011, 80) This policy help the Mayor bring all the key stakeholders together to understand and manage the policy drivers of flood risk and references that SuDS can be used to mitigate flood risk and has many other benefits to the community.

2.3 Local Level

This section discusses the local policies (Figure 5) that developed in Camden that have bearing on SuDS and explains how these policies have been shaped by policies at the regional and national levels.

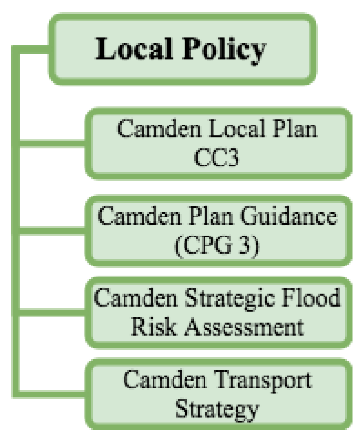

Figure 5: Local Policies on SuDS.

2.3.1 Camden Local Plan 2015

"The Camden Local Plan 2015" describes Camden's responsibility to mitigate flood risk, state the risks of new developments, and lays out the parameters guiding new developments. The local plan states that the council is fully responsible to mitigate flood risk in its own borough: "Since 2010 Camden has been a lead Local Flood Authority, which means we have responsibility for managing flood risk from surface water to groundwater in the borough" (LBC, 2015, 8.53). The plan also states the requirements of new developments which are summarized as follows; they must consider the impact of the development on Local Flood Risk Zones; not locate vulnerable developments in flood-prone areas; achieve greenfield run-off rates or, where this is not possible, achieve a 50% reduction in existing run off rates or, as a last resort, achieve run-off rates that do not exceed those predevelopment; incorporate water efficiency measures; and avoid harm to the water environment and quality (8.54). The plan also emphasizes "[w]here appropriate, SUDS measures will be secured by planning condition or by legal agreement" (8.67).

2.3.2 Camden Planning Guidance

The "Camden Planning Guidance" addresses how the borough should design projects for the betterment of the community and stresses the phrase "design excellence." The Guidance, more specifically chapter three, addresses sustainability. The chapter goes into great detail on how to reduce and manage flood risk through new developments. The section titled "Flooding" has three key messages that are (LBC, 2015, 79):

- All developments are required to be designed to prevent or mitigate floods
- All developments are expected to manage drainage and surface water
- There is a hierarchy you should follow when designing a sustainable drainage system

"The Camden Planning Guidance" adopted the SuDS hierarchy from "The Mayor's London Plan". One powerful statement in "The Camden Planning Guidance" is "The best way to deal with heavy rainfall and a traditional pipe drainage system is to introduce new areas for water to soak into the ground. Sustainable Drainage Systems (SUDS) provide a way to manage surface water in a way which mimics the natural environment. SUDS help reduce that amount of surface water leaving a site and can slow down the rate water flows. It also helps improve water quality by filtering out contaminants. SUDS can provide better benefits, including the capture and re-capture of water by linking into a rainwater or grey water harvesting system. They can also provide green, landscaped areas offering recreation and habitat for wildlife" (11.5). "The Camden Planning Guidance" also identifies SuDS as tools that help reducing the effects of climate change. This document particularly important with regard to the adoption of SuDS because it ensures that Camden considers SuDS during the design stage and planning process for projects where they can be implemented.

2.3.3 London Borough of Camden SFRA (Surface Flood Risk Assessment)

In order to decrease the risk of floods and better manage floods that do occur, "The London Borough of Camden SFRA (**Surface Flood Risk Assessment)**" strongly recommends the borough incorporate appropriate surface water mitigation methods into flood risk areas, especially Sustainable Drainage Systems (SuDS). to the National Planning Policy Guidance (NPPG) encourages boroughs like Camden to use SFRAs to analyze the risks of flooding. The SFRA is used by Camden to support "The Local Plan" and in making planning decisions. It is underpinned by analysis and modelling undertaken across the borough and includes maps indicating areas at risk of flooding. The SFRA emphasizes that "Sustainable Drainage Systems (SuDS) should be included in new developments unless it is demonstrably not possible to manage surface water using these techniques" (Timmins, 2014, 67).

2.3.4 Camden Transport Strategy

The goals of the "The Camden Transport Strategy" are to maintain the transport system and enhance the natural environment. "The Camden Transport Strategy" creates opportunities for the implementation of SuDS even though they are not explicitly mentioned. For example, policy 1.12 states, "Camden will continue its tree program to increase the number of street trees to an optimum level as well as seek to increase the number of street trees as a part of the area-wide transport schemes" (LBC, 2011, 83). Similarly, Objective 5.1 states: "Camden will continue to work with the local community, Councilors, Council staff and other stakeholders to introduce improvements to the public realm and streetscape environment. This will help to encourage more people to walk and cycle as well as make Camden a better place to live and work" (LBC, 2011, 125). While SuDS are not explicitly mentioned, this policy may facilitate the implementation of these methods since they are known to improve the environment in general and can contribute to some of "The Transport Strategy's" other objectives such as increasing walking and cycling, and improved water, air, and life quality.

2.4 Conclusion

We conclude that the implementation of SuDS is strongly supported by numerous government policies and planning guidance at the national, regional and local level. Unfortunately, a lack of knowledge and awareness among engineers, contractors, project planers, and others about the value of SuDS means that they have not yet been as widely adopted as the policy positions might imply. Nevertheless, the policies and planning guidance provide a strong base and rationale for the implementation of SuDS. Moving forward, Camden should use these policy positions to justify the implementation of SuDS into highway and streetscape projects in the future.

3. SuDS Technologies and Flood Mitigation

Numerous areas in the London Borough of Camden are at high risk of flooding due to the pooling of surface water runoff during heavy rainfall events. Figure 6 illustrates the areas prone to flooding in the LBC, among this areas are King's Cross Station and Camden Town. The hard, impermeable surfaces of the Borough's streetscapes and highways result in limited infiltration and rapid runoff. Figure 7 illustrates that natural ground covers are more effective than impermeable surfaces at reducing runoff and increasing infiltration. Typically, streets are designed to move runoff into the combined sewer and drainage system as quickly as possible. Ironically, this may overtax the drainage system which may back up and result in flooding.

Figure 6: Flood risk map. (SFRA, 2011)

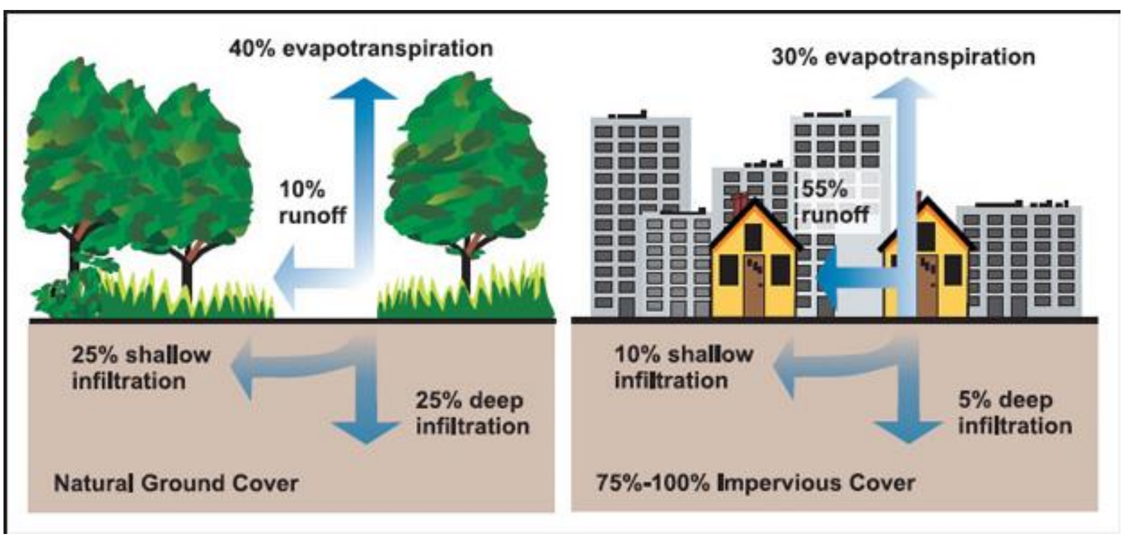

Figure 7: Infiltration rates under natural ground cover vs impermeable urban surfaces. (Wiebe, 2017)

London's sewage system was designed when two million people lived in the city. Currently, approximately 8 million people live in the city of London and its population is projected to increase by 1.5 million people by 2031 (Better Streets Delivered 2, Tfl). Thus, the drainage system is stressed well beyond its original design capacity and cannot meet the demands of modern day living and even less the expected increase of urban population. The population in Camden has been increasing (Table 5) and is expected to increase further in the future. Climate change and an increase in impermeable surfaces, as a result of further developments in the Borough, are two other factors that increase flood risk. The intensity and frequency of storms are expected to increase due to climate change, resulting in disruptive if not potentially catastrophic floods in many London Boroughs, including Camden. As a result of increasing flood risk, a pressing need a London's Boroughs is implementing measures that reduce flood risk by slowing or reducing surface water runoff that enters the city's drainage system.

Sustainable urban drainage systems (SuDS) are designed to reduce surface water runoff. These systems can:

- Remove rainwater from the drainage network.
- Slow down the passage of water into the drainage system.
- Retain the water through attenuation tanks that slowly releases it to the drainage system.

By reducing the rate and volume of runoff, SuDS would reduce the peak discharge into the combined sewer system and thus lessen the stress on the system and the risk of flooding. Rainwater would be either be stored and/or released later on into the drainage system when it is not saturated anymore, or it would infiltrate into the ground and eventually recharge the underlying aquifers.

3.1 Types of SuDS

Sustainable urban drainage systems are water management facilities, structures, or techniques that use natural components to channel, redirect, slow, and/or store water with the purpose of reducing the rate at which storm water enters the drainage system. SuDS help reduce runoff by encouraging infiltration with certain techniques such as permeable paving, trees in tree pits, trenches, filter strips, filter drains, and swales.

Permeable paving is a type of sustainable urban drainage system with high porosity that allows rainwater to pass through it (Figure 8) into the ground below or to an attenuation tank or drainage layer. To ensure the performance of this SuDS is optimal, silt, debris and liter need to be removed and the surface needs to be swept every six months.

Figure 8: An example of permeable paving.

Trees are a highly efficient type of SuDS. They attenuate storm water, contribute to soil permeability, and mitigate climate change effects by providing shade, cooling, and improving air quality. Trees can be placed all over the city using tree pits, comprise pits filled with soil and lined with geotextiles. The pits provide additional storage for storm water if integrated with an attenuation tank (Figure 9) (SuDS in London, 2016). They require a higher level of maintenance during the first three years after planting because roots need to establish good contact with the growing medium before they can efficiently extract water; after this inicial period their maintenance cost is low.

Figure 9: Picture of tree in tree pit (Alan Pritchard, July 3, 2014)

Figure 10: Trench Drainage System. (Trench Drain Systems, n.d.).

Trenches (Figure 10) are strips of grass that are predominantly dry, but in heavy rainfall, fill up and store water for a period of time before infiltrating it into the drainage system. Trenches need a periodic structural check and need to be periodically decompacted when under heavy use (SuDS in London, 2016).

Filter drains are deep, narrow, trenches filled with permeable material to collect and convey water from the edges of paved areas (See Figure 11). They often use a pipe at their base to encourage and direct drainage. This structure uses a geotextile below the surface to prevent the drain from clogging. Filters drains need routine maintenance to remove vegetation or debris from the surface (SuDS in London, 2016).

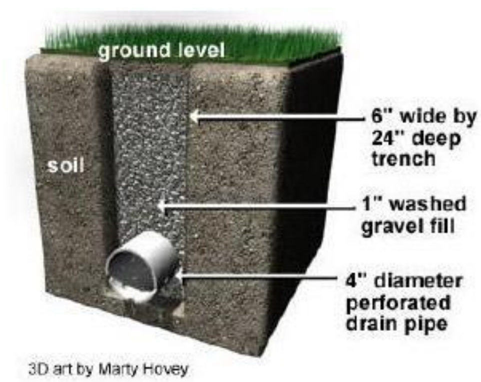

Figure 11: Scheme of filter drain (SuDS Wales, n.d.)

Swales are a broad, shallow grassed channels type of SuDS designed to route water, attenuate storm water, and infiltrate this water into the ground (Figure 12). This method is only effective when placed close to catchment areas. It requires routine maintenance to ensure its efficient operation at all times. There are two types of swales: dry swales and wet swales. Dry swales allow surface water to infiltrate and are designed to include a filter bed. Wet swales retain water like a linear wetland. They are usually located in sites where soil is poorly drained. After storm water is retained, it is then moved to a downstream outlet (SuDS in London, 2016).

Figure 12: Example pf swales (Susdrain, n.d.).

3.2 SuDS in Camden

While the London Borough of Camden is at risk of surface water flooding, SuDS are not widely known and have not yet be implemented by the council in any streetscape or highway project. Two private developments in Camden, however, have implemented SuDS. These projects are the Whitestone Pond and the King's Cross project (Figure 13), which have a filter strip with a gully and Arborflow tree pits with attenuation tanks, respectively.

Figure 13: An image of Whitestone Ponds (Biotechture, 2011)

4. Benefits of SuDS

Sustainable urban drainage systems are a type of drainage that offer a range of different benefits, from cost to environmental benefits, that can positively affect the environment and the people that live or transit these locations. Based on the team's research, SuDS acceptance is growing because people are learning about them and their benefits (see Figure 14). SuDS are an opportunity to create green spaces while tackling air and water quality and drainage issues in cities. In this section, the team discusses the most prominent benefits. These benefits are flood mitigation, climate change, cost, and maintenance. While reflecting upon the other benefits of biodiversity, water quality, and flexibility.

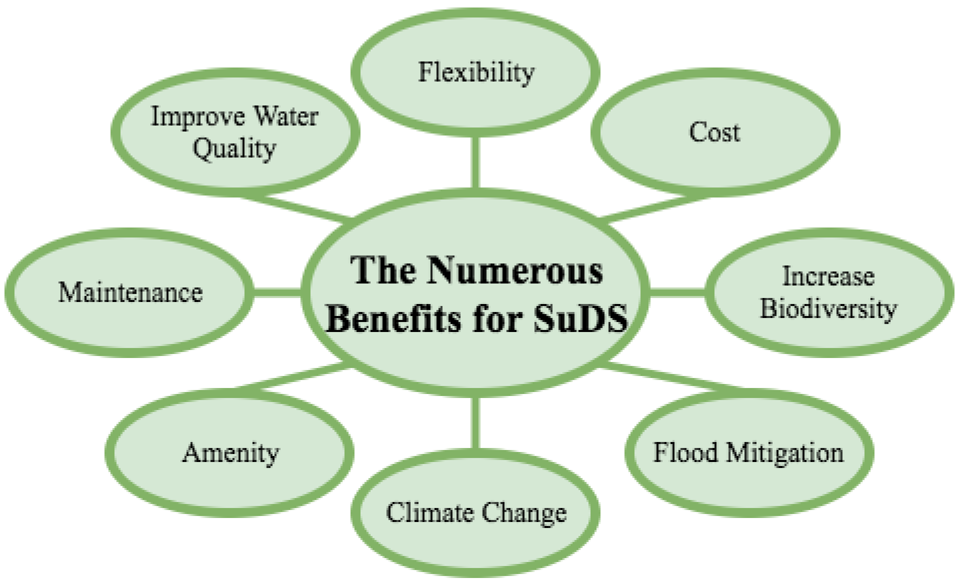

Figure 14: A web displaying the benefits of SuDS.

4.1 Explanation of Benefits of SuDS

In this section, we individually consider the benefits of SuDS, focusing specifically on the context of London and Camden.

Flood Mitigation: As noted in Section 3 above, SuDS redirect, slow down or/and store storm water that is gradually released into the main drainage system. If implemented properly, they can significantly reduce the stress on the main system reducing flood risk and water runoff, henceforth mitigating risk on properties and people that could be affected by floods. Moreover, SuDS increase infiltration which reduces the volume of runoff, reduces the pollutant levels in water flowing into streams, rivers, and sewers, and helps to recharge aquifers.

Climate Change: SuDS may help reduce air pollution since trees and other vegetation filter out particulate matter and moderate ozone levels. Another improvement SuDS provide to the climate is the reduction of "The Heat Island Effect". This is a phenomenon that states that air temperature in densely built areas is higher than in its rural surroundings. London already suffers substantially higher summer temperatures than the surrounding rural areas (Figure 15). Heatwaves are likely to be an increasing problem in London in the future due to climate change. Since many SuDS components incorporate vegetation, such as trees, sustainable urban drainage systems may help alleviate the impact of climate change in London.

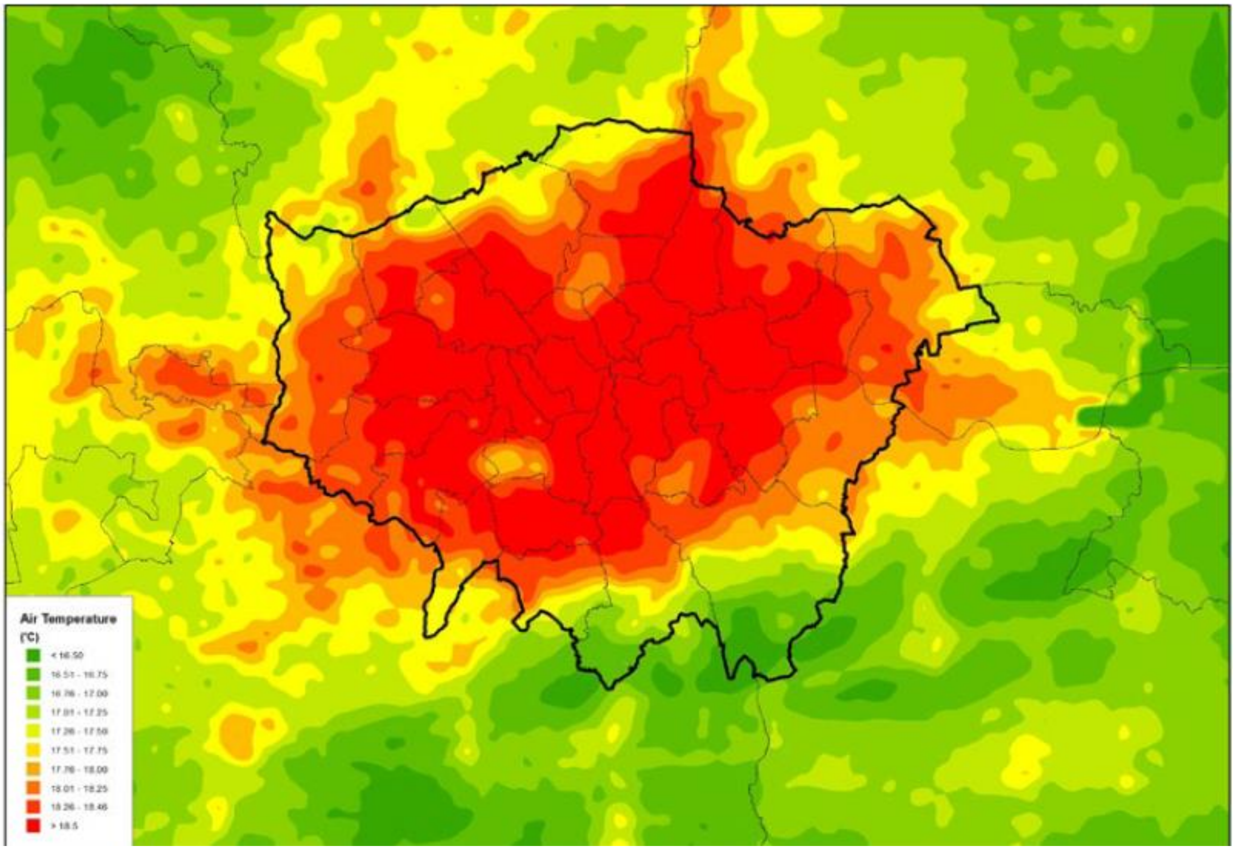

Figure 15: The London heat island effect. (ARUP, 2014)

Amenity: SuDS can create an attractive environment for residents and visitors, with many aesthetically pleasing components, like trees, rain gardens, or swales. SuDS create open spaces that encourage people to run, walk, and socialize, which will have positive outcomes for human health and well-being. SuDS tend to increase property values because of their aesthetic improvements and, by encouraging people to congregate in particular areas, they may offer business opportunities.

Maintenance and Cost: The benefits of maintenance and cost are closely related to each other. Based on interviews and reviews of documents such as “Greater Dublin Strategic Drainage Study”, it appears that sustainable urban drainage systems are often cheaper to install and maintain than traditional drainage methods (Environmental Management, n.d.). This completely differs from popular beliefs that sustainable urban drainage systems are expensive to construct and maintain. If a knowledgeable contractor is hired, maintenance prices decrease drastically (Environmental Management, 2017). The cost of SuDS is discussed more in depth in Section 6 below.

Water Quality: Sustainable urban drainage systems filter water pollutants as they work to reduce flood risk. The systems trap silt and other pollutants in the water that would otherwise clog the main drainage system and flow into the major water bodies in the area, especially the Thames River.

Flexibility: SuDS components are easy to adapt to multiple types of landscapes due to the range of different components that can be implemented. SuDS are flexible enough for retrofitting with existing traditional drainage systems to work together, improving drainage performance.

Increases biodiversity: SuDS are also used to increase biodiversity in the sites where implemented. They can be sites of great ecological value, not only because of the vegetation placed in them, but the wildlife they attract.

4.2 Conclusion

SuDS can alleviate flood risk and offer many other benefits. Contrary to common opinion, SuDS are often cheaper to install and maintain than traditional street and highway schemes. In spite of the numerous benefits provided by SuDS, adoption has been slow due to barriers and constraints explained in the following section.

5. Barriers and Constraints to the Adoption of SuDS

Based on a review of pertinent documents and a series of interviews with staff members of the London Borough of Camden, London Borough of Enfield, Thames Water, Thames 21, and Tfl, the team has identified a range of barriers that have prevented the implementation of SuDS. The barriers identified were concerns about maintenance, cost, funding, locational issues, impacts on parking, the relevance of projects to overall transport goals, and resistance by contractors, engineers, and project planner towards the use of SuDS. An overriding barrier to adoption is the lack of knowledge regarding SuDS components, their benefits, and the associated installation and maintenance costs (Figure 16).

Figure 16: Number of interviewees identifying particular barriers.

5.1 Maintenance, Lack of Knowledge, Cost

This subsection presents an integrated discussion of the barriers concerning maintenance, cost, and lack of knowledge because these three topics have many overlapping concerns.

From the interviews and research conducted by the team, concerns about maintenance were seen as the major barrier in adopting sustainable urban drainage systems. SuDS may require constant maintenance depending on the SuDS method implemented and cost is another major concern for many contractors, engineers, and other council staff. Concerns and misunderstandings about the responsibility for maintenance have prevented the implementation of several schemes. Because SuDS schemes often entail cooperation among several departments from highways to parks, there is often confusion about who should be responsible for maintenance.

Lack of knowledge has been noted as another barrier deterring the implementation of SuDS. Multiple projects across the borough could have implemented SuDS but staff did not know about the different types of SuDS available and the associated benefits. Another problem with the lack of knowledge and education is the misconception of the cost of SuDS. Since SuDS are a relatively new type of construction and not well understood by many, they are seen as an expensive type of construction, however these methods can be cheaper than traditional methods if implemented properly and introduced in combination with other planned works.

5.2 Funding

Seven of the thirteen interviewees discussed their concerns about the availability of funding for SuDS schemes. Interviewees were concerned about the source of funding, since internal funds are always limited and they feared redirecting funds to SuDS would take funds away from other projects or may not be applicable in the first place. Interviewees were unaware of alternative options for funding from within or outside the council.

5.3 Location

Figure 17: Photo of the damage done to one of the planters on Royal College Street.

The locational choices and decision making process were of concern to several interviewees. Finding suitable locations to implement SuDS schemes can be a challenge. Interviewees were concerned about issues such as the location of utilities, impacts on heritage areas, access for maintenance, and damage to the SuDS infrastructure installed. Depending on the SuDS component being implemented and where they are implemented, utilities can pose problems. For example, tree pits need a depth of about two meters and some utility cables are buried as little as 0.7 meters deep. An alternative SuDS components would have to be implemented in such areas since rerouting utility cables can be expensive. In heritage areas with the SuDS schemes would have to be designed to match the character of the area. SuDS schemes need to be located in areas that are easily and safely accessible for maintenance. For example, using rain gardens to separate bicycle lanes from traffic lanes can pose problems of safe access. Finally, poorly placed, infrastructure can get damaged by cars or people, as seen in damage to planters in the Royal College Street Project (Figure 17).

5.4 Resistance

Seven of the thirteen interviewees indicated that resistance to change from constructors, architects, contractors, and others is one of the main barriers for the implementation of SuDS. Many people are unsure about adopting sustainable urban drainage systems in their projects since they are a new form of drainage and not well understood. SuDS are not a traditional type of construction, which can result in people refusing to adopt these drainage components.

5.5 Irrelevance

Six out of thirteen interviewees found irrelevance to be one of the main constraints. SuDS were referred to as an “add-on” in one interview, and generally viewed as not very important or effective in the mitigation of flood risk. From the interviewees’ previous experience, engineers, and project managers would rather use the space for other uses, since they do not see SuDS as something relevant or useful for the community. Besides they believe that the benefits traditional methods have to offer are better and cost less. People believe that SUDS are too costly and time consuming to implement for the benefits they offer the community, this is why they rather build another structures, meaning that they do not see SuDS as a relevant option.

5.6 Parking

Some SUDS may result in a loss of parking spaces, which could result in substantial objection to the scheme from residents during the consultation stage. Furthermore a loss of Pay and Display parking would mean a loss of revenue for the Council. However, including SUDS on roads doesn’t necessarily mean parking space needs to be lost, for example, permeable paving can be used in parking spaces or other SUDS can be built in around parking spaces.

5.7 Conclusion: Overcoming the Barriers to the Adoption of SuDS

Clearly there are many barriers to the adoption of SuDS. The primary concerns are in regard to the costs of construction and the cost and ease of maintenance, but the staff that we interviewed raised a host of other concerns ranging from issues about parking, funding, impacts on heritage areas, and the difficulties of finding suitable locations for SuDS schemes. Many of these barriers result from a lack of knowledge and awareness about the costs and benefits of SuDS, as well as misperceptions and misinformation about costs in particular, which is why we focus on these issues more closely in the next section. Overcoming the barriers will involve a concerted effort in outreach and education to staff and stakeholders to enhance knowledge and awareness about the costs and benefits of SuDS. Our recommendations in this regard are discussed at the end of the report.

6. Costs of SuDS

Determining the costs of SuDS in general can be difficult and there a few publicly available documents that detail the precise costs of different SuDS schemes that have been installed. Furthermore, given the relatively recent attention to SuDS, there are few estimates of the long term maintenance and repair costs associated with SuDS. Nevertheless, the data we were able to gather indicate that SuDS schemes are often cheaper to install and maintain than conventional highway drainage schemes. The cost of SuDS schemes range from less than £50,000 to more than £500,000 depending on the size and complexity of the scheme (See Appendix B). Unfortunately, there are few detailed descriptions of the different cost elements for SuDS schemes, such as design, land preparation, installation, maintenance, and repair. Similarly, there are few estimates of the costs of new schemes versus retrofitting SuDS into existing drainage schemes, although some studies suggest that retrofitting SuDS is less expensive than new constructing (SNIFFER, 2006).

Capital costs vary depending on the SuDS design, materials selected, and size of project. Table 1 shows the range of materials costs for different elements that may be used in a SuDS design. Generally, we found that the cost of construction for SuDS is lower than for traditional methods (Table 2).

Land preparation is one factor that can dramatically alter the cost of a particular scheme. For example, the slope of the landscape can increase the price for the implementation of certain SuDS components, such as permeable paving. The type of soil can play an important role in cost of a project. It is generally cheaper to implement SuDS in areas with permeable soils since this obviates the need for more extensive drainage systems. Planting costs vary since different plants are used for different purposes and in different locations. If planting depths are limited due to the presence of utilities, the project may substitute rain gardens for trees and tree pits. The plants will be cheaper, but installation may require more expensive digging by hand to avoid disturbing the utilities.

Maintenance cost fluctuates depending on the SuDS method used, size, and accessibility to the component. Depending on the SuDS method used and its size, the maintenance fluctuates because the activities vary and the area that need to be maintained varies too.

Table 1: Estimate Unit Cost Different Kind of SuDS. (Kevin Keating, 2015).

SuDS Component	Cost	Source
Permeable Paving	£30-£40 per m². £27 per m² of replacement surface.	CIRIA, 2007 Stovin & Swan, 2007
Filter Drain	£100-£140 per m³ stored. £120 per m².	CIRIA, 2007 Environment Agency, 2007
Swales	£10-£15 per m-².	CIRIA, 2007
Infiltration Basins	£10-£15 per m³ stored.	CIRIA, 2007
Infiltration Trenches	£55-£65 per m³ stored. £60 per m².	CIRIA,2007 Environment Agency, 2007
Filter Strip	£2-£4 per m².	CIRIA, 2007
Retention Basins	£15-£25 pero m³ treated. £16 per m².	CIRIA, 2007 SNIFFER, 2007
Detention Basin	£35-£55 per m³ stored.	Stovin & Swan, 2007
Concrete Storage Tank	£449-£518 per m³ stored.	Stovin & Swan, 2007
Attenuation Crates	£344 per m³ (including attenuation system, civils/groundworks, all associated works and on costs).	Argent, 2017
Urban Tree Soil	£3500 per tree (total scheme).	Argent, 2017.

Table 2: Savings in SuDS construction compared with Conventional methods.

SuDS	Savings in Construction Costs Compared to Conventional Methods (%)
Pipe Drainage System and Gullies	**0%**
Permeable Paving (no infiltration)	**30%**
Permeable Paving (infiltration)	**44%**
Filter Strip and Filter Drain	**13%**
Filter Strip and Swale with Kerb Inlet	**24%**
Filter Strip and Swale with Gullies	**15%**
Filter Drain and Gullies	**3%**

If SuDS are implemented in a location that is hard to access, maintenance may be more difficult and take longer to perform, which will increase costs.

Design costs vary depending on the creator of the design, features in the design, and its hydraulic design. Costs may be lower if the design is done in-house compared with contracted out. Since SuDS are a flexible, all sorts of features can be added to the design, altering the price. Hydraulic design can affect the cost depending on the volume of storage and capacity of water draining. The more storage volume, the bigger the attenuation tanks, and the higher the cost. The faster these schemes drain water, then more expensive they tend to be because they use more sophisticated techniques and more expensive materials.

Location can be an important factor when implementing SuDS since the price shifts depending on the land being bought, the accessibility of the location, number and type of properties affected by the scheme, and if the area has many underground utilities. The location of the land being used can exponentially increase the cost of the project, as well as the accessibility of this area since it can bring construction and maintenance costs up. Also, the properties affected by this location can be an important factor, since if the maintenance needs to close a road or some activity of this sort, it can affect residents of the area and businesses. Underground utilities can bring prices of any construction up since the rerouting of these can cost huge sums of money, even working around them can be costly and troublesome.

Replacement of SuDS components cost is hard to estimate because the scheme's life depends on many factors like maintenance, damages, and the component itself. If maintenance is not done properly, the life of the SuDS component can be reduced, therefore accelerating the process of replacing it. If these schemes are damaged, they also need to be replaced, this is also affected by the location of the scheme. Finally, the component itself has a useful life, but there is not a great deal of information about the life of SuDS components, although Table 3 below can serve as a guide (Environment Agency, 2015).

Table 3: Design Life Estimates for SuDS

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SuDS Component	Design Life	Component Design
Green Roofs	Unlimited design life	N/A
Permeable Paving	Unlimited design life	20-25 years before replacement of filter material
Filter Drain	Unlimited design life	10-15 years before replacement of filter material
Swales	Unlimited design life	5-20 years before deep tilling required and replacement of infiltration surface
Infiltration Basin	Unlimited design life	5-10 years before deep tilling required and replacement of infiltration surface
Infiltration Trench	Unlimited design life	10-15 years before replacement of filter material
Filter Strip	Unlimited design life	20-50 years before replacement of filter surface
Wetland	20-50 years	Sediment disposal after 10-15 years
Retention Basin	20-50 years	
Detention Basin	20-50 years	Sediment disposal after 10-15 years

Cost Estimation

To estimate the cost of a SuDS scheme, there are certain steps that need to be followed. The first step to consider is to evaluate all planning, administration, and design costs. Then determine the capital costs and any future replacement costs. Afterwards, determine all inspection, annual, and intermittent costs. Then, discount future costs to present value which can be easily done in Excel with the formula "PV", which uses the number of years, inflation, payment done each period, and the future value. Moreover, sum capital, maintenance, and replacement costs. Finally, evaluate the whole life cost (Environment Agency, 2015).

7. Missed Opportunities for SuDS in Camden

Many streetscape and highway projects in Camden have been designed and implemented to account for the risk of flooding, but none of the projects have yet used SuDS. In the documents "Better Streets Delivered" and "Better Streets Delivered 2", Transport for London reports on nine street projects recently completed in the London Borough of Camden, but none of these incorporated SuDS (See Table 4).

Table 4: Highway projects and measures taken.

Project	Measures
Great Queen Street	Remove all unnecessary clutter, add kerb crossings and low kerb, remove signals and increase pedestrian crossing points.
Bloomsbury	Widened footways, relocated car and coach parking, one way exit removed, raised the carriageway, relocation of trees, introduction of seating, and carriageway reduction.
Britannia Junction	Narrowing carriageways, relocation of kiosks, installation of signals at road crossings, and introduction of advanced cycle stop lines.
Royal College Street	Two cycle lanes, armadillo bumps, planters, relocation of parking.
Euston Circus	Facilitating two way travel for buses and cyclists, bicycle parking, enhanced stop signs, tree planting, and better signage.
Holborn Circus	Realigning the junctions, adding of pedestrian facilities, advanced stop lines, lead-in lanes, and a more legible layout.
Earlham Street	N/A
West Hampstead	N/A

Table 4.1: Highway projects and stakeholders.

Project	Stakeholders
Great Queen Street	London Borough of Camden and City of Westminster.
Bloomsbury	British Museum, Camden Cycling, Coach operators, Confederation of Passenger Transport, English Heritage, LB of Camden, Tfl, University of London and UCL, 2012 Olympic Development Authority.
Britannia Junction	Camden Town Unlimited, London Borough of Camden, Tfl.
Royal College Street	Camden Cyclists, LB of Camden, Tfl, UK Power Networks.
Euston Circus	British Land, LB of Camden, London Cycling Campaign, Mayor's Design Advisory Group, Mayor's Great Outdoors Program, Tfl, University College Hospital.
Holborn Circus	Camden Cyclists, City Cyclists, City of London, Historic England, LB of Camden, Local businesses and residents, Tfl, St. Andrew Holborn church, Various statutory utilities, The Victorian Society.
Earlham Street	N/A
West Hampstead	N/A

Table 4.2: Highway projects with information on SuDs.

Project	SuDS Scheme	Implemented	Performance	Difficulties	Date of Completion
Great Queen Street	None	No	N/A	N/A	September 2009
Bloomsbury	None	No	N/A	N/A	Summer 2011
Britannia Junction	None	No	N/A	N/A	July 2012
Royal College Street	None	No	N/A	N/A	August 2013
Euston Circus	None	No	N/A	N/A	December 2013
Holborn Circus	None	No	N/A	N/A	2014
Earlham Street	Arborflow Tree Pits	No	N/A	Utility cables and maintenance concerns	In Progress
West Hampstead	Tree Pits	No	N/A	Underground utilities	In Progress

These projects have aided the community by enhancing the Borough's streets and made them safer by taking measures to reduce traffic speed (Better Streets Delivered 2 page 16, 2017). These projects have encouraged cycling and walking, which is one of the priorities of the Boroughs Transport Strategy, as stated by "Camden's Transport Strategy" from the previous chapter. Some of these projects have:

- Increased biodiversity
- Added green components;
- Encouraged active travel, exercise (walking and cycling), and reduced carbon emissions.

Unfortunately, the schemes could easily have incorporated SuDS elements, which would have delivered added benefits. For example, the Great Queen Street development, contractors (Volker Highways) created several large public spaces with relocated parking areas and wide footpaths that could have incorporated various SuDS elements that would have further enhanced aesthetics. The Bloomsbury

Figure 18: Montague Place project. (Google Maps, n.d.)

project was a huge scheme broken down into four smaller sections (Montague Place, Malet Street, Great Russel Street, and Byng Place). The section involving Montague Place (Figure 18) at the rear entrance of the British Museum, creates an informal square which has plenty of room to implement sustainable drainage in the form of tree pits, rain gardens and permeable paving.

Figure 19: Royal College Street planters.

In the Royal College Street scheme, planters were used to separate the bike and traffic lanes (Figure 19). These have no flood control benefits, present a hazard to cyclists and drivers, and have become an eyesore due to lack of maintenance. A raised strip of grass could have been used (with infiltration to soil) instead. Such a strip would have reduced runoff, increased infiltration, been easier to maintain, aesthetically more pleasing, and safer.

Figure 20 shows how JB Riney & Co Limited (Better Streets Delivered 2, page 43, 2017) redesign the Holborn Circus road junction to improve safety and traffic flow. Trees were incorporated into the pedestrian plaze created to the south of the intersection, but additional SuDS elements, such as tree pits and rain gardens could have been incorporated. These would have reduced runoff, increased water infiltration, and enhance aesthetic and amenity values.

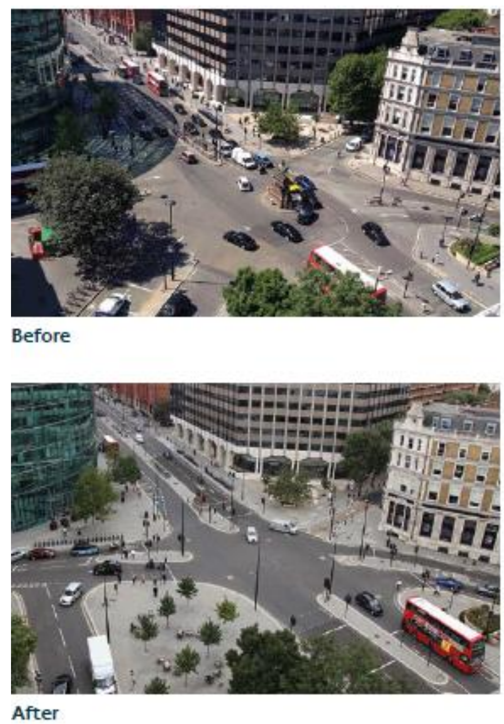

Figure 20: Holborn Circus project. (Better Streets Delivered 2, 2017, page 43)

7.1 Current Projects in Camden

Earlham Street project included plans for Arborflow tree pits on the side of the roads that would have replaced parking spaces. The trees and tree pits could not be installed, however, due to the dense clutter of utilities (such as fiber optic cables) just 0.3 meters underground, Figure 21). Tree pits require 2 meters of soil and rerouting of the utility cables would cost thousands of pounds. Designers consider the use of planters as an alternative, but those options were discarded due to a variety of concerns, mostly pertaining to maintenance.

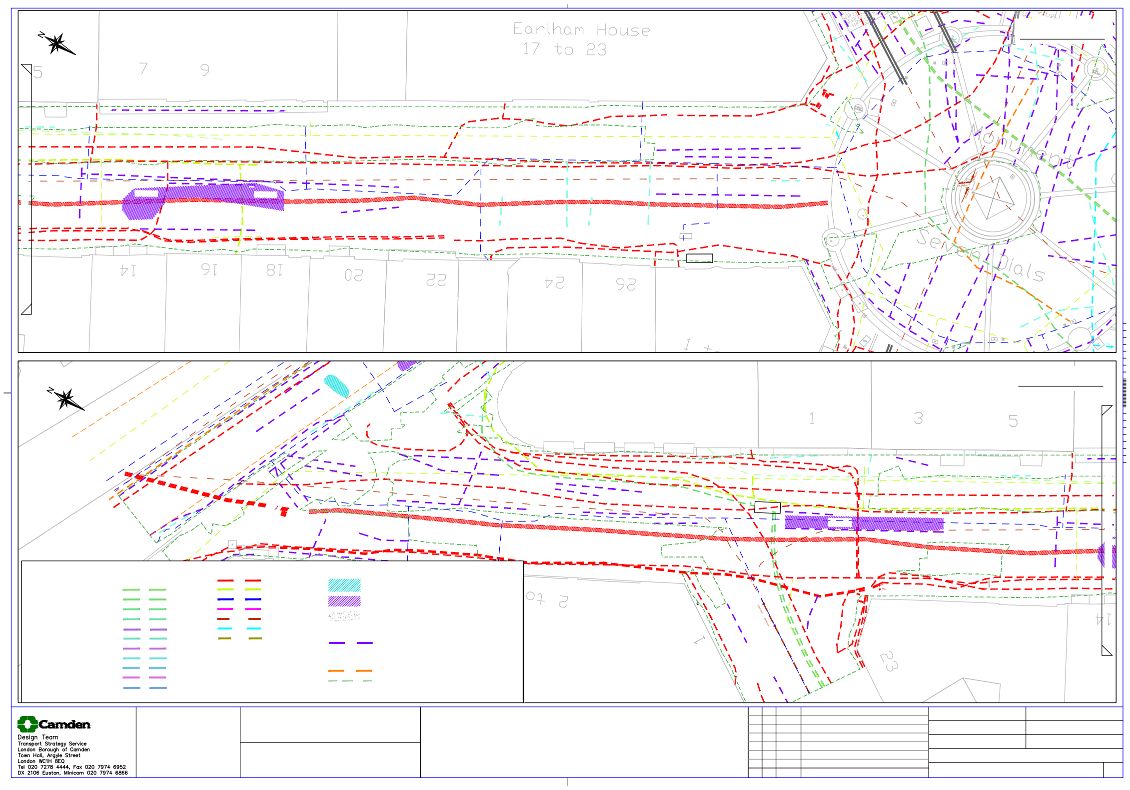

Figure 21: AutoCAD drawing of Earlham Street.

The proposed surfacing for the Earlham Street project will be granite, an expensive material costing from £130 to £160, per square meter excluding the cost for the base. Although it is more aesthetically pleasing than the current roads, granite is costly and implementing permeable paving could be a cheaper option. Permeable paving costs about £30 to £40 per square meter, and would reduce runoff and increase infiltration.

The West Hampstead area suffered from the floods in 1975 and 2002. The council has plans to revamp all of West Hampstead, specifically the West End. The plan was to implement Arborflow tree pits and permeable paving but the plan did not go through due to concerns about underground utilities although it would seem that resin bound gravel (permeable paving) could be used.

In sum, the council is beginning to consider the inclusion of some SuDS elements in highway projects, but there are likely many other opportunities available. In the next section, we review a case study from Enfield that illustrates a more comprehensive SuDS project.

8. Alma Road Case Study

Introduction

Alma Road is a street located in the London Borough of Enfield. It has houses on both sides and a primary school and a secondary school close by. This road, as well as some nearby roads, was prone to flooding before this SuDS scheme was implemented. Previously, the street was paved with several gullies for drainage. Now the street has a number of rain gardens retrofitted to the gullies (Figure 22), that can accommodate 1/100 year rain storms. The project has enhanced the drainage capacity of the road and improved aesthetics and safety. The SuDS scheme in Alma Road was mainly pushed by the "All London Green Grid" (ALGG) policy that promotes the design and delivery of green infrastructure across London (London Government, 2015).

This project is a part of "The Green Infrastructure Strategy", which is a network of green spaces that have been planned or implemented with the goal of providing recreation and amenities, healthy living, reducing flooding, improving air quality, cooling the urban environment, encourage walking and cycling, and enhancing biodiversity and ecological resilience (London Government, 2015).

Summary

Location: London Borough of Enfield.

SuDS Component: Rain Garden.

Type of Scheme: Trial Scheme.

Date of Completion: March, 2016.

Size: 130 square meters.

Cost of Construction per m^2: £300

Cost: £50,000 total scheme (including a nearby school seminar and a mural painting).

Sponsor: GLA

Stakeholders: LB of Enfield

Maintenance: Littering and weeding.

Maintenance Cost: £0.60 per m^2.

Objective of Project: Improve drainage, filter water pollutants, infiltrate water underground, reduce traffic speed, and improve pedestrian infrastructure.

Main Policy: GLA Green Infrastructure Project.

Figure 22: Comparison of Alma Road before and after implementation of rain gardens. (Mayor of London, 2016)

Retrofitting SuDS

The SuDS design integrated rain gardens with the previously existing drainage system (See Figure 24). If severe rains exceed the infiltration capacity of the gardens, excess water flows into the existing drainage gullies.

Maintenance

According to the Borough, the maintenance for this project is not only simple but inexpensive. These rain gardens only need maintenance twice a year, and it consists of weeding and litter picking. The cost for the annual maintenance is approximately £78.

Figure 23: Satellite photo of Alma roads. (Google Maps, n.d.)

Challenges

The project faced a few minor problems. The granite curbs were damaged by cars and had to be reinforced with additional concrete. The rain gardens had to be installed through manual digging due to the shallow depth of the utility cables. While maintenance costs are low, the contractor under-bid the costs and has been reluctant to maintain the area adequately since the rate of return is minimal.

Figure 24: Gully in rain garden.

Benefits

This scheme has brought multiple benefits to Alma Road and the people residing and transiting it. Not only is this project aesthetically pleasing, but it also improves the water and air quality, mitigates flood risk, encourages slower driving, and encourages walking and cycling due to the improvement of the road's infrastructure.

Recommendation

Based on the LBE reviews, they recommend that in similar projects in the future the borough should consider:

- Hiring knowledgeable contractors to be in charge of the maintenance, not necessarily taking the lowest bid.
- Reinforcing curbs when constructing to protect them against damage.
- Increasing the frequency of maintenance from semiannually to quarterly.
- Replant every 2 or 3 years to ensure that the scheme is full of plants, not weeds.
- Build the rain gardens at the same level as the gullies

9. Potential Opportunities for SuDS Schemes in Camden

We obtained a list of 104 current street projects and overlaid them on a GIS version of the SFRA flood risk map Figure 25 shows the schemes inside flood risk zones (red circles). TheBusiness Improvement District boundaries are marked in yellow circles. In consultation with council staff, we identified seven schemes (Table 5) that might be suited to the inclusion of SuDS. After reviewing the list and meeting with some of the scheme owners, we determined that we would create potential SuDS schemes on Pratt St with Yavuz Kalayci, Arlington St with Alexis Bielich, and a Kings Cross Gyratory Scheme with Acacia Hasler. We discuss the SuDS options for each below.

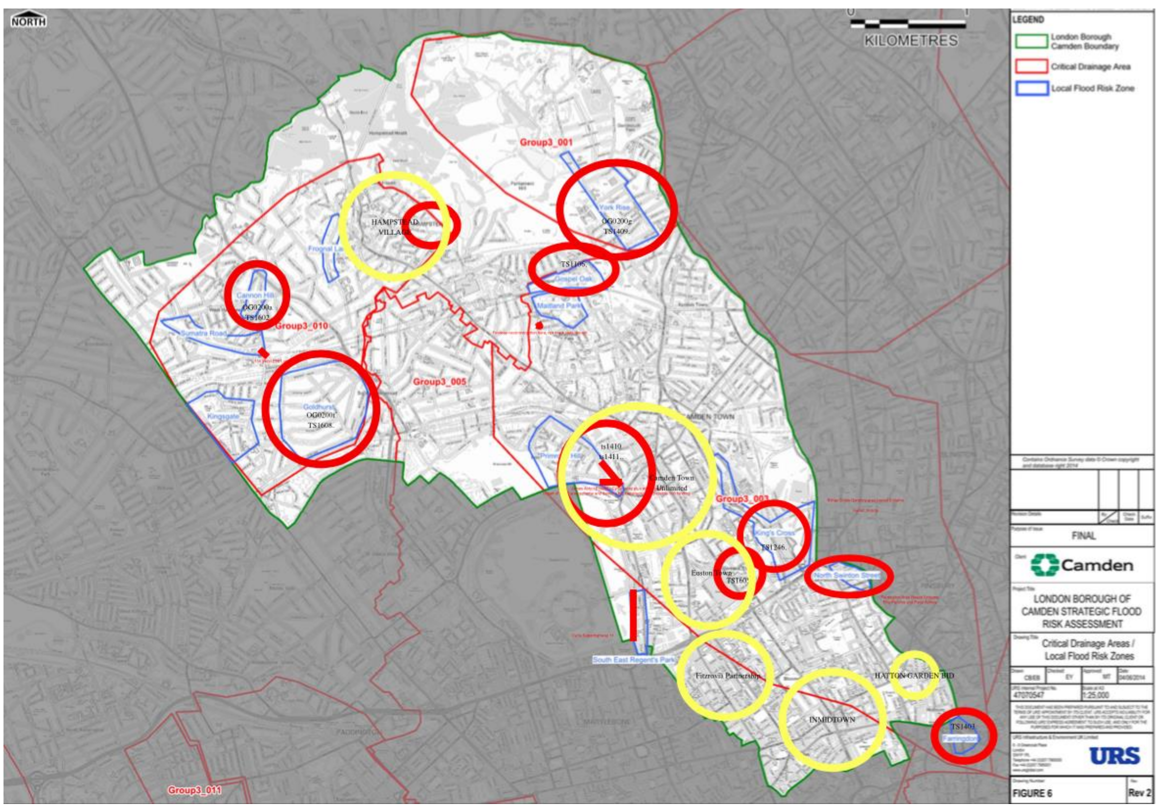

Figure 25: flood risk zone, BIDs, and current street project in flood risk zone.

Table 5: List of street project candidates.

Scheme Code	Status	Priority	Cost Code	Scheme Name
TS1246.	Live	3	CDCP7404	KingX and wider area ABS
TS1106.	Live	6	CDCD7336	Gospel Oak - ABS
OG0200b	Live	19	sub-scheme	STP-Christopher hatton
TS1403.	Live	8	CDCD7438	Farringdon ABS
TS1605.	Live	27	Code Needed	Somers Town ABS
ts1410.	Live	52	CDCP7519	St Pancras Way to Parkway via Delancey and Pratt St
ts1411.	Live	54	CDCP7522	Jamestown Road South along Arlington Road and Hampstead Road to Euston Road
TS1608.	Live	57	Code Needed	Q3 Regents Pk to Gladstone Pk

9.1 Pratt Street

Introduction

The Pratt and Delancey Scheme is a cycle project on Pratt Street and Delancey Street (Figure 26). The scheme is designed to make it safer for pedestrians and cyclists. Pratt Street will become one-way westbound with a cycling track in the other lane. The step track is a raised pavement track to protect cyclists from passing vehicles. Buildout islands will make it safer for pedestrians to cross. Step tracks will also be created on Delancy Street with additional features to improve pedestrian safety. This scheme is located near Primrose hill, which is a flood risk zone. It is also located in the center of one of the Business Improvement Districts, Camden Town Unlimited. We are proposing SuDS designs for Pratt Street only (boxed in red on Figure 26. Delancey Street will not include any build outs or SuDS elements, since there are cellars and utilities under the footway.

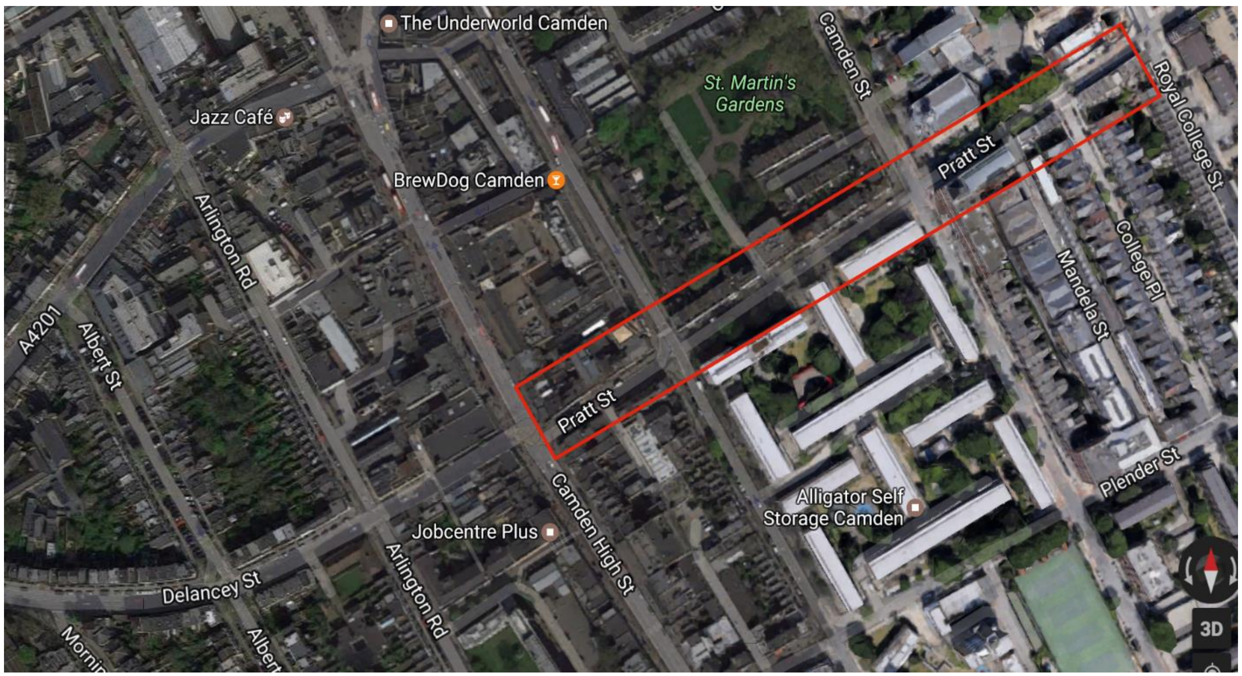

Figure 26: Satellite photo of Pratt Street. (Google Maps, n.d.)

Summary

Location: Pratt and Delancey Street

Type of Scheme: Cycle Scheme

Scheme Owner: Yavuz Kalayci

Objective: Make safer crossings for pedestrians and safer cycling lanes through the use of step-tracks for cyclists and raised intersections for pedestrian crossings

Potential SuDS Locations: Build-outs on Pratt St where there are few utilities underneath and gullies nearby for drainage

SuDS Components: Rain Garden or Tree Pits

Scheme 1: Rain Gardens with Drainage Pipes

We are proposing to use the build outs on Pratt Street to implement rain gardens (Figure 27). Each purple marker on this figure represents a gully. The gully location is important because with London clay being highly impermeable, the water needs to be drained slowly into either a nearby gully or the combined sewer network. Since Thames Water charges to connect directly to the sewer, we propose connecting the drainage pipes to the gullies. Two locations have been boxed; one in pink and one in blue, as the preferred locations for the SuDS due to the plethora of gullies. The blue box is the main focus as there is more room to implement the rain gardens. A conceptual drawing of the rain gardens can be seen in Figure 30.

Figure 27: Street scene of Pratt Street. (Google Maps, n.d.)

Figure 29: Gullies on Pratt Street. (Google Maps, n.d.)

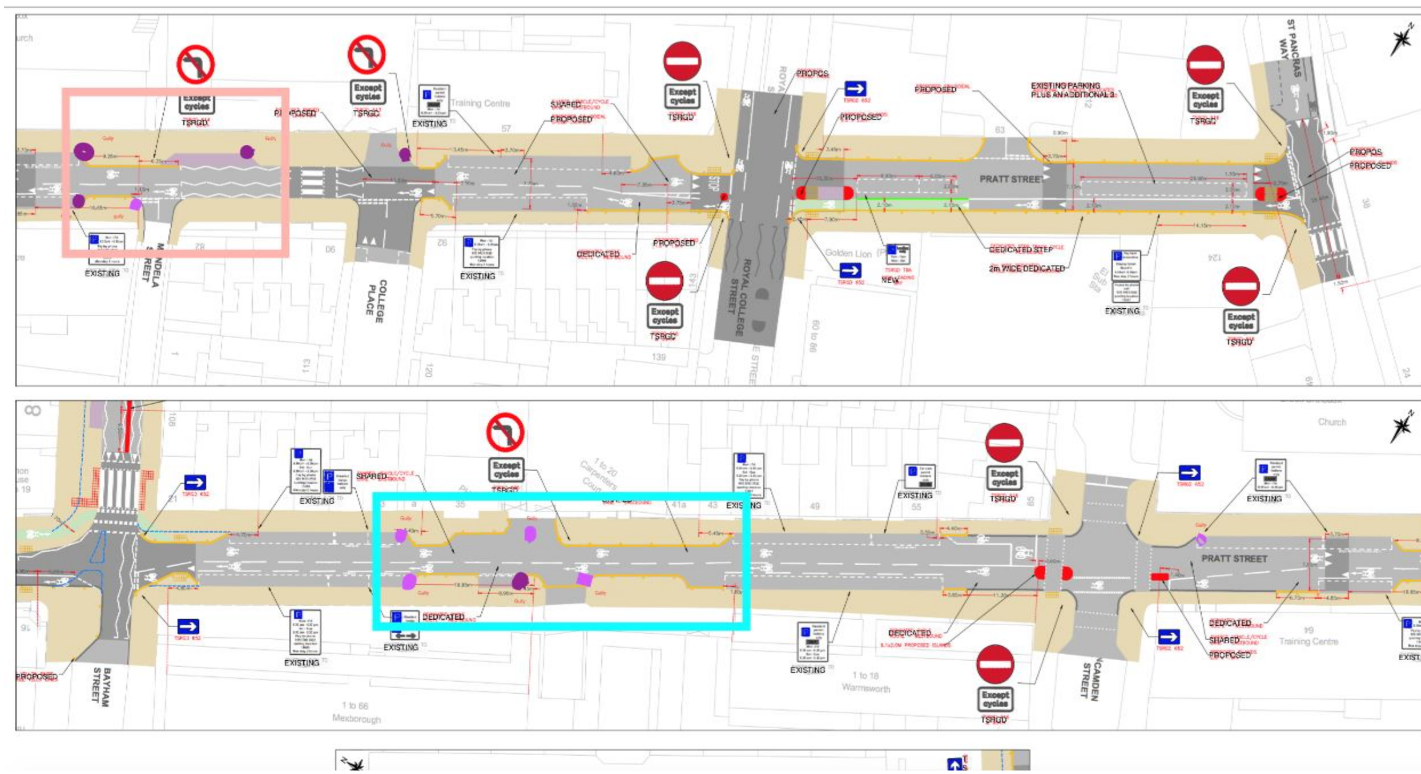

Figure 28: CAD drawing of Pratt Street.

Barriers

Possible barriers to this scheme are the presence of underground utilities. Since the build-outs are recent, it is likely no utilities are located below, but an underground survey will be necessary before any real planning can begin. If there are utilities underground, a rain garden can still be built but it will require hand digging around the utilities, which will increase the costs. The largest barrier that must be overcome is maintenance funding. While funding for the capitol costs is readily obtainable, there is virtually no funding given for maintenance. The council itself does not have money put aside for the maintenance. The EA does offer maintenance funding, but only to non-LLFAs. Some possible ways to obtain funding for maintenance could be through Camden Town Unlimited, a local Primary School could cover the maintenance as a science project, or as proven in some cases by Thames 21, businesses that are directly impacted by the scheme can contribute money towards the funding.

SWOT Analysis:

- Alma Rd coped with a 1 in 100 year storm with no flooding. Same result could be possible in this site.
- No danger of property flooding, as any excess water will drain to the gully.
- Amenity, biodiversity and water treatment benefits as well as reduced surface water run-off:
- Easy to maintain, funding is issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

Figure 30: Conceptual drawing of garden on Pratt Street. (Google Maps, n.d.)

Costs

Rain Garden: £300/m^2
Maintenance: £0.60/m^2

Drainage Pipes: £120/m^2
Maintenance: £30-50/m^2, (up to £100 with inexperienced contractor)

Overall Maintenance: should be maintained twice a year, but some recommend four times a year. Replant every two or three years to ensure that the rain garden is full of plants and not weeds

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding. Also Camden Town Unlimited is interested in collaborating on a scheme within their boundaries.

Scheme 2: Tree Pits

The concept for the second design on Pratt Street is quite similar to the first one. Like the first, we propose using the build outs given the likely absence of utilities. Since we propose placing attenuation tanks under the tree pits to collect the water, the location of the gullies are still important. The tree pits will be dug near the gullies and attenuation tanks will be placed below to collect water and release some into the ground. If the capacity is exceeded, the excess will flow into the gullies through drainage pipes. As seen in Figure 31, the tree pit needs to be around 1.5m deep with $12m^3$ of urban tree soil. Figure 32 is a rough sketch of what trees on these build-outs might look like.

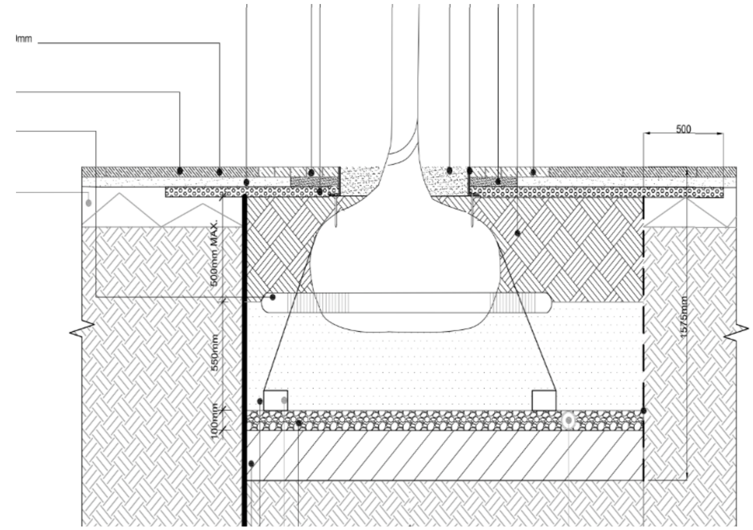

Figure 31: Scheme of tree pits' root part. (Argent LLD, 2017)

Figure 32: Conceptual drawing of tree pits on Pratt Street. (Google Maps, n.d.)

The barriers to this design are quite similar to that of the first. The build outs are recent so the chance of utilities is slim, but with tree pits there is a chance of large cost increases. If encountered, the utilities would have to be rerouted which would increase costs substantially, which makes an underground survey more imperative. Maintenance funding will still be a barrier, but it will be less important because the trees will be maintained by the green space team. Funding would have to be found for attenuation tanks and the drainage pipes.

Polystorm Attenuation Crate

There are multiple options when choosing which attenuation crate to use. We recommend the Polystorm crate as seen in Figure 33. This crate is lightweight, durable, and has a 50-year design life. It also has premade pipe connection locations, which will make it easier to connect these crates to a nearby gully. They even have two different versions depending on how much load will be applied on top. Since these crates will go below trees, we recommend the Polystorm Lite. With a depth of only .4 meters and a length of 1 meter, it will fit right into a normal tree pit with very little extra excavation.

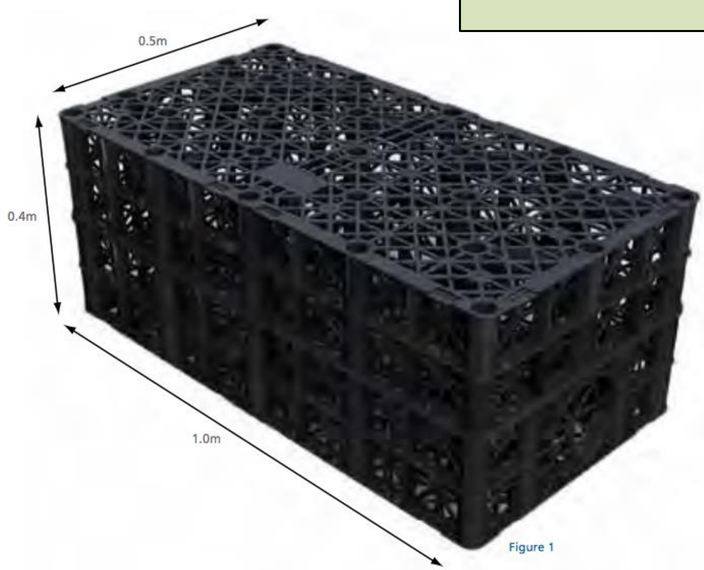

Figure 33: A photo of polystorm crate. (Polypipe, n.d.)

SWOT Analysis:

- Presents no danger in property flooding, as any excess collection will drain to the gully.
- Amenity, biodiversity and water treatment benefits as well as reduce surface water run-off:
- Easy to maintain, funding is an issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

Costs

Tree with Urban Tree Soil: £3500 per tree
Maintenance: £20.50 per tree per 3-year cycle

Attenuation Tanks: £344/m^3
Maintenance: only maintenance is keeping the pipes and gullies clear.

Drainage Pipes: £120/m^3
Maintenance: £30-50/m^2, (up to £100 with an inexperienced contractor)

Overall Maintenance: should be maintained twice a year, but it is recommended to inspect the tanks after any major storm event.

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding. Also Camden Town Unlimited is interested in collaborating on a scheme within their boundaries.

9.2 Arlington Street

Introduction

The Arlington Road scheme runs from the crossing of Jamestown and Mornington Crescent (Figure 34). This street is located near Primrose Hill, which is a known flood risk area. The scheme is not complex. It consists of some signage changes, minimal road resurfacing, and proposed tree planting locations. Since there is minimal work being done on this scheme, the only viable SuDS option would be to use tree pits with Polystorm attenuation crates, since the funding for trees will already be provided, the only funding needs will be for will be for capital and construction costs.

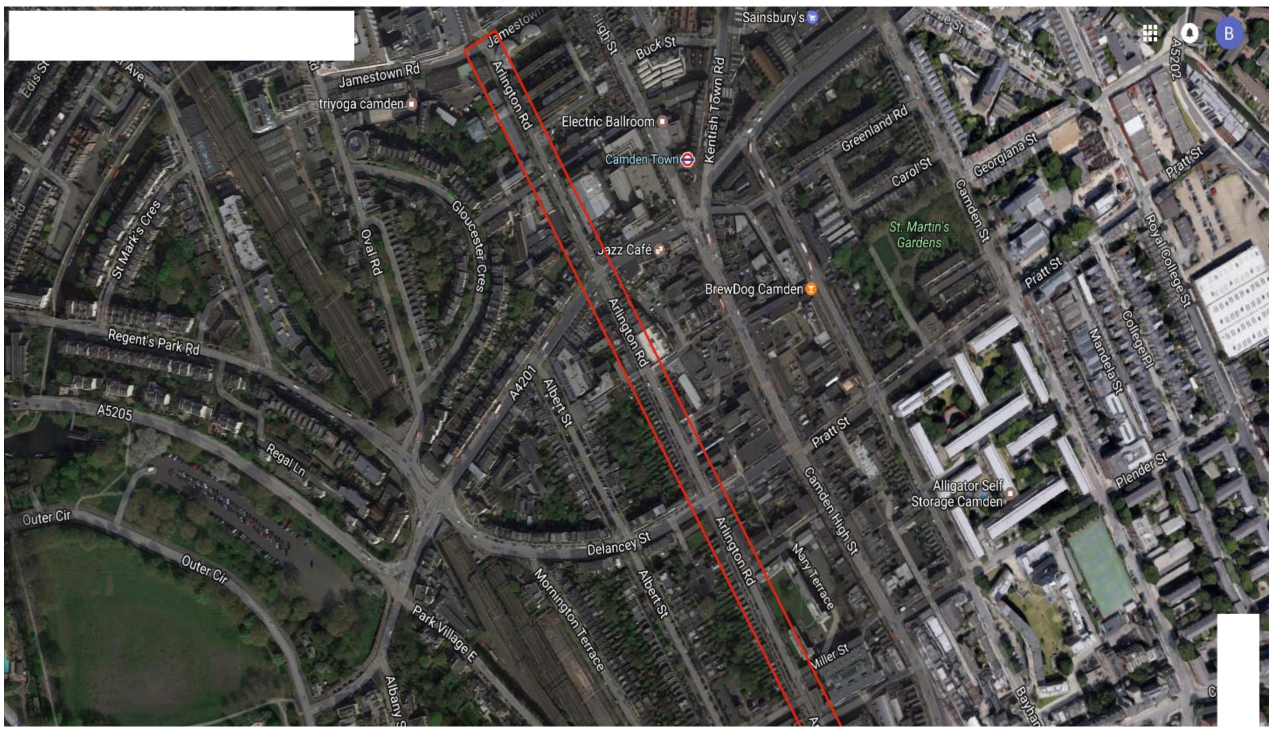

Figure 34: Satellite photo of Arlington Street. (Google Maps, n.d.)

Summary

Location: Arlington Road.
Type of Scheme: Cycle Scheme.
Scheme Owner: Alexis Bielich
Objective: Create safer cycle lanes through minimal road resurfacing, signage changes, and some parking bay relocations. There is also a push for tree placement.
Potential SuDS Locations: All potential tree placement locations.
SuDS Components: Tree Pits with Polystorm attenuation crate.

Scheme Design:

We propose installing trees on Arlington Street (Figure 35) at potential locations marked in Figure 36. A red “X” marks locations with existing gullies, and blue “X” indicates location without gullies. We found only three of the locations had nearby gullies (Figure 37) which are the preferred locations. Since they are located on the main street, we recommend using the Polystorm crates because they are rated up to 40T of load. Details of the Polystorm crate can be found in the manufacturer pdf that will be provided along with the summary of it in the Pratt Street Scheme. If a car were to park too close to the tree it would not damage the crate. The orange arrow in figure 37 is pointing to a proposed raised chicane, which could hold a rain garden, however when the scheme owner proposed the idea, it was declined.

Figure 35: Street scene of Arlington Street. (Google Maps, n.d.)

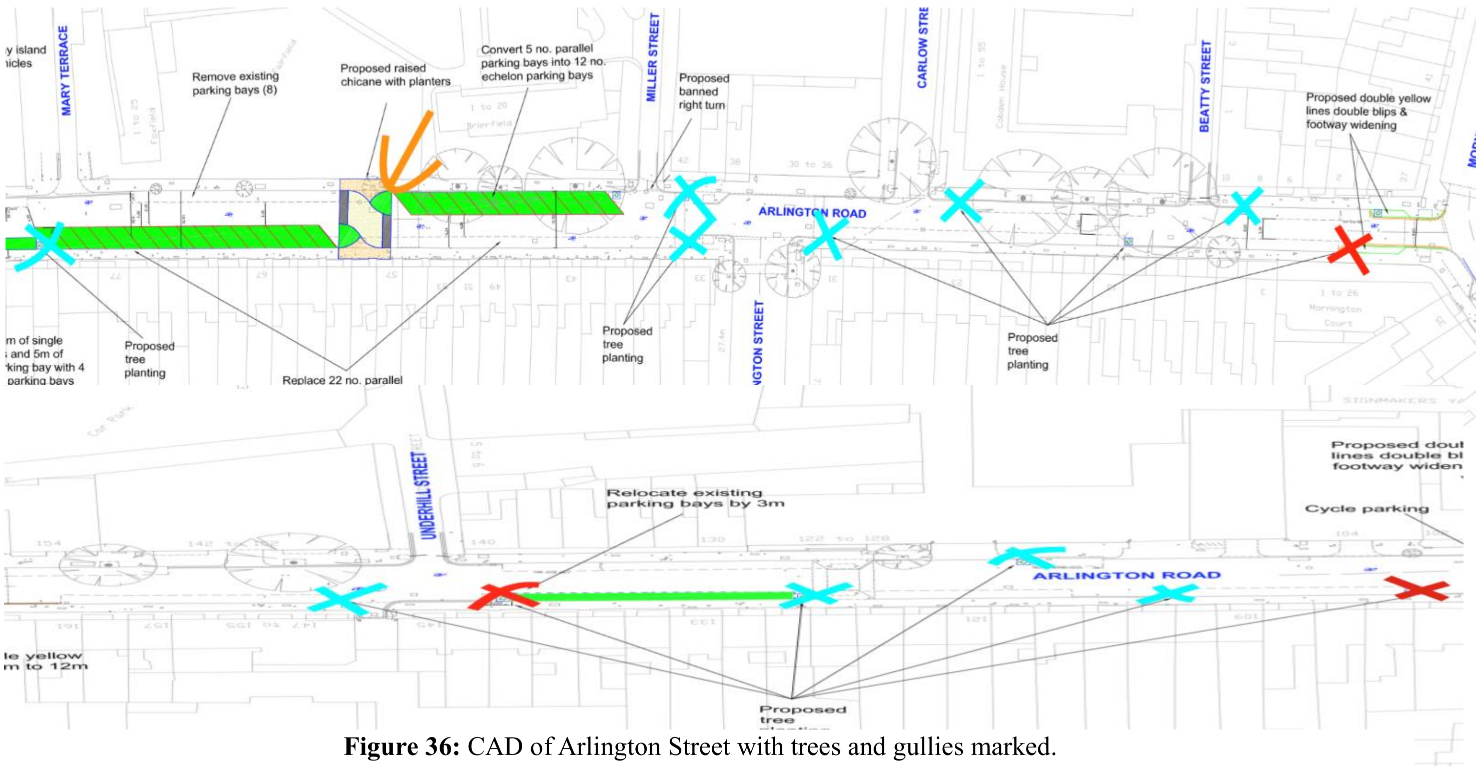

Figure 36: CAD of Arlington Street with trees and gullies marked.

Figure 37: Gullies on Arlington Street. (Google Maps, n.d.)

Barriers

The main barrier to this design will be underground utilities and the need to protect the trees with bollards or buildouts. Since the trees will be located on the side of the carriageway, there is only a small chance of utilities being in the way, however an underground survey will be necessary to confirm. The scheme is close enough to a flood risk zone that it may be possible to get capital funding from the Environmental Agency if the Council can prove flood risk. However maintenance funding will be a barrier that currently has no definite solution. The green space team has the funding to maintain the trees, but the pipes need to be cleaned of debris twice a year. One possible solution to this is using businesses that are directly impacted by the scheme to help fund the maintenance.

SWOT Analysis:

- Presents no danger in property flooding, as any excess collection will drain to the gully.
- Amenity, biodiversity and water treatment benefits as well as reduce surface water run-off:
- Easy to maintain, funding is an issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

Figure 38: Conceptual drawing of tree pits on Arlington Street. (Google Maps, n.d.)

Costs

Tree with Urban Tree Soil: £3500 per tree
Maintenance: £20.50 per tree per 3-year cycle

Attenuation Tanks: £344/m^3
Maintenance: only maintenance is keeping the pipes and gullies clear.

Drainage Pipes: £120/m^2
Maintenance: £30-50/m^2 (up to £100 with an inexperienced contractor)

Overall Maintenance: should be maintained twice a year, but it is recommended to inspect the tanks after any major storm event.

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding.

9.3 Gyratory Street

Introduction

The gyratory scheme in the Kings Cross area consists of Midland Road, Gray's Inn Road, York Way, Pentonville Road, Swinton Street, Acton Street, and Penton Rise as seen in Figure 39. The two crossed out roads are Pancras Road and Goods Way, which were removed after Midland Road was added to the scheme. The main purpose of this scheme is to turn these one-way roads into two ways to make for a more simplified traffic pattern. As seen in the figure, the red arrows are the current directions of each road, and the green arrows are the proposed directions. The roads will all be resurfaced to make it safer for pedestrian crossings and cyclists. Besides the adjustments to the road surfacing there will be an increase in footways or additions of a public realm. While those areas are not yet known, those would be the obvious areas to incorporate SuDS. SuDS to consider include permeable paving, rain gardens, tree pits with attenuation tanks, and swales. While there are several other options we confine our discussion to these four because they are the most replicable across Camden's highway and streetscape projects.

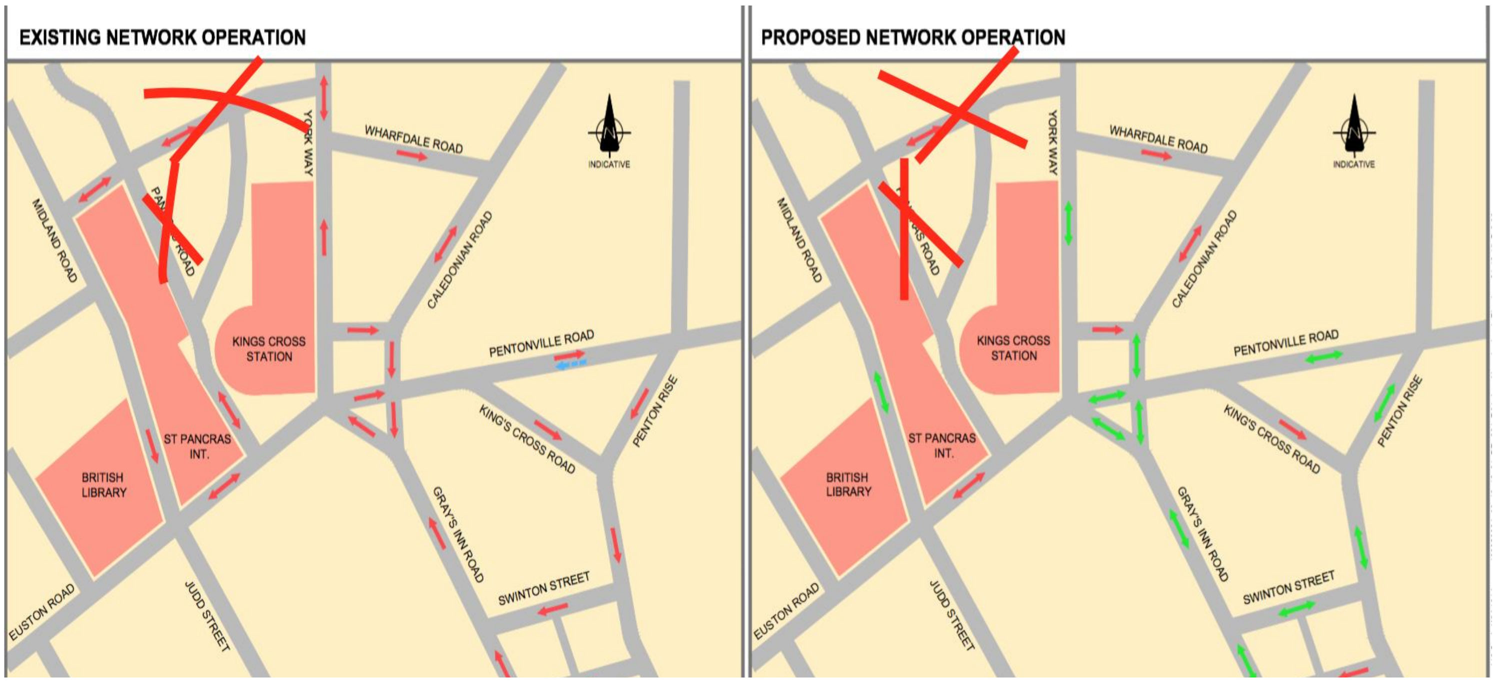

Figure 39: Map of proposed scheme on Gyratory Street.

Summary

Location: Kings Cross

Type of Scheme: Gyratory Scheme

Scheme Owner: Acacia Hasler

Objective: Turning one-way streets into two ways to make safer crossing for pedestrians. There will be some public spaces and extended footways but their locations are unknown.

Potential SuDS Locations: Extended footways, public spaces.

SuDS Components: Permeable paving, rain gardens, tree pits with attenuation tanks, and swales.

Scheme Design Options:

Since this scheme is still in its conceptual phase, we are proposing only general ideas about different SuDS options that might fit into the scheme. Since there are expected footway expansions, instead of concrete, the Council could expand using permeable paving as seen in Figure 40. Another option on these extended footways would be to instead build rain gardens and attach the drainage pipes to a nearby gully, as seen in Figure 41, a swale could also be placed on the extended footway with the drainage pipe connecting to a gully as seen in Figure 42. Since the scheme also has possible public spaces a rain garden or swale could be placed there also. The ground could also be made of permeable paving because it does have an aesthetic look. Also in this public space the Council can place trees with attenuation crates such as what the private developer, Argent, has done in Granary Square as seen in Figure 43.

Figure 40: A photo of permeable paving.

Figure 41: A photo of rain garden with a gully nearby.

Figure 42: A photo of a swale. (Susdrain, n.d.)

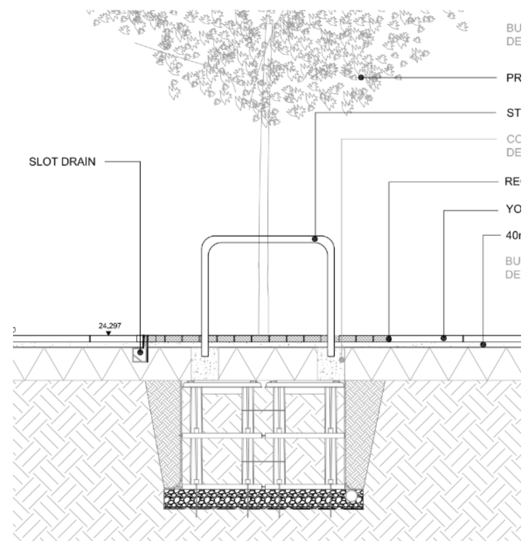

Figure 43: Scheme of tree. (Argent LLD, 2017)

Barriers

The potential barriers to these SuDS schemes are similar to those discussed previously. Underground utilities (Figure 44) are problematic. Swales or rain gardens can be worked around utilities, but tree pits would require rerouting utilities, which is expensive. Another barrier would be gully location. Since London's clay is impermeable, the SuDS need to be attached to a nearby gully to drain any excess water in times of intense rainfall.

SWOT Analysis

- Presents no danger in property flooding, as any excess collection will drain to the gully.
- Have amenity, biodiversity and water treatment benefits as well as reduce surface water run-off:
- Easy to maintain, funding is an issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

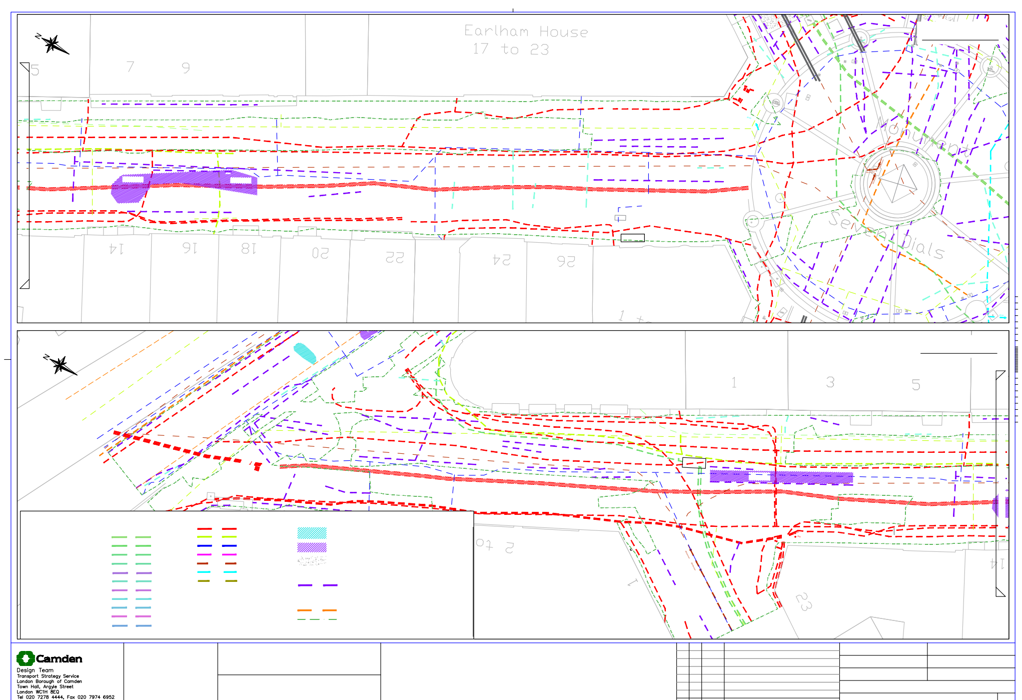

Figure 44: Example of utilities under the street.

Costs

Tree with Urban Tree Soil: £3500 per tree
Maintenance: £20.50 per tree per 3-year cycle

Attenuation Tanks: £344/m^3
Maintenance: only maintenance is keeping the pipes and gullies clear.

Drainage Pipes: £120/m^2
Maintenance: £30-50/m^2 (up to £100 with an inexperienced contractor)

Rain Garden: £300/m^2
Maintenance: £0.60/m^2

Swale: £10-15/m^2
Maintenance: £5-100(less expensive with experienced contractor)

Overall Maintenance: should be maintained twice a year, but it is recommended to inspect the tanks after any major storm event.

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding.

9.4 Royal College Street

Introduction

The Royal College street scheme, (Figure 45) was a cycle scheme that has already been implemented. The council created new cycle lanes along the road and used above ground planters to separate the cycle lanes from the cars. The planters themselves had no real flooding benefits and ended up being hit by cars. They were not properly maintained either so the plants inside them have died and filled with litter. We propose replacing the planters with a more permanent and effective SuDS component. The two different designs we will be using are rain gardens and swales. These two options are the most viable given the shallow depth of utilities in the street.

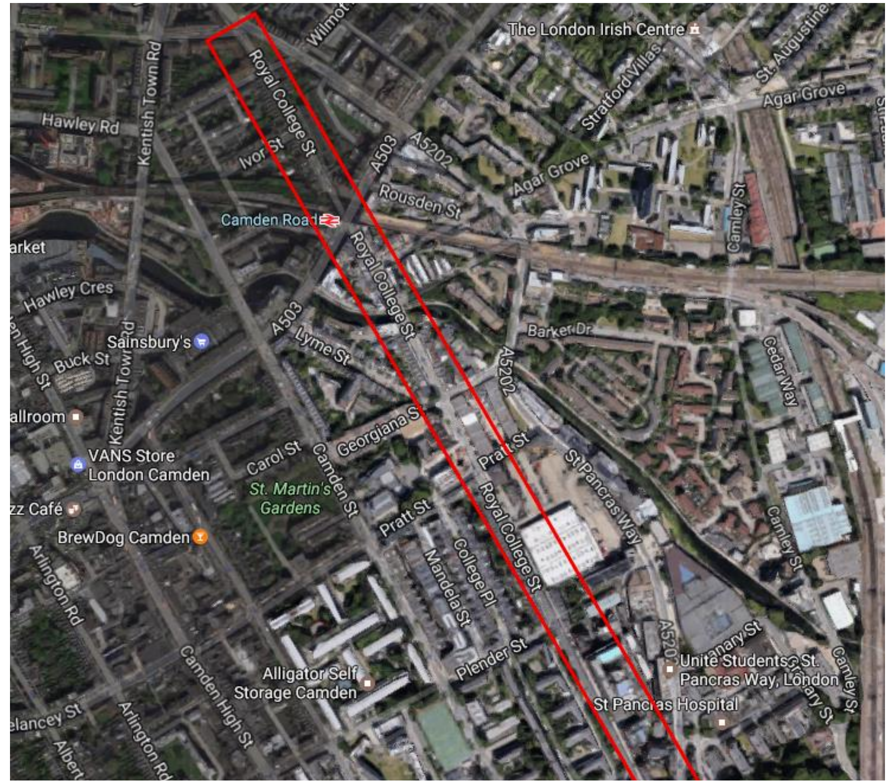

Figure 45: The satellite photo for Royal College Street. (Google Maps, n.d.)

Summary

Location: Royal College Street
Type of Scheme: Cycle Scheme
Scheme Owner: Darren Barton
Objective: Reduce the flood risk and make safer crossings for pedestrians and safer cycling lanes
Potential SuDS Locations: Replacing the planters with a SuDS solution to divide the cycling lanes from the cars
SuDS Component: Rain Garden or Swales

Scheme 1: Rain Gardens with Drainage Pipes

The concept behind this scheme is to remove the planters on Royal College Street (See Figure 46) and build a raised concrete curb to enclose rain gardens (similar to Figure 47, but without the trees because utilities limit digging to 400mm). A drainage pipe at the bottom of the garden will drain excess water to the nearby gullies. The finished road scene is shown in Figure 48.

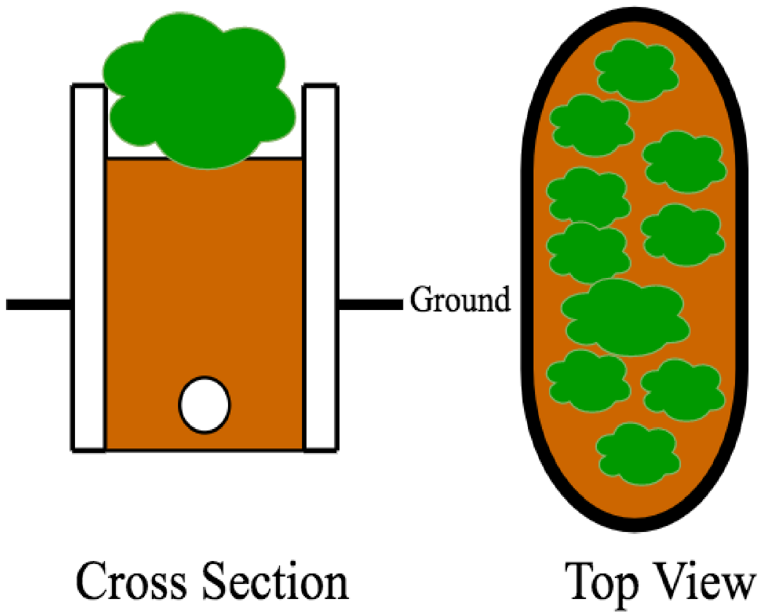

Figure 46: Conceptual drawings of the rain garden.

Figure 47: Street scene of Siwei 2nd road at Kaohsiung, Taiwan.. (Google Maps, n.d.)

Figure 48: Street scene of Royal College Street. (Google Maps, n.d.)

Barriers

The two main barriers to this scheme are underground utilities and maintenance funding. Since Royal College Street has a lot of utilities underground (Figure 49), a careful, comprehensive, and detailed survey will be necessary before any real planning starts. As far as maintenance funding goes, there are some possible solutions from local businesses funding. The council does not have any money allocated for SuDS maintenance, and though Environmental Agency does offer maintenance funding, it only offers to non-LLFAs.

SWOT Analysis:

- Alma Rd coped 1 in 100 year storm with no flooding
- Presents no danger in property flooding, as any excess collection will drain to the gully.
- amenity, biodiversity and water treatment benefits as well as reduce surface water run-off:
- Easy to maintain, funding is an issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

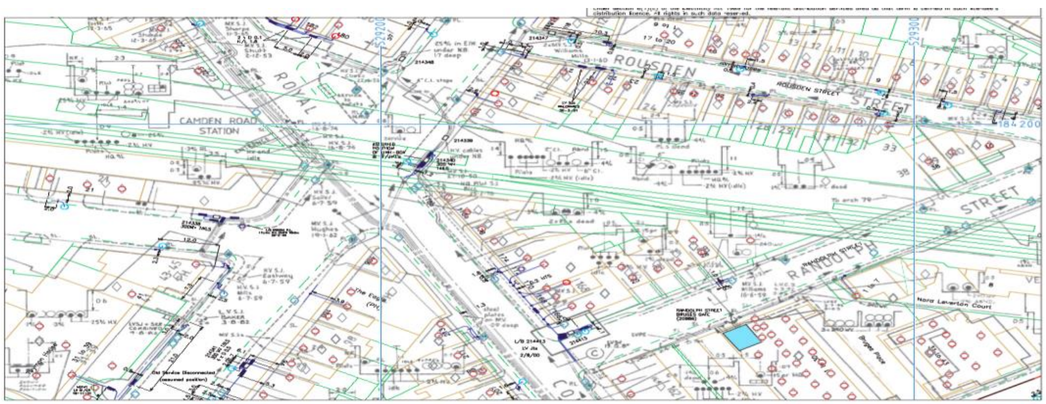

Figure 49: Utilities on Royal College street.

Costs

Rain Garden: £300/m^2
Maintenance: £0.60/m^2

Drainage Pipes: £120/m^2
Maintenance: £30-50/m^2 (up to £100 with an inexperienced contractor)

Overall Maintenance: should be maintained twice a year, but some recommend four times a year. Replant every two or three years to ensure that the rain garden is full of plants and not weeds

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding.

Scheme 2: Swales

Conveniently, there are several gullies (Figure 50) on Royal College Street and most of them are located near the cycle lane (Figure 51). The concept for the second scheme on Royal College Street is quite similar to the previous option and entails installing swales (Figure 52) as the divider between the cycle and traffic lanes. Soils in swales can absorb water and even if they become waterlogged, the pipes underground will collect excess water and slowly drain into gullies. In Figure 53 we have drawn a rough sketch of how swales in between the cycle lanes might look.

Figure 52: Example of a swale. (Susdrain, n.d.)

Figure 50: Street Scene of Royal College street with cycle lane. (Google Maps, n.d.)

Figure 51: Gullies at the cycle lane on Royal College street. (Google Maps, n.d.)

Barriers

The main barriers for this scheme is basically the same as the first scheme. There are a lot of utilities underground and there is really no funding option for maintenance. In addition, cost will be another big barrier in this scheme. Since swales will need to dig deeper than the rain garden in scheme 1, they will have to hand dig around the utilities which will cost the Council more.

SWOT Analysis:

- Presents no danger in property flooding, as any excess collection will drain to the gully.
- Have amenity, biodiversity and water treatment benefits as well as reduce surface water run-off:
- Easy to maintain, funding is an issue.
- Quick implementation (.e.g, similar scheme completed in 6 weeks)

Costs

Swales: £10 – 15/m^2
Maintenance: £5-100/m^2 (Less expensive with experienced contractor)

Drainage Pipes: £120/m^2
Maintenance: £30-50/m^2, (up to £100 with an inexperienced contractor)

Overall Maintenance: Should be maintained 2 to 4 times a year depend on the water absorbance of soils. The sward should be maintained and pruned depend on the growth of plants, as long as the swales looks green at the surface should be fine.

Capital Funding: Possible funding could from the EA if flood risk is proven. Lucy Evans or Sally Tully, as points of contact for funding.

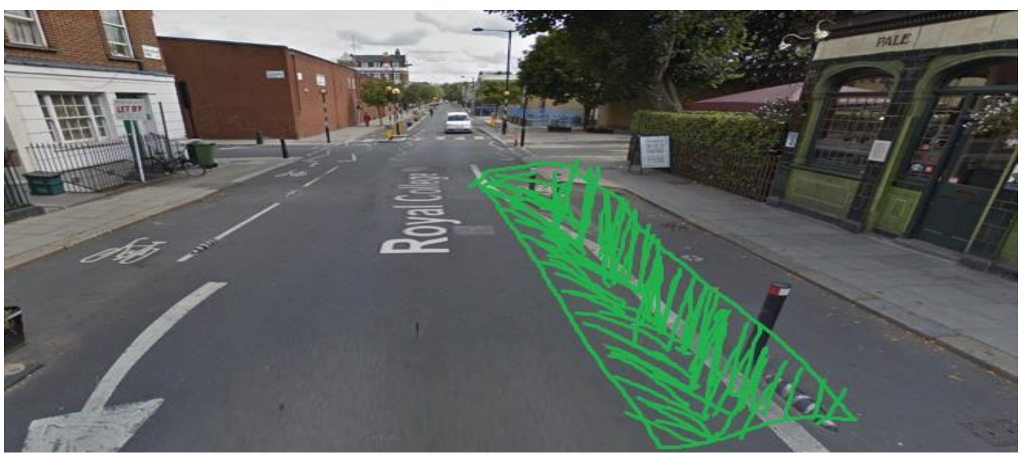

Figure 53: Conceptual scheme with swales. (Google Maps, n.d.)

10. Conclusion and Recommendation

The London borough of Camden is at risk of surface water flooding from severe storms and is working on ways to mitigate this issue because the intensity of these storms is projected to increase in the future. London has a drainage system that is struggling to cope with the increasing population and increased severity of storms. The policies set forth in the Flood Risk Regulations gives responsibility to Lead Local Flood Authorities in managing the risk of surface water flooding. The Camden Planning Guidance has adopted the SuDS hierarchy that is in the Mayor's London Plan. The borough is working towards implementing SuDS but because SuDS are not well understood their adoption has been challenging. This report, discusses the teams research into reducing the risk of surface water flooding through the use of SuDS while giving detail to the policies that are driving SuDS , the benefits, and the barriers its of adoption.

The team's results show that there are many policies set in place at the National, Regional, and Local level that promote the use of Sustainable urban Drainage Systems in new developments. However there are few policies that encourage the use of retrofitting SuDS into highway and streetscape projects. Along with that, policy does not mean acceptance. The team recommends that the Council write new policies encouraging the use of SuDS for retrofitting into highway schemes. One possible option for this is in the "Camden Transport Strategy". While some of the goals stated in the plan can be solved by SuDS, it is never directly mentioned, it is implied that it can be used, but **we recommend a revision of the "Camden Transport Strategy" that emphasizes the importance of the use of SuDS in future streetscape and highway projects**.

Through research of past streetscape projects in Camden, the team has determined that while Camden is aware that there is flood risk and that SuDS is a possible solution, they have not been able to successfully plan and implement SuDS into their highways. At the private level however, there has been some SuDS success, but the purpose was not necessarily for flood mitigation.

Our team has determined through extensive research and interviews there are several benefits of SuDS that can be considered when adopting SuDS, some of these benefits include:

- Reducing the risk of flooding
- Reducing the effects of climate change
- Amenities
- Maintenance (if implemented correctly)
- Costs
- Improved water/air quality
- Flexibility in implanting
- Increased biodiversity

Our results showed that the lack of understanding of SuDS can be detrimental in the adoption of SuDS. **In order to address this problem we recommend that the borough of Camden endeavors in learning about SuDS to apply the many benefits in its adoption. In addition, the borough should develop pilot schemes based on the feedback council staff, residents near the schemes, and other users, such as cyclists have of the projects' success.**

While there are many benefits from SuDS, the team has determined that there are multiple barriers hindering the adoption of SuDS. The main barriers determined were lack of knowledge of SuDS, and misconceptions about costs and the associated maintenance. There were other barriers noted such as:

- Funding
- Location
- Resistance
- Irrelevance
- Parking

The team then determined possible recommendations to overcome these barriers. We recommend that the borough reaches out to **George Warren**, of London Borough of Hammersmith and Fulham, offered to give educational workshops to the Council on SuDS. The team also recommends further research into possible funding solutions. While we have a good base, there was no one solution so further research is needed. We also recommend the creation of a document outlining the different types of SuDS and how they might be implemented. **The team recommends that the Council do their own cost analysis, preferably with the BeST (Benefits of SuDS Tool) to evaluate the cost and the benefits SuDS can provide to a certain project**. While we have provided basic cost data. There are many factors that affect the cost that we were not able to assess.

Through a thorough analysis of the Alma Road Scheme. The team determined that the implementation of SuDS is cost effective, has low maintenance costs, is effective at flood mitigation, and is easy to retrofit into an already designed highway. While we wanted more case studies, we ran out of time to establish any more effective ones. The team recommends contacting **Ian Russel, of The London Borough of Enfield, to discuss his Green Lane Cycle scheme**, because having a case study with a cycle scheme as a base is important due to the future growth of cycle lanes in the northern part of Camden.

By overlaying a list of upcoming streetscape projects and a GIS map of street works with a flood risk map provided by the Strategic Flood Risk Assessment (SFRA), and then outlining the Business Improvement Districts (BID), the team was able to choose three possible schemes to retrofit SuDS into. Two of the schemes were cycle lanes on Pratt and Arlington Street, and the third scheme is a Gyratory Scheme in the Kings Cross area. The third scheme is a broader conceptual scheme outlining the use of four different SuDS while the first two outline the use of one or two SuDS. The team recommends contacting **Georgie Street, of Camden Town Unlimited,** as she has shown interest on working with the LBC to develop SuDS schemes in the district. The team also recommends contacting **John Bryden, of Thames 21,** since he has completed numerous SuDS scheme projects and possesses vast knowledge on funding. He offered to help the LBC to implement SuDS in their projects.

The purpose of this report was identifying a way to mainstream SuDS into the London borough of Camden. If SuDS is adopted in the borough the risk of flooding can be reduced extensively. The people of Camden can benefit from this project because of the damage that flooding can bring as well as the other benefits that SuDS can offer, improving the quality of life for everyone in the borough. The information in this report con be used by the London borough of Camden and any borough throughout London in an area that is at risk of surface water flooding to develop a better understanding of SuDS so that it can be adopted. Looking into the future it is interesting what SuDS can do for not only Camden and London, but for the world in not only reducing the risk of flooding but mitigating the risk of climate change and creating a more aesthetically pleasing planet in the future.

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12. Appendix A: Interview Scripts

Preamble,

We are a group of students from Worcester Polytechnic Institute's (WPI) London Project Center (LPC). We are conducting this interview to learn more about the barriers to the adoption of Sustainable Urban Drainage Systems and learn ways to overcome the barriers. This project is being conducted in collaboration with the London Borough of Camden and we appreciate your assistance. Your participation in this interview is completely voluntary and you may withdraw at any time. By completing this interview you consent that any information given can be used in our research. Please remember that your identity will remain confidential. If interested, we are happy to provide you with our result at the conclusion of this study. If you have specific questions about this research please feel free to contact us at: Camden-17E1@wpi.edu. You may also contact our WPI project advisors, Dominic Golding and Jennifer DeWinter, at golding@wpi.edu and jdewinter@wpi.edu

Objective 1: Policy Drivers

1. What do you see as the primary policy drivers pushing SuDS?
2. Which of the policy drivers are most effective and which least effective?
3. Are there any documents you recommend we research?
4. Do you know of anyone else we should speak to in regards to policy drivers at the national, regional, and local level?
5. Are some policy drivers redundant or unnecessary?
6. Are there policy drivers that should be put in place?
7. Are some policy drivers more effective at the local level rather than the regional scale?
    a. What about the national scale?
8. Are there any other people or documents that you would consider important in our research that we may not have looked into already?
    a. Are there any groups or organizations similar to LODEG or Central North London Flood Partnership the team should consider communicating with?

Objective 2: Flood Risk Mitigation

1. What are some of the highway projects that have been completed to date?
    a. Did they mitigate flood risk in any relevant areas?
2. Did any of the completed highway projects incorporate SuDS?
    a. How are those projects which incorporated SuDS performing now?
3. Were there schemes of SuDS that were considered but not being implemented?
    a. What was the reasoning behind not implementing SuDS?
4. *Specific to David Wells*
    a. Is there any information you can provide us about your contract with Volker?

        i. Such as seeing if the maintenance they provide is flexible enough to include SuDS maintenance

5. Are there any other documents we should refer to, or people we should speak with in regards to current flood risk mitigation?
6. Did the engineering focus on ways to reduce flooding?
    a. Did the designers consider the incorporation of SuDS? Why/why not?
7. Did the redesign of a major roundabout take potential impacts on flooding into account?
8. Have any of the completed projects incorporated SuDS?
9. To what extent did other highway and streetscape project mitigate flood risk?
    a. Did the designers consider the incorporation of SuDS? Why/why not?

Objective 3: Barriers and Constraints

1. What are some of the most notable barriers and constraints to implementation of SuDS?
    a. Are there any case studies we can refer to for information on these barriers?
    b. What are some barriers and challenges you have personally come across while trying to implement SuDS?
2. What are some possible solutions to the challenges of implementation of SuDS?
    a. Can you name any other consultants of SuDS or case studies that can provide information on these solutions?
3. Are there any locations that you suggest conducting site visits for gathering information on the challenges of implementing SuDS?
4. What impacts do you think the lack of familiarity with the technology will cause?
5. What are some of the cost issue barriers do you think exist?
6. Are there any other documents we should refer to, or people we should speak to in regards to identifying the barriers/constraints that prevent the implementation of SuDS?

Objective 4: Benefits

1. What are some benefits of SuDS in highways that you believe to be most prominent based on evidence that you have found in your research?
2. Do you see any possible solutions to some of the barriers to implementing SuDS?
3. Are there any highway projects that have implemented SuDS in London that we should visit?
    a. Who might we speak to in regards to those projects?
4. What are the main sources of funding for SuDS, both capital and maintenance funding?
    a. What are the restrictions to receiving funding that you are aware of?
5. How does the LIP bidding process work?

    a. How has this program benefited the highway projects for Camden in the past?

6. Have there been any SuDS highway projects for Camden in the past?

How much funding has been given in the past for highway projects?

13. Appendix B: Case Studies Summary

London Borough of Camden, London

A green wall, also known as a biowall or a vertical garden, is a sustainable urban drainage system method that consists of a structure composed of or filled with growing plants or vegetation. This method was implemented in the project done in the London Borough of Camden. The objective was to minimize the urban heat island effect (city that is warmer than surrounding rural areas), intercepting water, filtering air and water, and contributing to the SuDS strategy in this borough. This green wall encourages wildlife and helps reduce the risk of flooding (SuDS in London, 2016).

Streatham Common South, London Borough of Lambeth (2013)

The London Borough of Lambeth implemented de-paving, tree planting, and kerb inlets in their highway maintenance scheme because they are a critical drainage area. Pavement SuDS were inserted with verges, which replaced concrete dished channels (SuDS in London, 2016).

50 & 60 Reedworth Street, London Borough of Lambeth (2012)

In this area, permeable paving, a SuDS method which consists of a porous form of pavement that drains water, was implemented with the objective of increasing permeability of front gardens that would not affect parking and improved aesthetics (SuDS in London, 2016).

SuDS in Mill Pond Road, London Borough of Wandsworth (2016)

In this borough, there was a project that used a series of SuDS to attenuate surface water. The methods used were bioretention swales, kerb inlets, and tree planting. This infrastructures collect rainwater and store it underground, releasing it slowly into the main drainage system (SuDS in London, 2016).

A24 London Road, London Borough of Sutton (2014)

In the Borough of Sutton, another project took place. Many commonly used SuDS methods were implemented in this project, like bioretention and tree planting, but it also de-paved six different areas to plant trees in this specific areas of the road were pavement was removed. The objective was to reduce pavement areas and transform this road into a “green” part of this borough (SuDS in London, 2016).

Mendora Road, London Borough of Hammersmith & Fulham (2016, under construction)

Permeable paving is a sustainable urban drainage system currently being implemented in the latest SuDS project of the London Borough of Hammersmith & Fulham, sponsored by Thames Water. Three streets were selected as a trial to implement permeable paving. This project also has underground storage for water. This project is expected to manage storm water (SuDS in London, 2016).

Brixton, London Borough of Lambeth (2014)

The objective of this project was to improve streetscape aesthetics of the Brixton Market while improving surface water drainage. Tree were planted and an area of concrete pavement was replaced with permeable paving. Below the permeable pavement, there are crates that store storm water to manage storm water better. This project is a great example of how SuDS are not only aesthetically pleasing and effective storm water managers, but they can also be used to recycle water. In this project in the Borough of Lambeth, water is recycled for water planters on Brixton Station Road (SuDS in London, 2016).

Kensal Green, London Borough of Hammersmith & Fulham (2015)

The objective of this project was to improve underused public areas and to enhance the existing drainage system in the Kenmont Gardens . The methods used to achieve these objectives were permeable paving, rain gardens, geo-cellular storage, and tree planting. The London Borough of Hammersmith & Fulham worked with FM Conway and Green Blue Urban to make this project possible. The size of this project was 435 square meters with a total cost of 300,000 pounds. It was funded by two organizations: TFL LIP Funding and Lead Local Flood Authority (SuDS in London, 2016).

Upper Norwood, London Borough of Lambeth (2012)

This project is aimed to remove pavement, as part of highway maintenance to address ponding, without exceeding traditional footway maintenance. This project effectively reduced runoff by simply replacing pavement with vegetation. The total size of the project was 640 square meter with a cost of 30,000 pounds. The main organizations involved were London Borough of Lambeth and FM Conway who, after the project, concluded that footway works were cheaper than traditional footways (SuDS in London, 2016).

Upper Street, London Borough of Islington (2011)

This project consisted of transforming a car park into a green public space for community and ceremonial events; using a series of SuDS components such as permeable paving, trees, and removing pavement. This project was 1000 square meters and costed 100,000 pounds to be built. The main organizations involved were the London Borough of Islington and J&L Gibbons (SuDS in London, 2016).

Hornsey, London Borough of Haringey (2016)

The objective of this project was to transform a green space to manage road runoff while enhancing the biodiversity of this area. The SuDS components used were retention basins, detention basins, and planted channels. It had an extension of 1000 meters and a cost of 80,000 pounds. This project was carried out due to the collaboration of the Haringey Council, Robert Bray and Associates, Thames21, and Hugh Pearl Ldt (SuDS in London, 2016).

Eltham, London Borough of Greenwich (2015)

The objective of this project was to enhance streetscapes by de-paving, installing kerb drainages, and bioretention basins with the objective of reducing flood risk. This project was carried out by the London Borough of Greenwich with the collaboration of Trees for Cities. It occupied 2600 meters and costed 23,000 pounds to build (SuDS in London, 2016).

Coulsdon, London Borough of Croydon (2006)

This project was performed with the objective of attenuating runoff flow from the highway. This was achieved by using SuDS methods such as kerb drainages, soakaways, filter strips, and filter drains. This project had a surface of thirty four hectares and a total cost of thirty three million pounds. This project was possible because of the work done by Transport for London and Atkins (SuDS in London, 2016).