LONDON STRATEGIC SUDS PILOT STUDY

Evaluating the Flood Mitigation, Economic, Social and Environmental Value of Catchment-scale Distributed Sustainable Drainage Infrastructure (SuDS)

Westminster, Camden, Southwark, Enfield, Kingston & Hillingdon

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CONTACTS

SIMON AINLEY
Project Technical Lead

dd +44 (0)1752 986006
e Simon.Ainley@Arcadis.com

Arcadis.
Arcadis House, 34 York Way
London
N1 9AB
United Kingdom.

IAN RUSSELL
Lead Sponsor

dd +44 (0)#### ######
e Ian.Russell@Enfield.gov.uk

London Borough of Enfield
Silver St
Enfield
London
EN1 3XA
United Kingdom.

ANDY SPARKS
Environment Agency Sponsor

dd +44 (0)7824 123505
e Andy.Sparks@Environment-agency.gov.uk

Environment Agency
King's Meadow House
Reading
RG1 8DQ
United Kingdom

GRAEME KASSELMAN
Thames Water Sponsor

dd +44 (0)2035 772522
e Graeme.Kasselman@Thameswater.co.uk

Thames Water
Coal Wharf 2, Coal Wharf Complex
Lower Sunbury Road
Hampton
Middlesex
TW12 2ES
United Kingdom

GEORGE WARREN
Greater London Authority Sponsor

dd +44 (0)2079 834322
e George.Warren@London.gov.uk

Greater London Authority
City Hall
The Queen's Walk
London
SE1 2AA
34 York Way

CONTENTS

APPENDICES

APPENDIX A

Register of Supporting Technical Notes

APPENDIX B

Normalisation of Comparative Metrics

APPENDIX C

Stage 2, Comprehensive Economic Valuation - CAPEX Cost Metrics

APPENDIX D

Stage 2, Comprehensive Economic Valuation - Natural Capital Value Metrics

APPENDIX E

Stage 2, Comprehensive Economic Valuation - Natural Capital Value of SuDS Evaluation Scenarios

1 FOREWORD

The London Boroughs, Thames Water Utilities and Transport for London inhabit a critical and demanding position of influence, the services they provide forming the foundation of civil society, alongside other critical infrastructure, underpinning the increasingly interconnected nature of society. They not only cater for **relentless urban growth and the emerging and uncertain pressures of climate change**, but also must secure the quality of life for local communities while enabling continued economic prosperity in the face this change.

Resilience describes the quality of being able to survive, adapt, and recover from rapid change, stresses or shocks, and failure of individual components of a larger interconnected system. One key catalyst for establishing and increasing resilience is to limit the risk of systemic failure by distributing and overlapping numerous assets or components of a wider system to embed redundancy. This creates adaptability to fluctuations in the performance of individual components and helps to incentivise innovation.

Using Sustainable Drainage Systems (SuDS), as an approach to manage rainfall runoff and mitigate flooding, creates an **opportunity for incremental investment in a highly scalable and adaptable strategy, applicable to the diverse and dense urban environments in London**. The various bodies with responsibility for flood management and mitigation under the Flood Act 2010 will need to take a more holistic and exploratory approach to improving resilience as we move further into the 21st century. The progressive impacts of climate change and increased likelihood of complex and prolonged socio-environmental crises imply that focusing on current or short-term impacts will become less and less effective. SuDS provide a valuable option that should be considered an engineering cornerstone to address this resilience challenge.

The scale of investment in SuDS infrastructure necessary **to realise practicable system resilience inherently requires effective planning, to both understand funding mechanisms and justify their value to investors**. However, achieving a robust and measurable level of resilience cannot be pursued at-all-costs. Absolute resilience is ultimately unaffordable and unobtainable. Moreover, a fixation on SuDS as the sole solution would distract from capital expenditure on critical engineering schemes needed to address specific system deficiencies.

Working towards a practical and affordable level of resilience will require focused planning and strategizing, utilising SuDS where they are most cost-effective and can achieve tangible local improvements. Scale is an essential limitation that will also need to be overcome. **The true value to local communities and London as a whole will only start to be realised once SuDS features become more commonplace within residents' day-to-day experience of their urban environment, both where they live, work and along their commute**.

It is also important to recognise that measurable resilience cannot be achieved if organizations labour too long in the strategy phase – "what can we do to be better prepared". Resilience can only start to be realised following the implementation of projects that prove the concept – "here's how we've reduced the risks". The transition from planning to action, especially where the approach proposed is considered novel or 'risky', can be very difficult to navigate, and in many cases can be severely inhibited by uncertainty around how it will function and perform. In relation to SuDS, the biggest resistance to this transition will typically be a lack of clarity around costs, both construction and maintenance, and magnitude of benefit that they can generate. Although both elements can be tangibly appraised post-construction, the majority of **funding opportunities will obligate a prior 'proof' of an adequate return on investment, necessitating effective 'up-front' planning and evaluation**.

Achieving the necessary sustainability of a long-term commitment to investing in SuDS across London will need to convert strategy to action, growing initially from small-scale pilot investments. **Demonstrating the inherent value of nature-based solutions can be an effective catalyst to unlocking a robust and diverse sources of funding, a critical element of sustainable investment**.

This study has been formulated with an aspirational objective to provide a holistic London-focused evidence-base to help the water management authorities effectively move through this transition from planning to action. The information presented and recommendations made should enable pragmatic and empirical assessments of commercially viable retrofit SuDS opportunities, justifying positive returns on investment and proving tangible natural capital gains.

Ultimately, the aim is to help stimulate a robust and self-sustaining commitment to SuDS in London that could improve the quality of life for millions of residents.

2 PROJECT OVERVIEW

2.1 Introduction

From the many Surface Water Management Plans (SWMP) completed across London, as part of 2012 Drain London, it was recognised that the only practical opportunity to reduce flood risk in urban areas would be via retrofit of small-scale SuDS features across whole catchment areas, driven by the common constraint on space within the public realm to construct larger or strategic flood risk management schemes *(e.g. flood storage areas)*. However, it has become clear that the current mechanisms for attracting Flood and Coastal Erosion Risk Management (FCERM) Grant in Aid (GiA) or Thames Regional Flood and Coastal Committee (TRFCC) local levy funding for these 'micro-projects' can be ineffectual because individually these SuDS measures cannot deliver the necessary magnitude of benefit.

A proposal was prepared ("The Proposal") and submitted to the TRFCC in January 2017 by London Drainage Engineering Group (LoDEG) members, led by the London Borough of Enfield (LBE). The Proposal aimed to address this problem by investigating the catchment-scale benefit of wide-scale SuDS implementation, accounting for the potential to deliver a whole range of supplementary socio-environmental benefits to justify long-term collaborative funding opportunities.

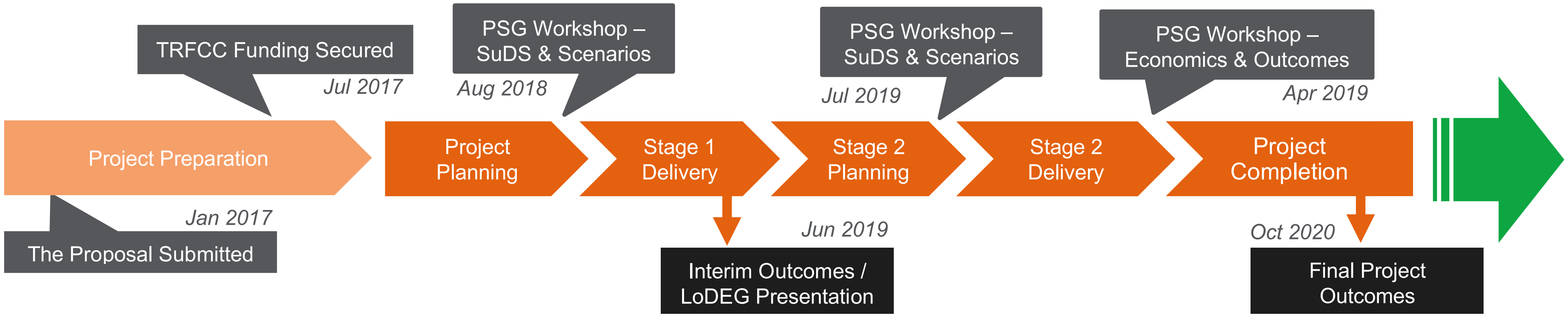
The Proposal was approved for funding by TRFCC in 2017 (match funded by Thames Water Utilities Limited (TWUL)), which led to the commissioning of the London Strategic SuDS Pilot Study ('The Pilot Project'), presented in this document.

The project has been run within a Project Steering Group, led by the LBE and including representatives from:

- Environment Agency (EA)
- TWUL
- Greater London Authority (GLA)
- Thames Flood Advisors
- London Borough of Hammersmith and Fulham

Additional project partners included the Royal Borough of Kingston upon Thames (RBKC), London Borough of Hillingdon (LBH), City of Westminster (CoW), London Borough of Camden (LBC), London Borough of Southwark (LBS), and Transport for London (TfL).

2.2 Project Timeline



2.3 Aims & Objectives

The fundamental aim of this project has been to demonstrate that the strategic long-term delivery of small-scale SuDS at a catchment scale is an investable and sustainable approach to address flooding in London. Supplementary to this is the clarification through numerical and hydraulic assessment of whether this approach can provide sufficient benefits to justify FCERM GiA funding through the current process (using the Partnership Funding Calculator).

The primary project objectives which provided the technical and conceptual guidance can be grouped into following:

Develop Technical Workflow to Evaluate the Flood Risk Benefits of The Strategic Implementation of SuDS

Proposing and refining hydraulic modelling and numerical analyses techniques, seeking to classify key technical issues to constraints

Calculation of Catchment-wide Natural Capital Benefits

Calculation and incorporation of socio-economic and environmental wider benefits (e.g. biodiversity, amenity, health & wellbeing etc.) to understand and maximise the net value of SuDS

Eligibility for Funding under Current Systems

Evaluation of possible investment opportunities, including demonstration of eligibility for FCERM GiA funding

Future Delivery / Realisation Framework Potential

Identification of constraints and opportunities associated with enabling resilient long-term investment in SuDS across London, including delivering SuDS within general public works programmes

Develop Robust Financial Case for Long-term Investment

Derivation of key financial metrics to demonstrate return on investment and effective total value of SuDS to London residents

2.4 Sustainable Drainage Systems (SuDS)

The understanding of SuDS is typically associated with engineered and naturally constructed features, such as storage basins or living roofs. However, SuDS as a concept more accurately represents a departure from traditional engineering in preference for localised adaptations to provide a more natural, environmentally sensitive and resilient system. Naturalised systems can inherently be more complex, so the array of SuDS 'options' that should be considered is necessarily broad and diverse.

When looking to provide widescale and catchment-level flood risk mitigation the focus of any SuDS strategy should primarily be on 'source control', which is the improved management of rainfall runoff at source. For most catchments in London the 'source' of the majority of runoff will be roads and roofs.

2.4.1 Concept of Distributed SuDS

This project focuses on promoting the delivery of numerous small-scale SuDS features across whole catchments, collectively referred to as 'Distributed SuDS'. The primary hydraulic function of Distributed SuDS is providing source control to reduce flooding through the attenuation of rainfall runoff. The sources of rainfall runoff are generally consistent across most London catchments (roads and roofs), which provides a relatively consistent environment to evaluate the benefits of Distributed SuDS.

The SuDS feature types considered in this project provide source control via two key mechanisms:

- **Paved Surface Source Control** – Inclusion of storage on the surface, slowing the entry of paved runoff into the public drainage system
- **Roof Runoff Source Control** – Inclusion of storage on or within land adjacent to buildings to manage runoff prior to being discharged into the public drainage system

A few practical examples of constructed SuDS features in the UK which provide this source control function, as is proposed within the concept of Distributed SuDS, are shown in Figure 1.

Ribblesdale Road, Sherwood, Nottingham, NG5 3HW

This pilot retrofit SuDS project was a result of collaboration between the EA, Nottingham City Council, Groundwork Greater Nottingham and Severn Trent Water.

The scheme involved the creation of several pavement build-ins, which drained the local highway in small vegetated bioretention features.

Queen Mary's Walk, Llanelli SA15 1PG (and Regalia Terrace, SA15 1LN)

As part of a surface water separation and combined sewer flow management scheme several SuDS features were chosen, designed to reduce flows via evapotranspiration and attenuate flows.

The feature shown is a stepped swale, utilising check dams to maximise attenuation and an inlet within the road kerb

City of Cardiff Council

Long-term sustainable tree planting has been implemented across a number of residential streets. Where possible, tree pits were linked below ground, increasing available soil volume for the trees and simultaneously increasing water attenuation capacities.

Figure 1 – Example Individual SuDS Components Within the Project Concept of Distributed SuDS

A key benefit of Distributed SuDS is that the consideration of relatively small and common SuDS features creates greater flexibility in choice of locations. Having a larger and more diverse array of opportunities maximises the likelihood that a sufficient number of feasible locations can be identified, allowing for uncertainty over ground conditions, road traffic management systems, utilities, community engagement and other local constraints. In addition, the ability to align local Green Infrastructure (GI) requirements or initiatives elevates the likely success of implementation at a catchment-scale, which is essential for the long-term investability (investment attractiveness) and resilience that a Distributed SuDS approach could deliver.

2.4.2 Integrated Blue-Green Infrastructure

The recent growth of SuDS in the UK has been largely driven by the requirement to attenuate and manage surface water within development sites, designed as specific drainage assets to serve the defined site. This focus has driven investment in SuDS through the planning system, but sidesteps significant opportunities associated with works in the public realm which could be at an equivalent scale to new developments.

SuDS as a technical approach should not be considered separately from Blue-Green Infrastructure (BGI), which typically denotes the wider concept of creating a network of natural features to provide a whole range of environmental, ecological, community and urban quality functions. A blue-green network should aim to provide an ecological framework for social, economic and environmental health. Due to this association, the evaluation of SuDS cannot be disassociated from their inherent Natural Capital value and deriving this 'net value' forms a key outcome of this study.

Providing robust assessments of the benefits and value of Distributed SuDS is a core outcome of this study, considered a critical element to drive sustainable long-term investment in the re-naturalisation of our urban environments.

3 STUDY CATCHMENTS

The project study catchment boundaries are shown in Figure 2.

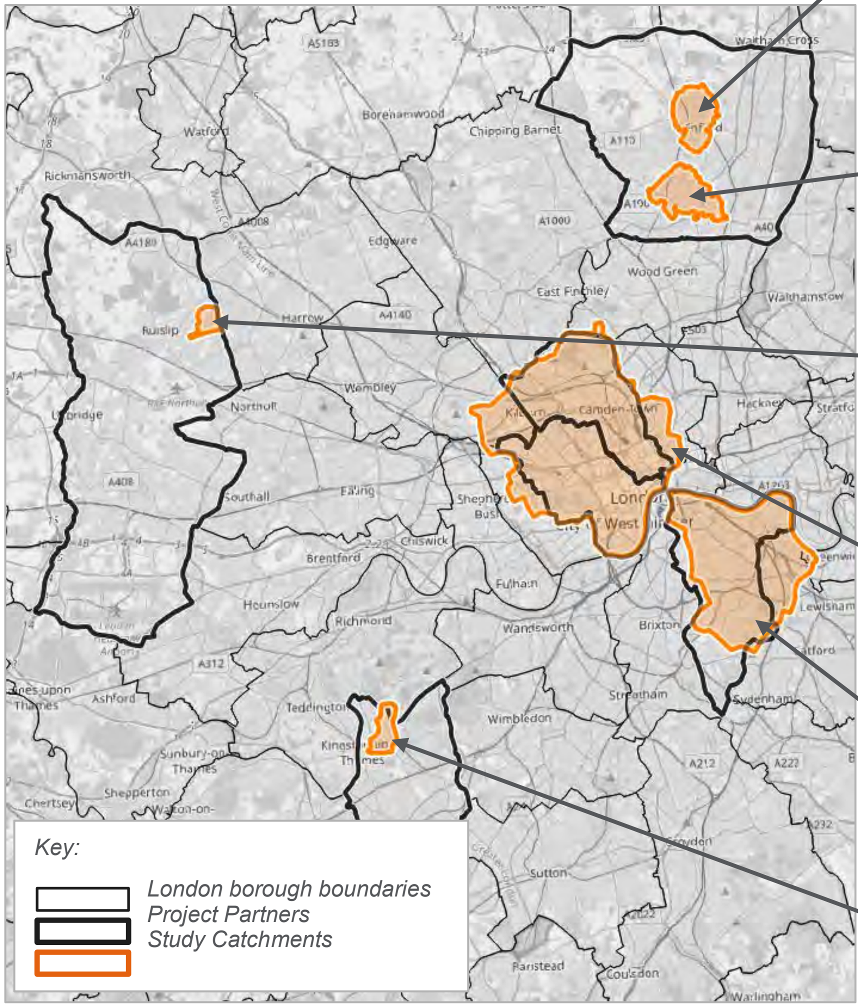


Figure 2 - Study Catchment Boundaries & Locations

Stage 1, Preliminary Conceptual Development – Enfield Town Centre (*London Borough of Enfield)*

An existing defined Critical Drainage Area (CDA) identified during the Creation of the LBE Surface Water Management Plan (SWMP) (2012), characterised as a mixed residential / commercial catchment which suffers from surface water and (culverted) watercourse flooding.

Stage 1, Preliminary Conceptual Development – Moore Brook Culvert (*London Borough of Enfield)*

An existing defined CDA identified during the Creation of the LBE SWMP (2012), characterised largely as residential which suffers from surface water flooding.

Stage 1, Preliminary Conceptual Development – Eastcote Town Centre (*London Borough of Hillingdon)*

A small catchment promoted for investigation to support an ongoing SuDS strategy, characterised as a mixed residential / commercial catchment which suffers from surface water and highway flooding.

Stage 2, Comprehensive Economic Valuation – Westminster & Camden Area (City of *Westminster / London Borough of Camden)*
The combined drainage catchments covering the majority of COW and LBC, plus small areas of Kensington and Chelsea, Brent, and Islington.

Stage 2, Comprehensive Economic Valuation – Southwark Area (*London Borough of Southwark)*

The major drainage catchment within LBS, extending across an area of Lewisham.

Stage 1, Preliminary Conceptual Development – Acre Road (*Royal Borough of Kingston Upon Thames)*

An existing defined CDA identified during the Creation of the LBK SWMP (2011), characterised as a mixed residential / commercial catchment which suffers from surface water and foul flooding.

4 TECHNICAL APPROACH

4.1 Key Project Components

The core technical components of the project are summarised in Figure 3.

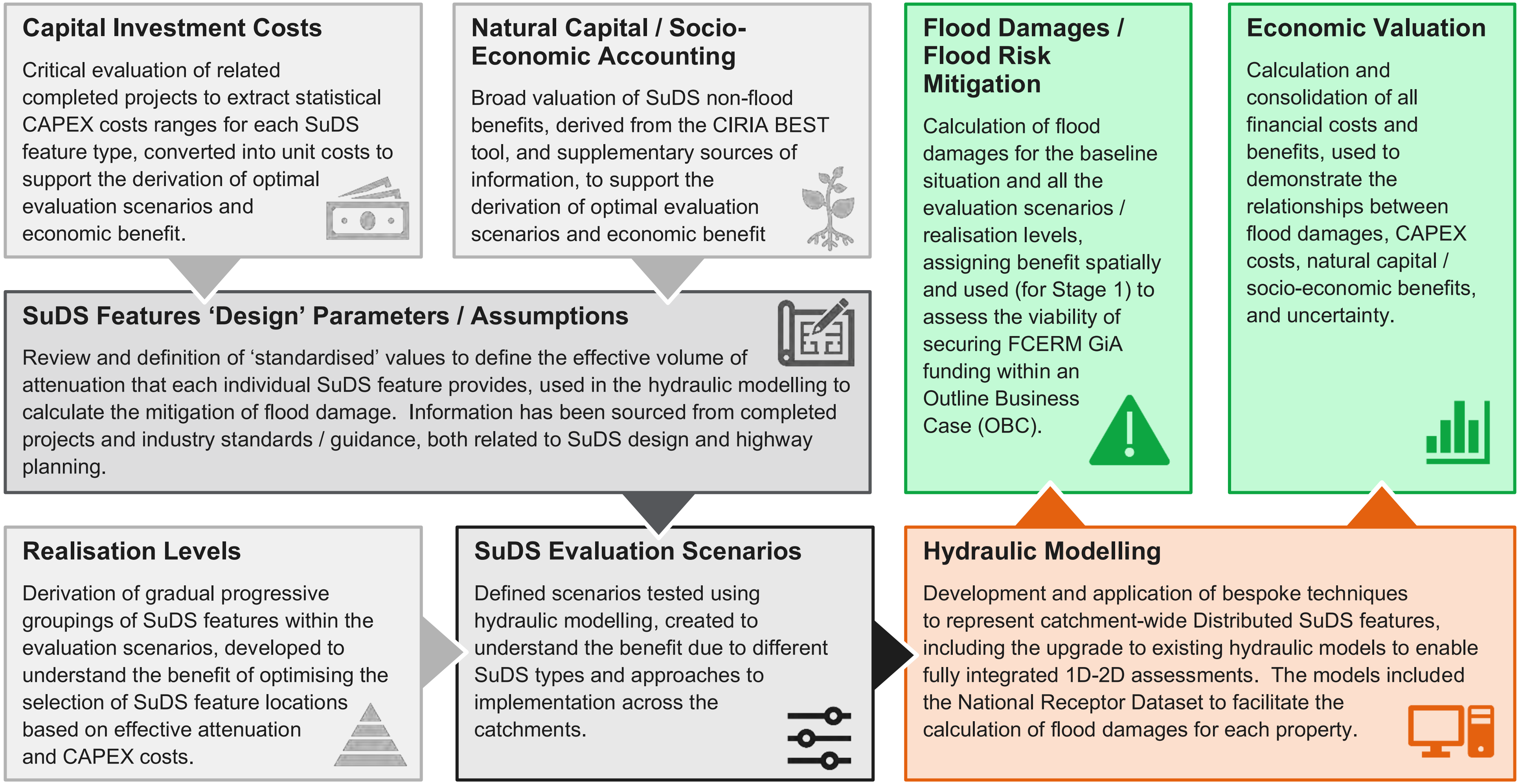


Figure 3 – Key Technical Components of the Project

4.2 Overview

Evaluating the specific flood mitigation and supplemental Natural Capital benefits required the identification of opportunities, locations where the effective attenuation volume and land take for individual SuDS features could be represented. An array of different SuDS feature types was also necessary to account for the variations in attenuation capacity, spatial distribution, capital expenditure (CAPEX), and Natural Capital value. This schedule of opportunities formed the basis for the effective SuDS 'capacity' of each catchment, representing a likely maximum outcome for long-term investment in Distributed SuDS.

Understanding the benefit of delivering these opportunities required the application of scenarios, to group SuDS features and evaluate return on investment. 'Realisation levels' were included to represent staged / proportional realisation of opportunities, to both understand how benefit would accrue over the long-term and identify optimal strategies to maximise benefit-cost.

4.3 Staged Development

The study was undertaken within two distinct but technically related stages of work, structured to enable an iterative and information developmental process:

- **Stage 1, Preliminary Conceptual Development** – development of an overarching framework behind the concept of Distributed SuDS, utilising existing models and standard CAPEX / Natural Capital data
- **Stage 2, Comprehensive Economic Valuation** – detailed development of a case-study based CAPEX and Natural Capital valuation approach and GIS-led opportunity assessment to fully assess benefit-cost, potential for optimisation, and justify long-term large-scale investment

The Stage 2 approach was formulated during several PSG workshops and consultations, seeking to ensure key limitations / assumptions of the Stage 1. The primary differences in technical approach between Stage 1 and Stage 2 is outlined in Table 1.

Technical Component	Stage 1	Stage 2
Capital Investment Costs	Estimates defined based on Industry standards, scaled to each defined SuDS feature type	Stage 1 values supplemented with SuDS case studies, including uncertainty ranges based on statistical deviation across the source data
Natural Capital / Socio-Economic Accounting	Derived from a selected set of BEST Tool benefits using central valuation and confidence estimates	Re-evaluated and extended Stage 1 BEST tool assumptions / inclusions, plus addition of several other benefits derived using academic research and government statistics
SuDS Features 'Design' Parameters / Assumptions	Specified a set of defined SuDS feature types (inc. set dimensions and layout)	GIS defined locations and footprints based on OS MasterMap to account for actual public open space opportunities
Realisation Levels	x4 equal ranges	x4 unequal ranges weighted towards the most optimal SuDS opportunities
SuDS Evaluation Scenarios	Set of strategic, common and local scenarios, to assess different SuDS feature types and combinations	Scenarios defined based on different SuDS feature types, plus an all SuDS scenario
Hydraulic Modelling	Use of previously available models and highway gullies as proxy locations for SuDS	Development of new models for the inclusion of SuDS features in defined locations with unique structural parameters
Flood Damages / Flood Risk Mitigation	General objective multi-criteria assessment of flood benefits	Explicit calculation of flood damages avoided (using the EA Multi-coloured handbook approach)
Economic Valuation	Evaluation to total value and benefit-cost, including indicative assessment of optimisation benefit	Calculation of benefit-cost / return-on-investment for all realisation levels, to enable the evaluation of FCERM GiA eligibility

Table 1 - Differences in Approach Between Stage 1 and Stage 2

5 STAGE 1 – PRELIMINARY CONCEPTUAL DEVELOPMENT

5.1 SuDS Features

This section covers the SuDS feature types selected, the design parameters used for the modelling, and derivation of locations across the catchments.

A more detailed breakdown of the selection process, key 'design' parameters, and modelling approaches are presented in the supporting SuDS Feature Technical Note[1]

5.1.1 SuDS Feature Types

The SuDS feature types selected aligned with the concept of Distributed SuDS and were projected to provide tangible benefit to the Stage 1 catchments were:

- **Streetscape Bioretention** - re-engineering of streetscape to include bioretention features within footway and / or protruding into the carriageway plus grassed highway verges, designed to collect, attenuate and evapotranspirate surface water runoff from paved surfaces
- **Swales** – open grassed longitudinal ditches / grassed highway verges, designed to collect, attenuate and evapotranspirate surface water runoff from paved surfaces
- **Street Trees** - construction or replacement / retrofit of tree pit attenuation within / adjacent to a trees root system, directly (e.g. road gully) or indirectly (e.g. permeable surface layer) connected to drain highway / pavement runoff
- **Property Rain Gardens** – Vegetated small depressions that attenuation and evapotranspirate roof runoff, typically by directly connecting downpipes
- **Rainwater Planters** - installation of roof runoff storage containers to properties with external guttering

The SuDS features were selected following a holistic review of relevant industry information and guidance, drawn from several key references.

5.1.2 Design & Attenuation Capacity

The different SuDS features were subdivided into different 'configurations' based on likely design integrations into the streetscape and / or several defined sizes.

The locations of all known highway gullies were used to provide an opportunity map for SuDS implementation (for Streetscape Bioretention, Swales and Street Trees). This approach was selected to maintain simplicity for Stage 1 while enabling the efficient creation of SuDS scenarios, since the highway gullies were included in the model as discrete nodes with defined volumes. The representation of individual SuDS features was achieved by adjusting the modelled gully pot dimensions and adjusting the level of the connecting pipework or reducing the effective runoff area (for roofs), both of which were automated for efficiency and precision.

5.1.3 Schedule of Opportunities

To enable the formulation of SuDS Evaluation Scenarios (See Section 5.2) a constraints analysis and suitability assessment were developed to identify the more relevant SuDS feature type(s) for each location.

- **Constraints Analysis** – Spatial assessment of a number of key highway, hydrological (inc. existing gully drainage capacity, surface water depths and infiltration characteristics), and land constraints (i.e. public / private ownership), used to both omit unfeasible SuDS features and order feasible SuDS features (based on number of non-relevant constraints)
- **Suitability Assessment** – Numerical weighted assessment of feasible SuDS features at each location based on predicted utilisation (i.e. attenuation of surface water) and a preliminary benefit-cost (based on attenuated volume vs. CAPEX)

This process provides a ranked schedule of feasible and effective SuDS feature type options for each location (i.e. existing gullies) across the catchments, from which the SuDS Evaluation Scenarios were created.

[1] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Features Technical Note

5.2 SuDS Evaluation Scenarios

This section covers the derivation of scenarios to evaluate the financial value generated with the implementation of different Distributed SuDS types and the approach to selecting the most optimal sites for investment.

A more detailed breakdown of the formulation of scenarios is presented in the supporting SuDS Evaluation Scenarios Technical Note[2]

5.2.1 SuDS Scenarios

Three groups of scenarios were evaluated to enable a holistic assessment of common approaches, geographical variations and specific local opportunities to integrate Distributed SuDS:

- **Strategic Scenarios** – Represent the full implementation of all SuDS opportunities, based purely on flood risk benefit and the maximisation of investment potential
- **Common Scenarios** - Holistically applicable approaches to implementing Dispersed SuDS, potentially applicable to any catchment, focusing on common delivery mechanisms and the impact of spatial variation
- **Local Scenarios** – Designed scenarios aligned to delivery mechanisms and influenced by local constraints, specific to each CDA

5.2.2 Realisation Levels

The evaluation of the most suitable SuDS types for each location (See Section 5.1.3) enabled the features to be ranked based on their projected individual benefit-cost. This ranking was used to derive realisation levels, providing four equal interim investment steps up to the maximum total catchment CAPEX.

The realisation levels selected were:

- **25%**
- **50%**
- **75%**
- **100%** - all features identified in the Schedule of Opportunities

[2] 10016816-ARC-XX-XX-DE-RP-0002-01-SuDS CAPEX Estimation, Technical Note

5.3 SuDS CAPEX Estimation

This section covers the derivation of unit CAPEX costs for each SuDS feature type.

A more detailed breakdown of the derivation of CAPEX estimates is presented in the supporting SuDS CAPEX Estimation, Technical Note[3]

An inventory of CAPEX costs was collated from standard industry assumptions and related project examples, covering all components of the preliminary design. Information was drawn from numerous sources, including:

- EA, Cost Estimation for SUDS - Summary of Evidence Report (2007)
- Stovin & Swan, Retrofit SuDS - Cost Estimates and Decision Support Tools (2007)
- CIRIA, SuDS Manual
- SPONS Civil Engineering and Highway Works Price Book (2018)
- SPONS External Works and Landscape Price Book (2018)
- SPONS Architects and Builders Price Book (2018)
- South West Water S104 Cost Estimation *(Capital works cost evaluation inventory for infrastructure investment)*

Indicative site costs were also included, derived from typical industry standards and experience, drawing from numerous water and wastewater infrastructure project examples.

[3] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Evaluation Scenarios, Technical Note

5.4 Natural Capital / Socio-Economic Accounting

This section covers the derivation of unit natural capital valuation for each SuDS feature type.

A more detailed breakdown of the derivation process is presented in the supporting SuDS Natural Capital and Socio-Economic Accounting, Technical Note[4]

The Benefits Estimation Tool (BEST) provides a structured approach to evaluating a wide range of benefits, supporting the quantification and monetisation of each benefit. It is currently considered in the industry as suitable for the evaluation of wider benefits for SuDS schemes and has been utilised here to calculate the financial benefits of the Evaluation Scenarios.

For Stage 1 a conservative set of Natural Capital metrics were selected for evaluation, shown below:

- **Air Quality** (calculated using the CIRIA BEST tool)
- **Amenity** (calculated using the CIRIA BEST tool)
- **Carbon Sequestration** (calculated using the CIRIA BEST tool)
- **Health** (calculated using the CIRIA BEST tool)
- **Traffic Calming** (calculated using UK Gov road accident statistics / project assumptions)

The metrics selected were considered to provide a pragmatic initial understanding of the potential magnitude of Natural Capital value, utilising efficient and proven assumptions / processes. It is recognised that there are a few specific benefits that Distributed SuDS could generate that likely substantially improve benefit-cost calculations, potentially inhibiting derived value.

These omissions include property value and urban cooling, which have both been addressed in Stage 2 (See Section 6.4), along with a number of other benefits.

The proportional split of benefit for the All Distributed SuDS scenario averaged across all Critical Drainage Areas (CDAs) each can be seen in Figure 4.

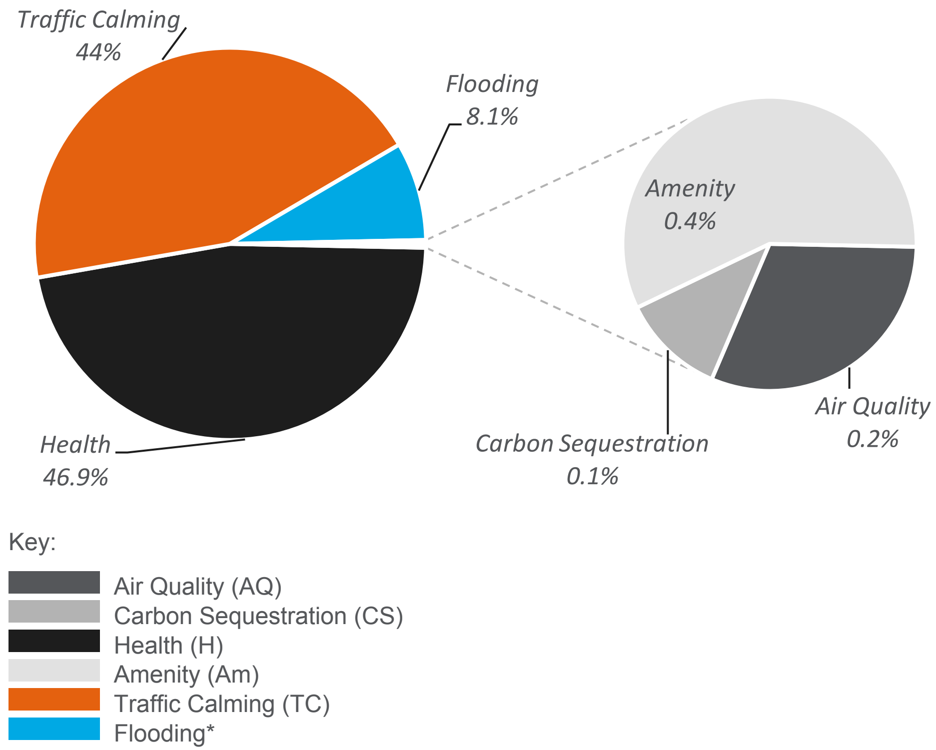


Figure 4 – Average BEST Evaluated Wider Benefits

Notes:
** Flood benefits derived, (as described in Section 5.6) for reference*

[4] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Natural Capital and Socio-Economic Accounting, Technical Note

5.5 Hydraulic Modelling

This section covers the hydraulic modelling used to assess the flood mitigation benefits of the SuDS Evaluation Scenarios.

A more detailed breakdown of the modelling activities undertaken are presented in the supporting Hydraulic Modelling, Technical Note[5]

5.5.1 Existing Models

The existing network models obtained were:

- **Enfield Town Centre CDA InfoWorks ICM Model** – An 1D-2D integrated surface water model developed as part of the Drain London forum, with a full representation of the surface water network and highway drainage system
- **Moore Brook Culvert CDA InfoWorks ICM Model** – An 1D-2D integrated surface water model developed as part of the Drain London forum, with a full representation of the surface water network and highway drainage system
- **Acre Road CDA InfoWorks ICM Model** – A WaPUG CoP type II 1D model, with a complete representation of the trunk foul / combined network and some major surface water sewers, but lacking street-level detail in many places

The Enfield Town Centre and Moore Brook Culvert CDA models were considered suitable for use in this study without the need for work to improve / amend the model. The Acre Road CDA model required the enhancement to a fully integrated 1D-2D model.

5.5.2 Acre Road CDA

The Acre Road CDA model required the enhancement to a fully integrated 1D-2D model, comparable to the Enfield Town Centre and Moore Brook Culvert CDA models.

The details of the model development process are presented in the supporting Acre Road Model Development, Technical Note [6]

5.5.3 Eastcote CDA

A new model has been developed for the Eastcote CDA in-line with the general approach used to develop the Enfield Town Centre CDA and Moore Brook Culvert CDA models.

The details of the model development process are presented in the supporting Eastcote Model Development, Technical Note [7]

5.5.4 SuDS Modelling

The representation of the streetscape SuDS features in the model is graphically demonstrated in Figure 5.

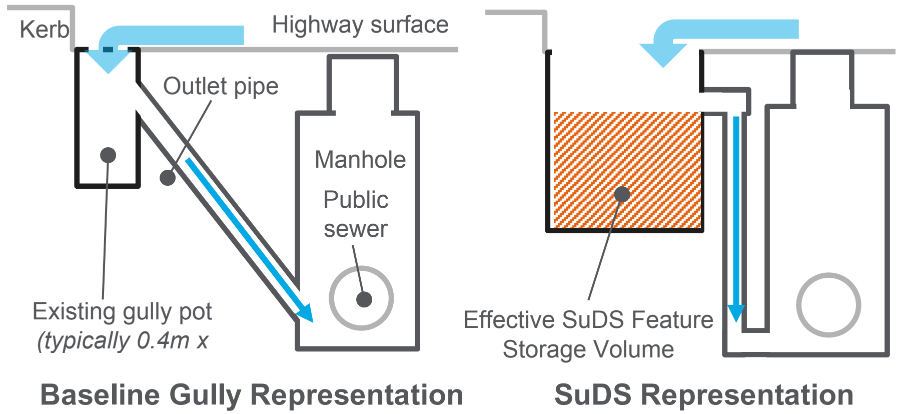


Figure 5 –Representation of Streetscape SuDS Features Using Model Nodes

The inclusion of Property Garden Raingardens and Rainwater Planters was achieved through the adjustment of effective roof areas used in the models to generate runoff. The adjustments calculated to ensure a net reduction in 1 in 5-year rainfall runoff volume matching the defined attenuation capacity for the SuDS feature type.

[5] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Evaluation Scenarios, Technical Note

[6] 10016816-ARC-XX-XX-RP-DE-0029-Acre Road Model Development, Technical Note

[7] 10016816-ARC-XX-XX-RP-DE-0028-Eastcote Model Development, Technical Note

5.6 Flood Mitigation Assessment

To provide a holistic understanding of the flood risk mitigation value that the various SuDS Evaluation Scenarios provide a Multi-Criteria Analysis (MCA) approach has been taken, comparing predicted performance with projected investment. The criteria included were as follows:

- **NRD Benefit** – Reduction in NRD flood depth and properties at risk
- **Catchment Flood Depth Benefit** – Return period weighted average reduction in surface water flood depth across the catchments
- **Projected Investment** – Sum of all SuDS CAPEX estimates
- **Number of Individual SuDS Features**

The full results of the multi-criteria assessment split into each metric and CDA are shown in Figure 8 overleaf.

The agglomerated and normalised (See Appendix B) results shown in Figure 6 demonstrate there is significant variability across all the CDAs for most SuDS Evaluation Scenarios, including the All Distributed SuDS scenario. This implies that the realising benefits is likely to be highly dependent of the specifics of each catchment, such as topography and effective drainage system capacity.

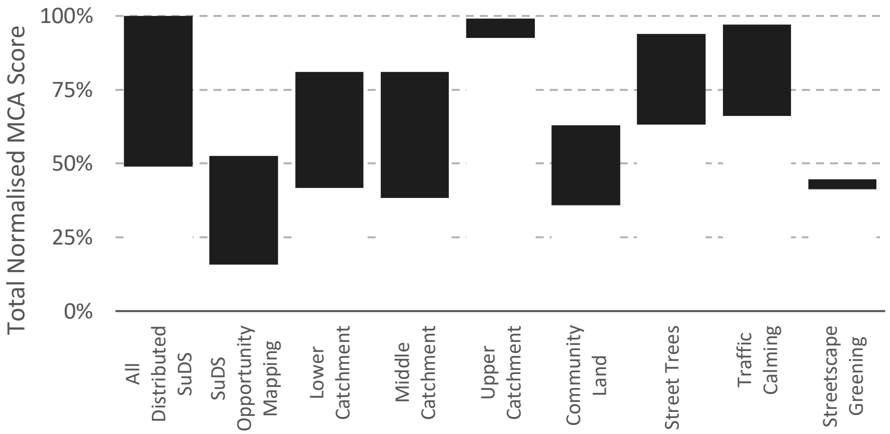


Figure 6 – Distribution Ranges of the Multi-criteria Analysis Results

Note: Eastcote results not included

The Street Trees and Traffic Calming scenarios generate the greatest net benefit for a specific application of SuDS features while the high score and low variability of the Upper Catchment scenario indicates the importance of catchment location, discussed further in Section 5.6.1.

5.6.1 Influence of Catchment Location

The purpose of deriving the Upper, Middle and Lower Catchment Evaluation Scenarios was not only to identify cost-beneficial strategic investments but also to generate some insight into the importance of location within a catchment. It was expected at the outset that Distributed SuDS would provide the greatest benefit higher up in a catchment. For these scenarios, location was defined based the elevation of each SuDS feature in comparison to the overall catchment topography (See SuDS Evaluation Scenario, Technical Note), in these cases the CDA boundaries.

The NRD Benefit metric from the MCA analysis for each CDA, plus the average, has been plotted in Figure 7.

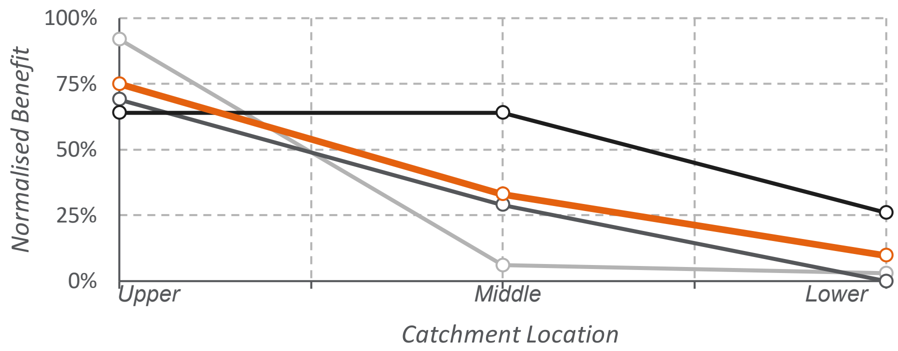


Figure 7 – Influence of Watercourse Proximity on NRD Flood Depth and Frequency Benefit

Key:

Enfield Town Centre CDA
Moore Brook Culvert CDA
Acre Road CDA
Combined Average

The results support the MCA results, demonstrating the value of focusing Distributed SuDS within Upper and Middle areas of defined catchments.

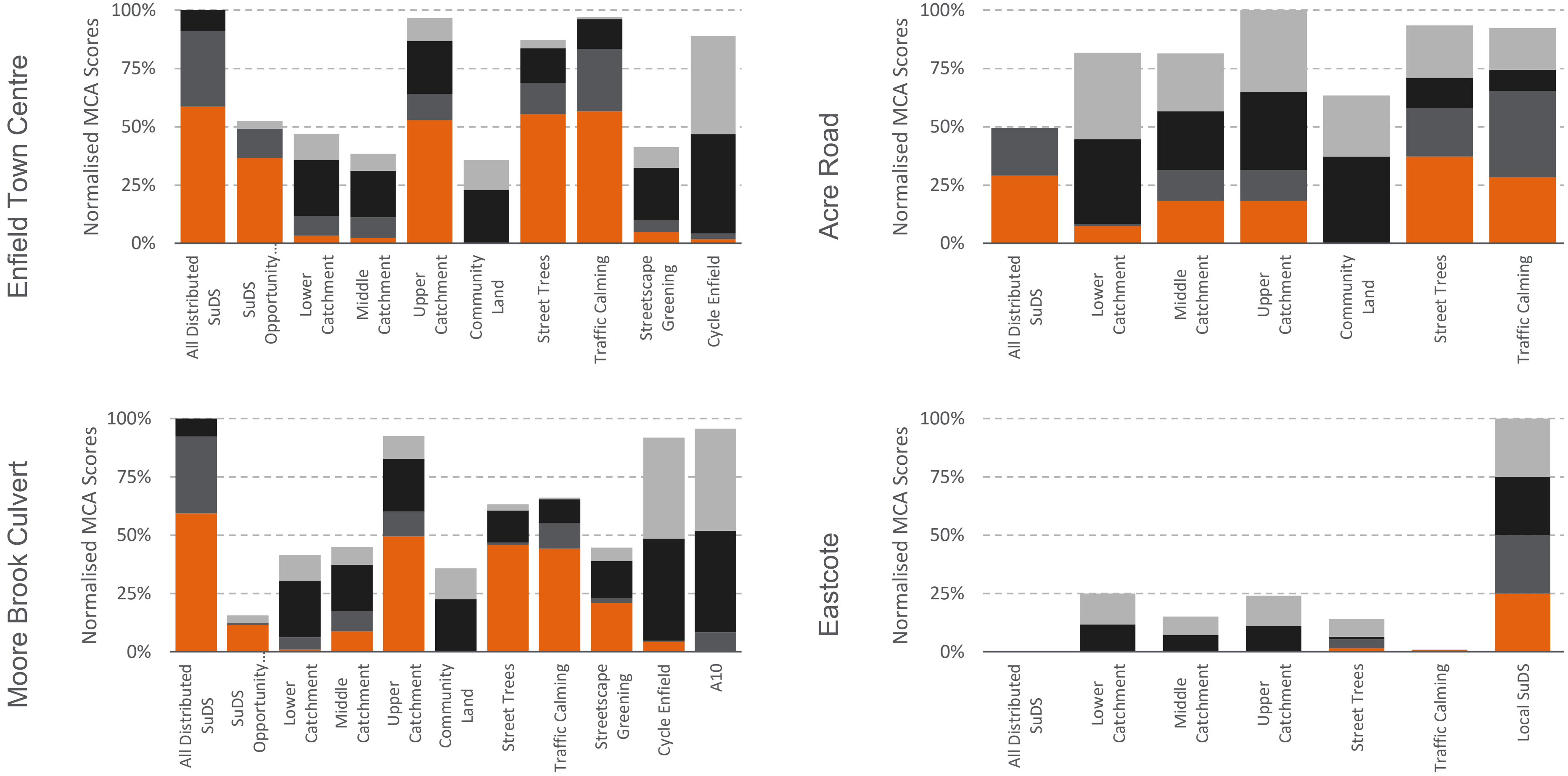


Figure 8 – Multi-criteria Analysis Results

Notes: For the Number of Individual Features metric the highest scoring SuDS Evaluation Scenario will include the least number of features (i.e. least CAPEX, minimised land-take etc.) / the normalisation of the MCA scores is explained in Appendix B

Key:

NRD Benefit
Catchment Flood Depth Benefit
Projected Investment
Number of Individual Features

5.7 Economic Assessment

Only the selected SuDS Evaluation Scenarios have been included in the economic assessment for Stage 1. The selection was undertaken by the PSG, focusing on scenarios that Common and Local scenarios that generated that largest MCA benefit and considered relevant to current aspirations within the catchments.

5.7.1 Total Benefits Value

The total value of flood damage reduction and Natural Capital compared to CAPEX (required to realise the flood damage reduction) is shown in Figure 9.

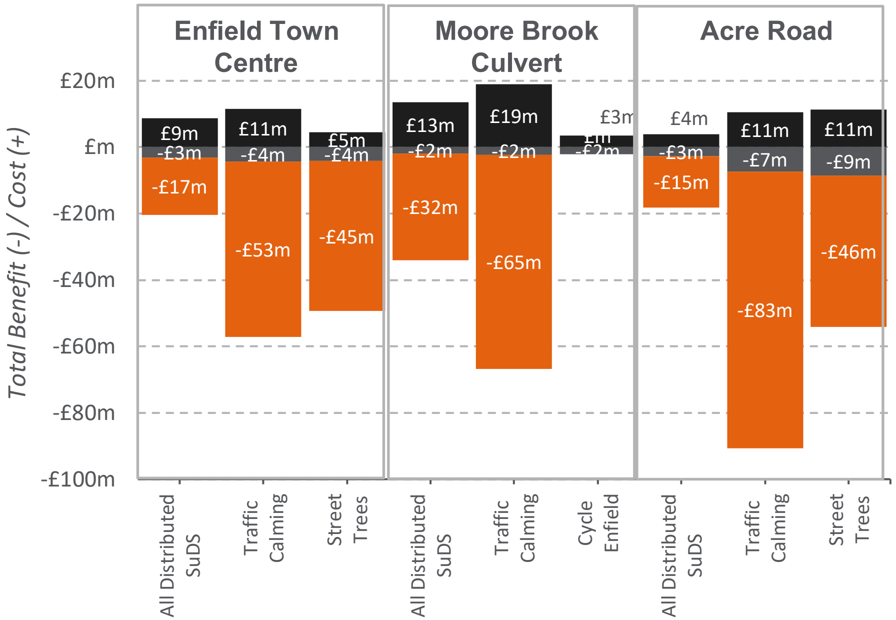


Figure 9 – Total Benefits Value

Key:

Flood Damages Avoided
CAPEX & 100 Year OPEX Costs
Monetised Wider Benefits

As would be expected, based on the assessment in Section 5.4) the Natural Capital derivation benefits provide the largest proportion of the total benefit. The Traffic Calming scenarios consistently generate the largest Natural Capital benefit for each of the catchments, but they incur the highest CAPEX.

Due to the projected significance of Natural Capital on the overall investability of Distributed SuDS the calculation of benefit-cost ratios (shown in Figure 10) have been split amongst flood damages, EA (i.e. environmental) and non-DEFRA benefits (i.e. socio-economic).

The inclusion of Natural Capital ensures the benefit-cost ratios of at least greater than 2, reaching around 10 for the Street Tree scenarios. The Acre Road catchment returns higher benefit-cost ratios that the other two catchments. This discrepancy is considered an emergent property of the difference in topography, specifically the lack of major parkland in the Acre Road catchment.

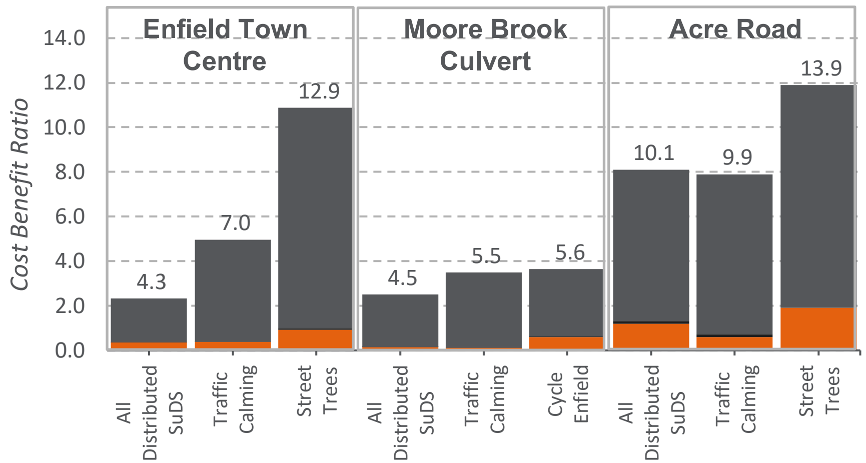


Figure 10 – benefit-cost Ratios, Selected Scenarios

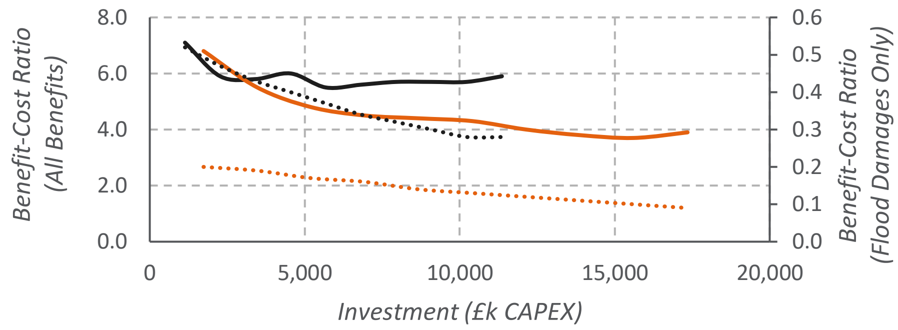
Key:

Flood Damages Avoided Only benefit-cost
Environmental (DEFRA only) BEST Evaluated benefit-cost
Social & Community (non-DEFRA) BEST benefit-cost

Note: DEFRA benefits inc. water quality and carbon sequestration / non-DEFRA benefits inc. amenity, traffic calming and health

5.7.2 Optimised Investment

The relationship between total investment and benefit-cost ratio provides an indication of the optimal strategy, to avoid potential over-commitment with limited to no return. The benefit-cost values for both flood damages avoided only and including wider benefits for each realisation level has been derived for the All Distributed SuDS scenario, plotted in Figure 11.



Key:

Enfield Town Centre Flood Damages Avoided Only
Enfield Town Centre All Benefits
Moore Brook Culvert Flood Damages Avoided Only
Moore Brook Culvert All Benefits

Figure 11 – All Distributed SuDS benefit-cost Ratio Profile

The profiles for both Enfield Town Centre and Moore Brook Culvert demonstrate the same basic shape, stretched over different total projected investment levels. The general downward trend is the result of the optimisation of the selected SuDS features, ensuring those with the most optimal flood and wider benefits are delivered first.

For Flood Damages Only Avoided the profiles are more linear, with Enfield Town Centre showing a more significant benefit-cost ratio than the Moore Brook Culvert catchment. The benefit-cost ratio for the 25% realisation level was calculated at between 2.5 and 7.0,

Variations in the All Benefits profiles is the result of different SuDS feature types being selected as investment increases. The characteristic profile 'U-shape' also demonstrates that there is likely to be an effective minimum level of benefit whatever the scale of investment. The benefit-cost ratio for Enfield Town Centre never drops below 5.5 while Moore Brook Culvert never drops below 3.7, both considered relatively healthy values.

5.8 FCERM GiA Pilot Funding Application

Following the economic evaluation, the PSG convened to select a several SuDS Evaluation Scenarios (one for each CDA) to be submitted for FCERM GiA funding through the current Business Case process. As part of The Proposal was an agreement in principle that the EA would approve up to £600k of FCERM GiA funding for SuDS (distributed across the contributing London boroughs), subject to the preparation of Outline Business Case (OBC) documents that comprehensively demonstrated the benefits of an investment in Distributed SuDS. The available funding was split amongst the London boroughs through a negotiated agreement, largely based on catchment size.

The Promoted Long-term Strategies for each CDA are as follows:

- **Enfield Town Centre** – Street Tree Retrofit
- **Moore Brook Culvert** – Cycle Enfield
- **Acre Road** – Traffic Calming Measures
- **Eastcote Town** – Public Realm Improvements

The financial values used in the OBC were derived using the ranked SuDS features (for the selected scenarios) up-to the agreed total funding allocation for each London borough. The Strategic Case section of the OBC document was written demonstrating the potential long-term return on investment, highlighting the supplementary benefits of Natural Capital.

6 STAGE 2 – COMPREHENSIVE ECONOMIC VALUATION

6.1 SuDS Features

This section covers the SuDS feature types selected, the design parameters used for the modelling, and derivation of locations across the catchments.

A more detailed breakdown of the selection process, key 'design' parameters, and modelling approaches are presented in the supporting SuDS Feature Technical Note[8]

6.1.1 SuDS Feature Types

The selection of SuDS feature types for the inner London catchments was split into two groups, split as follows:

- **Paved Public Streetscape** – primarily pavements, grass road verges and shared paved / pedestrianised areas
- **Building Roofs** – public or private properties, mainly larger than 600 m^2 and typically commercial offices, flats, and community housing complexes

The selection accounted for the highly urbanised nature of the catchments, projected lack of open green space (adjacent to the highway), and potential value of more 'engineered' features within commercial centres.

The SuDS features types included for Stage 2 are:

- **Streetscape Bioretention** (Stage 1)
- **Street Tree Pits** (Stage 1)
- **Living Roofs** – installation of living roofs (green roofs) to directly store rainfall, either as part of new builds, refurbishment or retrofit
- **Rainwater Planters** (Stage 1)

Swales and Property Raingardens considered in Stage 1 were dropped from the assessment. This was largely due to the projected lack of available space for swales in this more urbanised catchment and minimal opportunities for Property Raingardens.

[8] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Features Technical Note

6.1.2 Design & Attenuation Capacity

For each SuDS feature type a set of typical design characteristics, necessary to define their effective attenuation capacity, were derived from a selection of case studies and industry design standards. This was to enable the empirical assessment of flood and economic benefit, based on pre-defined and scalable physical parameters used to model individual SuDS features.

Unit values (per m^2) were derived for the Streetscape Bioretention and Living Roof features to enable them to be scaled to the spatial opportunities derived, as explained in Section 6.1.3.1 and Section 6.1.3.3. Conversely, the Street Tree Pits and Rainwater Planters have had a specific attenuation capacity derived.

6.1.3 Schedule of Opportunities

The identification of opportunities (locations) was undertaken using a GIS workflow developed to utilise OS MasterMap topographic data.

6.1.3.1 Streetscape Bioretention

For the identification of Streetscape Bioretention features, a set of typical design parameters were devised, including minimum pavement width (for access), minimum length of SuDS feature (tangential to the road), and maximum length (to account for the need for intermittent access from the pavement to the road). These values were collated from both standard industry guidance and numerous related case studies, focusing on SuDS schemes delivered in London. An automated GIS routine was used to delineate each SuDS feature relative to the available pavement space, based on these values.

An example of the delineated Streetscape Bioretention locations is shown in Figure 12.

Figure 12 – Streetscape Bioretention, Example of SuDS Feature Delineation

It is important to note that the areas delineated represent the total potential extent for the placement of SuDS features. The design and construction would have to account for pedestrian / vehicular accesses, presence of street furniture, services and utilities etc., which would limit what could be realised. This is accounted for within the modelling through an adjustment to the effective volume of storage that is applied.

6.1.3.2 Street Trees

There is insufficient data available to determine the suitability of existing street trees for retrofitting SuDS tree pits at this scale of assessment. The GLA tree map[9] data has been used to define the location of trees, forming the schedule of retrofit opportunities. For new street trees a GIS workflow was used to identify potential locations within paved areas based on a minimum proximity to existing trees and set spacing, both values estimated from interrogating sample locations from the existing tree map data.

6.1.3.3 Living Roofs

The suitability for living roofs was based on the selection of buildings greater than a defined minimum area, the value for which was evaluated from a review of case studies and with reference to sample areas in the catchment.

The development of living roofs as retrofit features onto existing buildings or integrated in new development / refurbishments has been considered, but only with the economic evaluation of benefit. It was not considered practical to identified 'sites' for new development / refurbishment opportunities due to the inherent uncertainty over future development, especially within this dense inner London area.

6.1.3.4 Rainwater Planters

It was assumed that rainwater planters would be most suitable predominantly for residential properties and small commercial units, due to roof drainage downpipes typically being external to ease of installation. The suitability was based on the selection of buildings less than a defined minimum area, the value for which was evaluated from a review OS MasterMap building footprints and Google StreetView within sample areas in the catchment. A roof area of 25m^2 was defined as the area the average downpipe serves, used to derive the number of rainwater planters to be installed per property (assuming one unit per downpipe).

The effective capacity of each unit was based on a specific TWUL product that has been developed, part of their Surface Water Management Programme. The total attenuation capacity is 0.31 m^3.

[9] https://www.london.gov.uk/what-we-do/environment/parks-green-spaces-and-biodiversity/trees-and-woodlands/london-tree-map

6.1.3.5 Total Opportunities

A summary of all SuDS opportunities identified and evaluated, across all three boroughs, is shown in Table 2.

SuDS Feature Type	No. Features	Area (m^2)		Volume (m^3)*	
		Average	Total	Average	Total
Streetscape Bioretention	29,551	83	2.45 m	23.5	694.4 k
Street Tree Retrofit	43,417	-	1.09 m**	2.1	91.18 k
New Street Trees	58,516	-	1,46 m**	2.1	122.9 k
Living Roofs	2,071	60	124.3 k	1.9	3,935
Rainwater Planters	25,921	-	-	0.2	5,184

Table 2 - Schedule of Catchment SuDS Opportunities

*Note: * effective function storage volume / ** area assumed based on average tree canopy of 25 m^2*

To provide a demonstrate of scale the total area values are presented in Figure 13 as proportions of the total study catchment area.

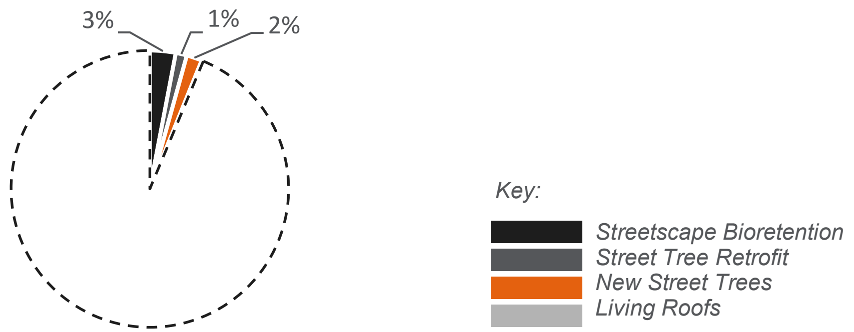


Figure 13 – Total SuDS Opportunity, area (m^2) compared to total catchment area

6.2 SuDS Evaluation Scenarios

This section covers the derivation of scenarios to evaluate the financial value generated with the implementation of different Distributed SuDS feature types and the approach to selecting the most optimal sites for investment.

A more detailed breakdown of the formulation of scenarios is presented in the supporting SuDS Evaluation Scenarios Technical Note[10]

6.2.1 SuDS Scenarios

Two sets of scenarios were developed. The first set focused on evaluating the benefit of each SuDS feature type independently, to enable the comparative analysis of flood / cost benefit. The scenarios evaluated were:

- **Public Realm Implementation**
  - Streetscape Bioretention
  - Street Tree Retrofit / Retrofit
  - New Street Trees
- **Private Realm Implementation**
  - Living Roofs (retrofit and redevelopment / refurbishment)
  - Rainwater Planters

The second set was based on the likely delivery of a mix of SuDS feature types, to create a more realistic reflection of potential value. The two scenarios evaluated cover the two different SuDS feature groups (See Section 6.1.1):

- **All Streetscape SuDS** – inc. Streetscape Bioretention, Street Tree Retrofit / Retrofit, and New Street Trees SuDS features
- **All Building SuDS** – inc. Living Roofs and Rainwater Planters

[10] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Evaluation Scenarios, Technical Note

6.2.2 Realisation Levels

It was noted that in the Stage 1 approach, the selection of individual SuDS features based on their projected benefit to the wider catchment did not directly account for flood mitigation, and resulted in relatively minor improvements in the benefit-cost ratios (See Figure 11). To address this, and account for the difference in scale and urban landscape characteristics present in the Stage 2 catchments, an alternative approach was developed.

6.2.2.1 Technical Overview

The Stage 2 approach did not attempt to evaluate the hydraulic function of each SuDS feature before the development of the SuDS Evaluation Scenarios. It was assumed that the more constrained urban landscape, extensive high-capacity drainage systems, and low-lying topography would likely limit the distance over which 'benefit' (i.e. reduction in flooding by storing water at source) would be generated. This assumption enabled SuDS features to be clustered into groups so that their local reduction in flood damages could be discretely evaluated.

Running the All Streetscape SuDS scenario allowed these groups to be sorted in order of benefit (to properties within their cluster) and form the realisation levels.

The realisation levels selected were:

- **1%**
- **2%**
- **5%**
- **25%**
- **100%** - all features identified in the Schedule of Opportunities

It was elected to utilise the TfL hex grid[11], developed by GLA for the Green Infrastructure Focus Map, to form the boundaries of these clusters. Their size was considered relevant to the likely extent that SuDS features would typically provide flood mitigation. In addition, it provided a suitably coarse graphical framework to present the results of the Stage 2 work, given the scale of the catchments and number of individual SuDS features assessed (as stated in Table 2).

[11] https://data.london.gov.uk/dataset/green-infrastructure-focus-map

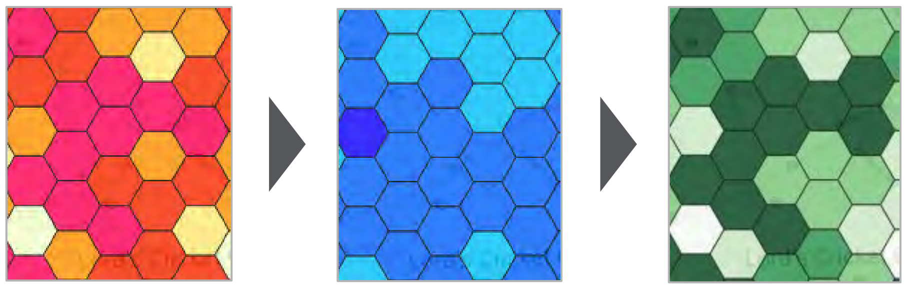
6.2.2.2 Approach to Optimisation

To 'sort' the SuDS features clustered into the hex grids (as explained in Section 6.2.2.1) model predictions were used to define the following two metrics (the sum within each hex grid) for each scenario:

- **Flood Damage Reduction** – calculated based on the EA 2014 Multi-coloured Handbook (Flood Hazard Research Centre, 2014)
- **Effective SuDS Feature Volume** – modelled functional volume

Dividing the Effective SuDS Feature Volume by the Flood Damage Reduction produced a SuDS Efficiency value, indicating where the most significant benefit is likely to be realised with the least investment in SuDS (i.e. the smallest effective volume).

The process is graphically demonstrated for a small section of the project study area in Figure 14.



Flood Damage Reduction		**Effective SuDS Feature Volume**		**SuDS Efficiency**

Figure 14 – Realisation Level TfL Hex Grid Optimisation Process

Once sorted by this efficiency value the hex grid clusters of SuDS features were grouped in the realisations levels, achieved by cumulatively adding the hex grids (in order from most efficient) until their total CAPEX value equated to the percentage value of all opportunities identified.

The spatial distribution of the realisation levels for the All Streetscape SuDS scenario is shown in Figure 15.

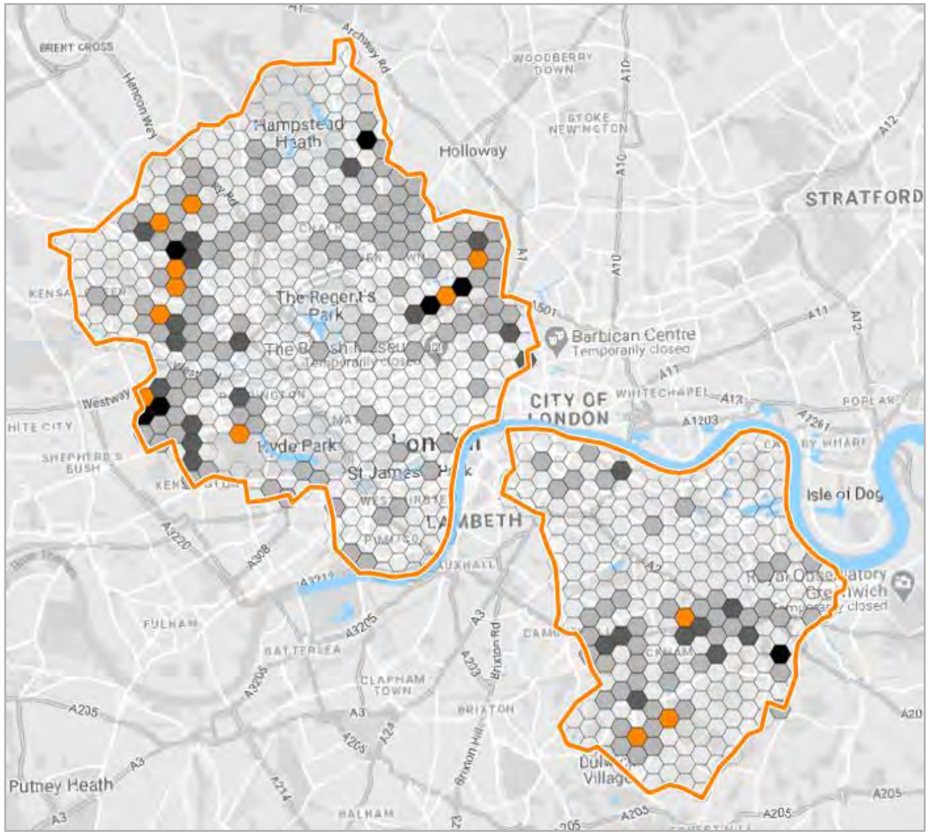


Figure 15 – All Streetscape SuDS Realisation Levels Hex Grid

Key:

- 1%
- 2%
- 5%
- 25%
- 100%

6.2.2.3 Limitations of Approach

The approached developed and outlined in Section 6.2.2.2 is considered pragmatic and appropriate for the level of evaluation being undertaken within this study. However, it does not (and cannot) account for several issues related to identifying 'causality', in respect to the individual benefits of different SuDS features on specific flooding locations.

A true determination of optimal approaches to Distributed SuDS would require the full assessment of all possible combinations of locations, to define the exact causality and mechanisms of benefit. Such an approach would necessitate a disproportionate and unachievable level of processing, currently beyond the technical capability and capacity of common modelling systems. An alternative method would require the use of neural networks / machine learning, which has been elaborated on as a recommendation in Section 8.2.5.

The inability to determine an empirical relationship between the distribution of SuDS features and resultant benefits is considered to create the following uncertainties and limitations:

- Unaccounted benefit in a hex grid from SuDS features proposed within neighbouring hex grids (or further), where they are location upstream
- Over-estimate of benefit due to SuDS features located at the downstream boundary of a hex grid (more likely to generate benefit in the neighbouring hex grid)
- Not accounting for the generation of flood benefit through sub-surface connectivity, including from CSO discharges (to surface water and storm relief sewers) and downstream of major pumping stations

The realisation levels and the optimised SuDS locations do provide a heat-map type understanding of the key benefit areas across the catchment, specifically the clustering of hex grid cells. The most significant impacts of these limitations on the outcome of the project will be focused on the most optimal locations, specifically where individual / isolated hex grid cells have been identified. To account for this and limit impacts on the key economic outcomes the 1% and 2% realisation levels will be shown within the various analytics but will not be used to draw direct conclusions, rather be left as a conceptual indication of the potential benefit of the most optimal locations.

6.3 SuDS CAPEX Estimation

This section covers the derivation of CAPEX costs for each SuDS feature type.

A more detailed breakdown of the derivation of CAPEX estimates is presented in the supporting SuDS CAPEX Estimation, Technical Note[12]

The commitment to SuDS should not be adversely impacted by uncertainty around the need for ongoing OPEX, since it is considered a common consideration for any technical solution to mitigation flooding. For this reason, OPEX has been omitted in Stage 2.

6.3.1 Case Studies

The derivation of representative CAPEX estimates is an essential component of the benefit-cost calculations, and critical in instilling confidence in the derived value of SuDS. The inherent variability of investment costs associated with SuDS schemes, specifically bioretention features, is evident within the case studies that have been collected to inform the estimates defined here.

Numerous SuDS cases studies (most within Greater London) have been compiled to provide sample CAPEX costs. Unit costs have subsequently been extracted at defined percentiles (of the dataset), ensuring that the calculation of CAPEX is benchmarked and relevant to the Distributed SuDS approach.

Some examples of bioretention case studies selected include:

- **Haselbury, London Borough of Enfield**[13] - schemes included several streetscape bioretention features, incorporating traffic calming function
- **Ribblesdale Road, Nottingham**[14] - schemes included streetscape bioretention features broken down into total and unit costs
- **Talgarth Road, London Borough of Hammersmith & Fulham**[15] - schemes included streetscape bioretention and new street trees

6.3.2 Design / Industry Standards

To provide a measure of benchmarking and statistical reliability further cost information was identified from a range of SuDS standards and information collated during Stage 1.

Several specialist suppliers were used to provide indicative costs for living roof products. The rainwater planter installation cost was provided by TWUL and was the sole cost basis used in the project.

6.3.3 Derivation of CAPEX

It has been recognised that perceived construction costs associated with SuDS can be a major blocker to their implementation, especially within a challenging funding environment. One strategy to reduce CAPEX costs is the integration of SuDS features / functionality within previously committed highway and streetscape works (e.g. pavement resurfacing, utilities upgrades etc.).

To understand the potential value of this, the calculation has been split into the following two approaches:

- **Opportunistic Delivery** – only includes SuDS material and design costs, assuming that all procurement / mobilisation costs, plus non-SuDS material costs, are covered by a different program of works
- **Direct Procurement** – assumes the work is commissioned solely to construct a dedicated SuDS features, including all procurement / mobilisation and construction costs

To enable this calculation the costs extracted from the case studies and design / industry standards have been broken down into procurement / mobilisation and material costs, then further split into SuDS and non-SuDS costs.

[12] 10016816-ARC-XX-XX-DE-RP-0002-01-SuDS CAPEX Estimation, Technical Note

[13] https://governance.enfield.gov.uk/documents/s72115/PL%2018.090%20Appendix%20APPROVED%20-%20EM.pdf

[14] https://www.susdrain.org/case-studies/case_studies/greening_streets_retrofit_rain_gardens_nottingham.html

[15] http://content.tfl.gov.uk/sustainable-urban-drainage-november-2016.pdf

6.3.4 CAPEX Values

The calculated CAPEX values, split into Direct Procurement / Opportunistic Delivery and showing the uncertainty range, are shown in Figure 16.

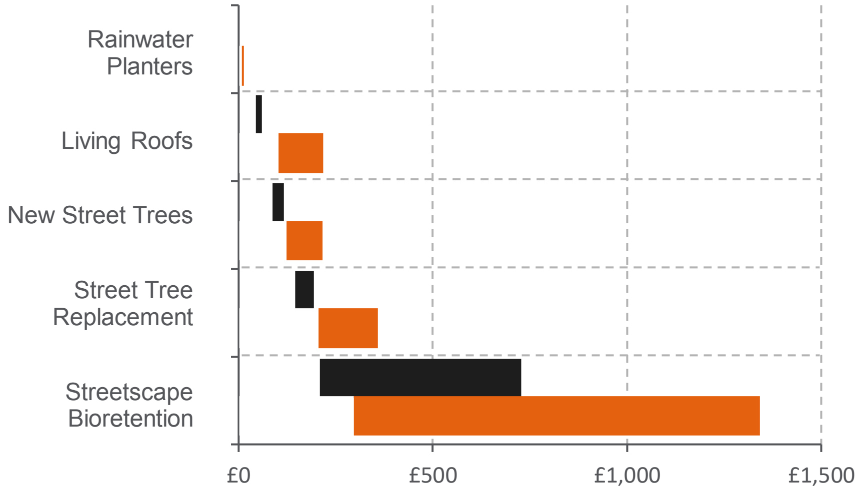


Figure 16 – SuDS CAPEX Estimation, Average Cost per m^2 of Green Infrastructure

Note: street trees have been split into pavement and highway as they have been allocated different costs, due to the projected difference in complexity of construction / an average street tree canopy area of 25m^2 has been assumed

Key:

Opportunistic Delivery Uncertainty Range
Direct Procurement Uncertainty Range

The calculated figures demonstrate a significant variation in the range of costs between opportunistic delivery and direct procurement. For all but Streetscape Bioretention SuDS the highest estimated opportunistic delivery costs are less than the lowest estimate direct procurement costs.

The more bespoke and engineered requirements for Streetscape Bioretention SuDS does limit the benefit of opportunistic delivery, with the lowest cost estimates equating to same value.

The average cost per individual SUDS feature, based on the schedule of opportunities and the CAPEX unit costs (shown in Figure 16) can be seen in Figure 17.

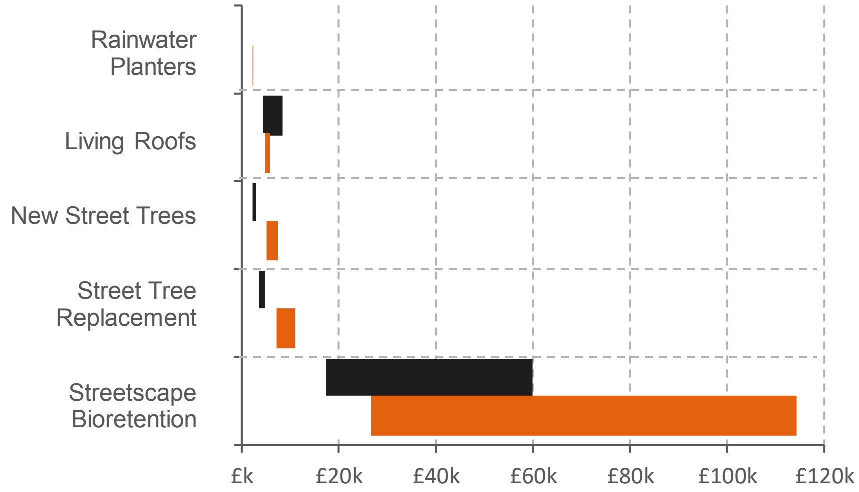


Figure 17 – SuDS CAPEX Estimation, Average Cost per SuDS Feature

Note: values have been derived from the schedule of opportunities multiplied by the CAPEX unit costs

Key:

Opportunistic Delivery Uncertainty Range
Direct Procurement Uncertainty Range

Streetscape Bioretention SuDS features require the largest individual investment due scale of works typically required, plus procurement / mobilisation costs and traffic management. Savings of approximately 50% can be realised through opportunistic delivery.

6.4 Derivation of Natural Capital

This section covers the derivation of unit natural capital valuation for each SuDS feature type.

A more detailed breakdown of the selection process, key 'design' parameters, and modelling approaches are presented in the supporting SuDS Natural Capital and Socio-Economic Accounting, Technical Note[16]

The natural capital value of the SuDS features considered was initially based on an expansion the Stage 1 approach to better account for the inherent uncertainty of the valuation process and considering the variability of urban environments.

The natural capital metrics have been split into 'Environmental' and 'Socio-economic' groups as follows:

Environmental	**Air Quality** (calculated using the CIRIA BEST tool)
	Biodiversity (calculated using the CIRIA BEST tool)
	Carbon Sequestration (calculated using the CIRIA BEST tool)
	Groundwater Recharge (calculated using the CIRIA BEST tool)
Scio-economic	**Amenity** (calculated using the CIRIA BEST tool / project assumptions)
	Health (calculated using the CIRIA BEST tool)
	Building Cooling (calculated using the CIRIA BEST tool)
	Building Heating (calculated using the CIRIA BEST tool)
	Property Value (calculated using Office of National Statistics data)
	Noise Reduction (calculated using the CIRIA BEST tool)
	Traffic Calming (calculated using UK Gov road accident statistics)
	Urban Cooling (calculated using information from DEFRA)

6.4.1 Area averaged Value

For Stage 2 area averaged benefit valuation has been used to enable effective benefit scaling for the evaluated scenarios and realisation levels (See Section 6.2). The area average value for each SuDS feature type assessed is shown in Figure 18 and Figure 19.

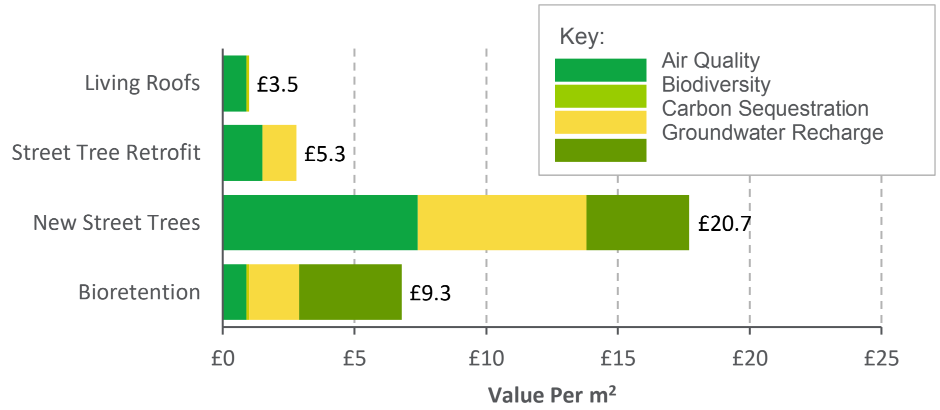


Figure 18 – Natural Capital, Environmental Value of SuDS Features per m²

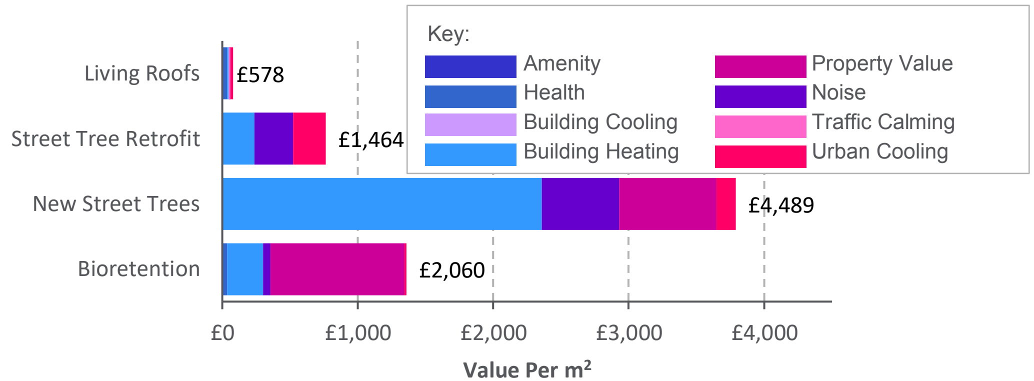


Figure 19 – Natural Capital, Socio-economic Value of SuDS Features per m²

16 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Natural Capital and Socio-Economic Accounting, Technical Note

6.4.2 Uncertainty Ranges

The inclusion of uncertainty ranges ensures a robust consideration of the variability in estimates made for natural capital value, taken through into the economic evaluation (See Section 6.7).

The impact of uncertainty assumptions on the calculated SuDS feature values can be seen in Figure 18 and Figure 19.

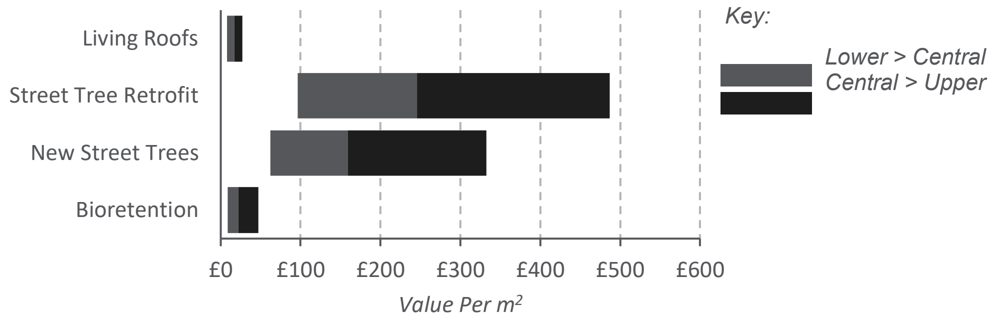


Figure 20 – Uncertainty Variation, Environmental Value of SuDS Features per m²

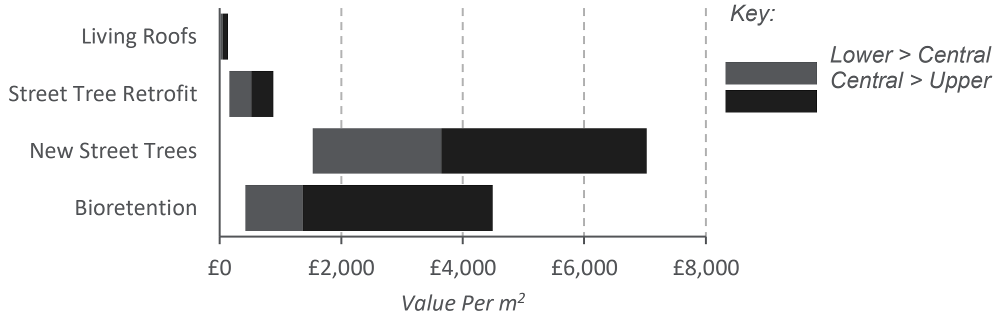


Figure 21 – Uncertainty Variation, Socio-economic Value of SuDS Features per m²

The degree of relative and absolute variation, shown in Figure 20 and Figure 21, is an inherent characteristic of natural capital valuation that has to be fully accounted for at all stages of decision making around Distributed SuDS. There will remain a high degree of local influence on the realisation of value which will always need to be evaluated following the commitment to invest in Distributed SuDS.

6.4.3 Geographical Distribution of Potential Benefit

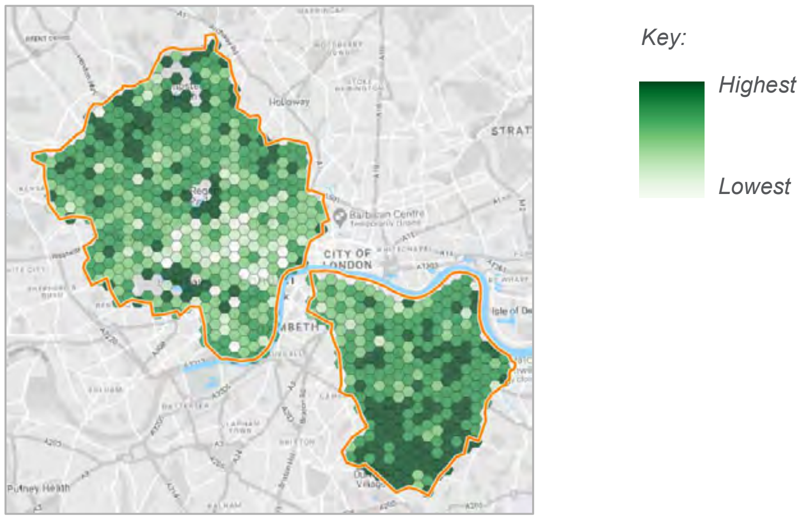


Figure 22 – Natural Capital, Distribution of Environmental Value

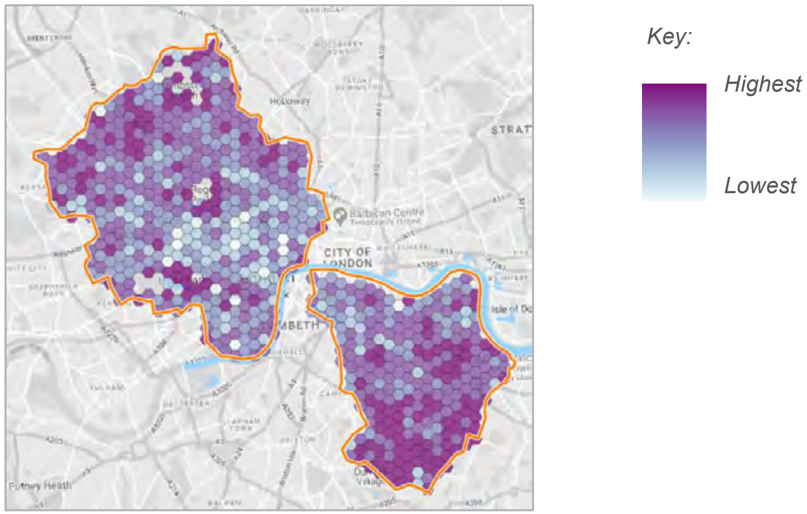


Figure 23 – Natural Capital, Distribution of Socio-economic Value

6.5 Hydraulic Modelling

This section covers evaluation of SuDS scenarios using existing and newly developed hydraulic modelling.

A more detailed breakdown of the modelling activities undertaken are presented in the supporting Hydraulic Modelling, Technical Note[17]

The hydraulic modelling strategy aimed to maximise the value of existing 1D network models covering the study site (held by TWUL), supplemented by the development of a supplementary 2D surface water model. All modelling was undertaken in InfoWorks ICM.

The preferred approach for this Stage (devised during the early stages of the project) was the development of a fully integrated 1D-2D model to enable the concurrent and dynamic assessment of predicted flooding and calculated damages. This was subsequently translated to the split modelling approach due to the limitations that the integrated 1D-2D model created, specifically long simulations times that would have prevented the full assessment of the various scenarios and realisation levels (as outlined in Section 6.2).

6.5.1 Existing Models

The existing TW network models obtained were:

- **Beckton STW Catchment** – A WaPUG CoP type II / type III model, with extensive foul / combined and surface water network detail in most areas, subject to recent re-verifications in places
- **Crossness STW Catchment** – A WaPUG CoP type I model, with a complete representation of the trunk foul / combined network and some major surface water sewers, but lacking street-level detail in many places

Following the halt of initial efforts to develop the integrated 1D-2D model, requiring the inclusion in additional network detail for the Crossness catchment, it was decided that the existing models would be retained without any additional enhancement work.

[17] 10016816-ARC-XX-XX-DE-RP-000#-01-SuDS Evaluation Scenarios, Technical Note

6.5.2 New 2D Model

A new 2D model was necessary to enable accurate and definitive predictions of surface water flooding to enable the calculation of flood damages. The model development process utilised OS MasterMap data, EA LiDAR, and supplementary hydrogeological data and assumptions, to define variable roughness and infiltration characteristics. The model also includes all NRD dataset points so that flood predictions could be extracted individually.

To account for the effective capacity of the drainage system, predictions from the existing TW models were used to adjust the 2D model parameters.

6.5.3 Overall Modelling Approach

The relationship between the two model types and their use in evaluating the SuDS scenarios is outlined in Figure 24

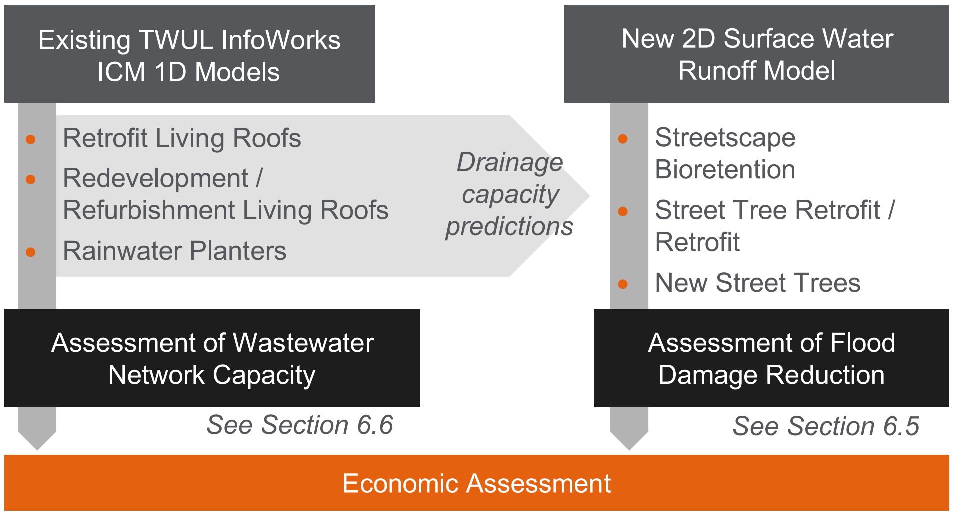


Figure 24 – Hydraulic Modelling Approach

6.6 Wastewater Network Capacity

One of the primary factors during the selection of an inner London study area was the projected value of reducing discharges to the predominantly combined wastewater networks, as a cost-effective method to provide headroom without major capital investment in infrastructure upgrades. This is specifically relevant to the Beckton STW catchment, which is served by a series of major trunk sewers and interconnecting bifurcations / overflows, creating complex hydraulic interconnections and drainage routes. Undertaking major sewerage upgrades within this central London area involving attenuation storage and / or increased conveyance capacity through sewer upsize is now largely considered unaffordable and undeliverable.

The assessment of wastewater network capacity has been to calculate the effective headroom (dry weather flow (DWF), typically around 150 l/hd/d), measured in additional dwellings that the SUDS scenarios evaluated could provide capacity for.

The calculation workflow is shown below:

1. Extract the top water level (TWL) at every modelled node (i.e. manhole) for the SuDS scenarios models
2. Create 'dummy' weirs at each node in the base model with crest levels equalling the TWL values extracted
3. Re-run the base models to record the volume of water discharged over these dummy weirs – effectively capturing the volume of additional capacity provided
4. Convert the volume at each node into dwellings, based on the DWF assumptions and standard occupancy rates

The derived dwellings have been aligned to the connecting sewers to enable practical visualisation of headroom created, demonstrated in Section 6.6.1.

6.6.1 Creation of Headroom

The total headroom created for the different SuDS scenarios is shown in Figure 25. It is important to note that this is representative of the realisation of all SuDS opportunities, presenting an effective 'average' headroom that does not account for the localisation of benefit (as shown in Section 6.6.2).

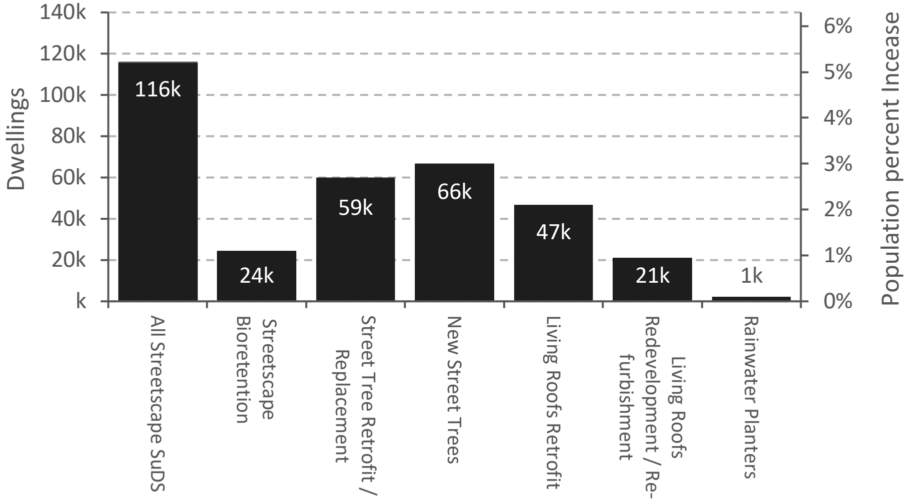


Figure 25 – SuDS Scenario Wastewater Capacity (Dwellings) Created

Note: 'Total Catchment Population Percent Increase' calculated as percent of combined Beckton / Crossness STW modelled population (5.31 m)

Due to the inherently hierarchical network layout of the sewerage system the areas that significant headroom could be created are widely distributed across the study area

The values shown in Figure 25 provide a general appreciation of the overall benefit but its value is relatively limited within geographic context, which has been provided in Section 6.6.2.1 to Section 6.6.2.5.

6.6.2 Benefiting Areas

In this section, the plans (Figure 26 to Figure 30) show the distribution of headroom created for individual pipe sections (typically manhole to manhole) for the All Streetscape SuDS scenario.

It is important to note that they do not directly identify areas where development could be facilitated by Distributed SuDS, which may be situated some distance from the sewers. Benefit is largely confined to the trunk network so additional capacity may need to be created within minor connecting pipework, through more traditional engineering approaches (e.g. sewer upsize).

The key for the plans in Sections 6.6.2.1 to 6.6.2.5 is shown below:

Key:

- > 250 dwellings
- > 600 dwellings
- > 12,000 dwellings (+0.5%)
- > 48,000 dwellings (+2.5%)
- > 120,000 dwellings (+5%)

6.6.2.1 Fleet Storm Sewer (Beckton STW Catchment)

The calculated headroom created along the Fleet Storm Sewer is shown in Figure 26.

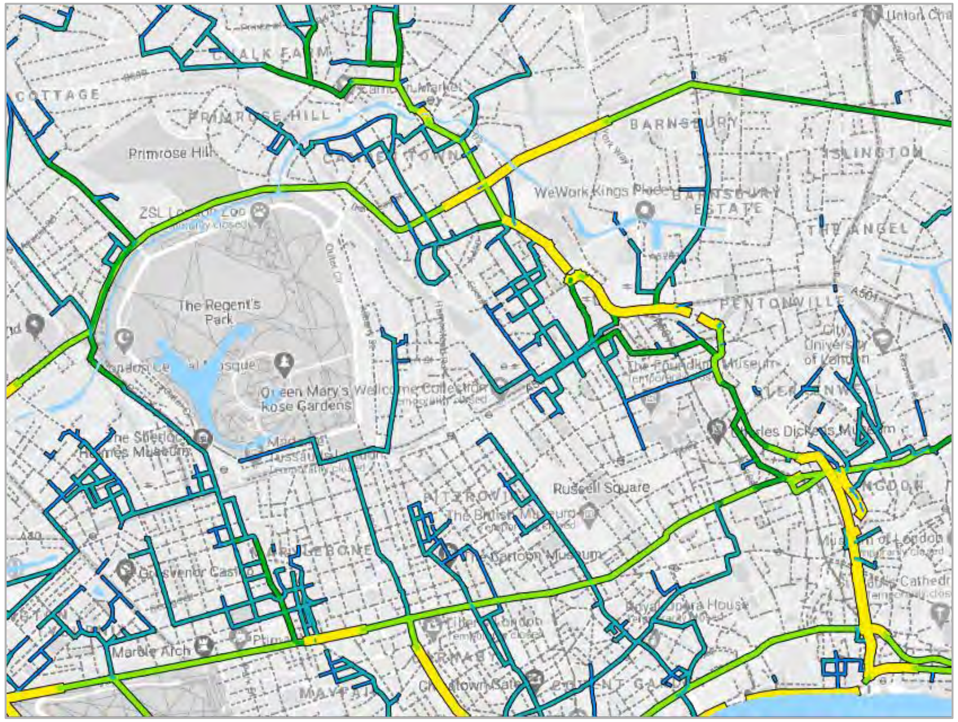


Figure 26 – Extent of Opportunity for Headroom Creation, Fleet Storm Sewer

Note: percentage denotes apx. Increase in total catchment capacity (combined Beckton and Southwark wastewater catchments)

6.6.2.2 Westminster (Beckton STW Catchment)

The calculated headroom within the southern Westminster area is shown in Figure 27.

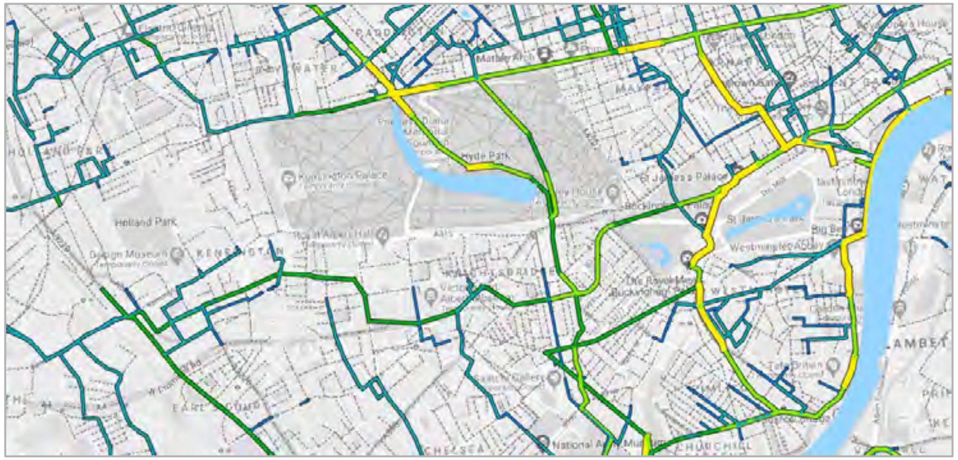


Figure 27 – Extent of Opportunity for Headroom Creation, Westminster

6.6.2.3 Northern Outfall Sewer (Beckton STW Catchment)

The calculated headroom along the Northern Outfall Sewer is shown in Figure 28.

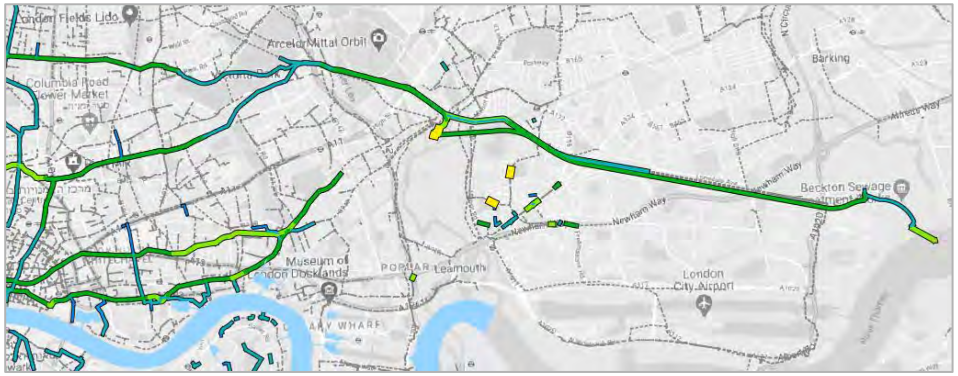


Figure 28 – Extent of Opportunity for Headroom Creation, Northern Outfall

6.6.2.4 Southern Low-Level Sewer (Crossness STW Catchment)

The calculated headroom along the Southern Low-Level Sewer is shown in Figure 29.

Figure 29 – Extent of Opportunity for Headroom Creation, Southern Low-Level Sewer

6.6.2.5 Southern Outfall Sewer (Crossness STW Catchment)

The calculated headroom along the Southern Outfall Sewer is shown in Figure 30.

Figure 30 – Extent of Opportunity for Headroom Creation, Southern Outfall Sewer

6.7 Economic Valuation

6.7.1 Overview

The assessment has been split into several key sections, focusing on both calculating the Return-On-Investment (Benefit-Cost) value and justifying a case for investment, through alignment with current funding structures:

Benefit-Cost

- **Flood Mitigation Value** – the raw predicted reduction in flood damages (calculated using the MCM depth damage data from the 2018 Multi-coloured Handbook (Flood Hazard Research Centre, 2018))
- **Value of all Benefits** – inclusion of Natural Capital benefits, providing a specific value supplementing flood mitigation
- **Optimising Investment** – re-presenting the flood mitigation and Natural Capital value across the realisation levels, to understand the effect of the optimisation process the on benefit-cost value
- **CAPEX & Natural Capital Value Uncertainty** – evaluation of the systemic effects of uncertainty applied to the CAPEX and Natural Capital figures on the benefit-cost value, and the implications on overall confidence

Case for Investment

- **FCERM GiA Funding** – demonstration that Distributed SuDS could be eligible for part or full funding under the current framework, showcasing a proof for the viability of investment
- **Catchment SuDS rates** – understanding the 'catchment' value of SuDS, linking to the TWUL 20 for 20 payment rates used between 2015 and 2020.
- **Sewer Headroom benefit-cost** – comparison of projected SuDS CAPEX with costs to generate the equivalent sewer headroom investing in a business-as-usual approach

Flood damages were calculated using the MCM depth damage data from the 2014 Multi-coloured Handbook (Flood Hazard Research Centre, 2014), and flood depths for individual properties (EA NRD dataset) were extracted using a point analysis of the model predictions. A 50-year appraisal period has been used and future damages, costs and benefits have been discounted using HM Treasury discount rates beginning at 3.5%.

6.7.2 Full Catchment SuDS Capacity

Prior to exploring the economic benefit of focused investments, the total projected value of all SuDS opportunities identified across the whole study area has been calculated. This is considered to represent the effective SuDS 'capacity', based on the approaches developed to identified feasible locations (See Section 6.1).

6.7.2.1 Flood Mitigation Value

The total calculated flood damages, flood damage reduction and CAPEX (required to realise the flood damage reduction) is shown in Figure 31.

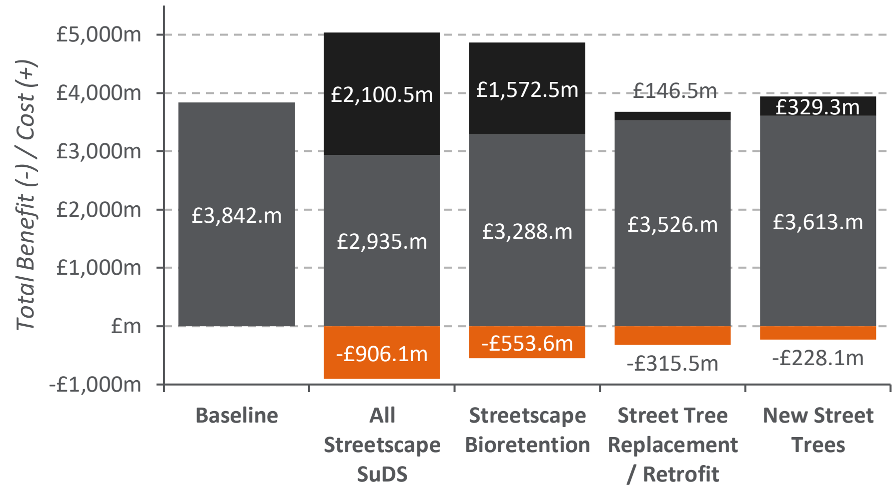


Figure 31 – Total Value of Flood Damages Avoided, Full Realisation of SuDS Opportunities

Key:

Flood Damages
CAPEX (Average)
Flood Damage Reduction

The figures calculated indicate that Distributed SuDS have the potential to prevent up-to approximately 25% of the £3.8b of current flood damages. This benefit is generated by investing over double that in CAPEX, no accounting for long-term OPEX (not considered here). Most of the CAPEX is related to the construction of Streetscape Bioretention SuDS, with the street tree SuDS approaches generating approximately comparable benefit against their cost.

The total calculated value and cost (CAPEX) of SuDS opportunities (shown in Figure 31) have been converted in scalable unit metrics in Figure 32, to enable an equal and unbiased critical comparison.

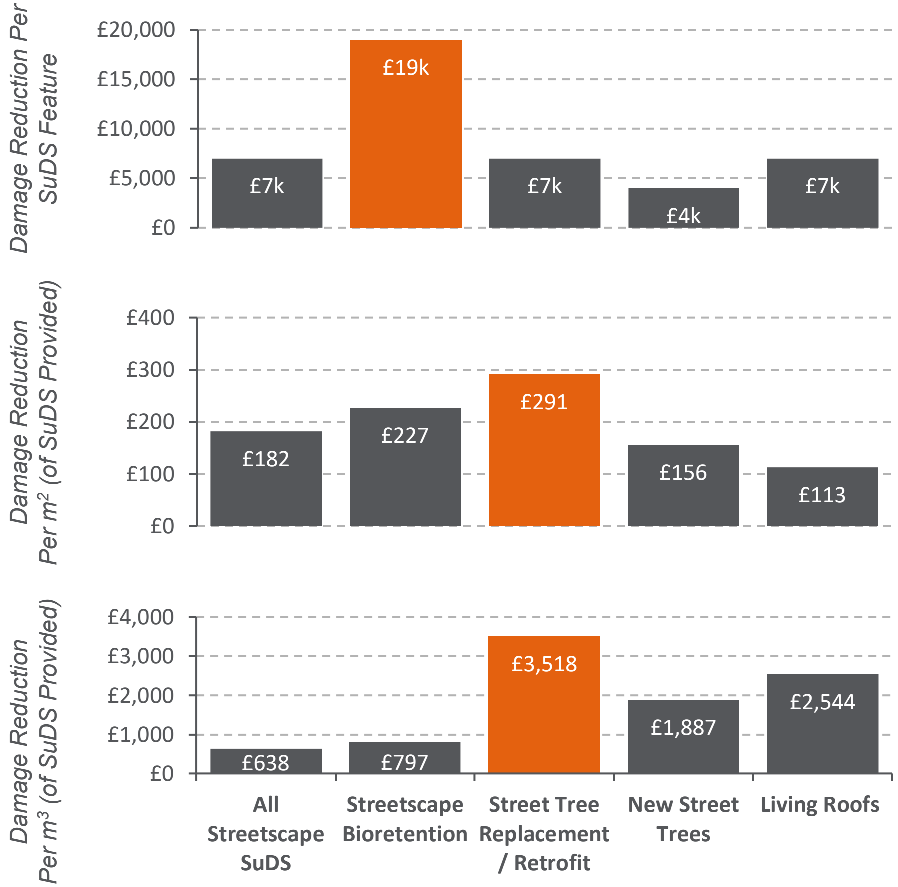


Figure 32 – Proportional Flood Damage Metrics, Full Realisation of SuDS Opportunities

The data indicates that while Streetscape Bioretention SUDS generate the largest flood damage reduction per feature, the Street Tree Retrofit / Retrofit SuDS provides more scalable benefit (i.e. m² / m³).

6.7.2.2 Value of all Benefits

Including Natural Capital (See Section 6.4) and cost savings generated from the creation of wastewater headroom (See Section 6.6) results in a more complete picture of the embedded value of Distributed SuDS.

The total calculated value and costs (CAPEX) of all the SuDS scenarios is shown in Figure 33.

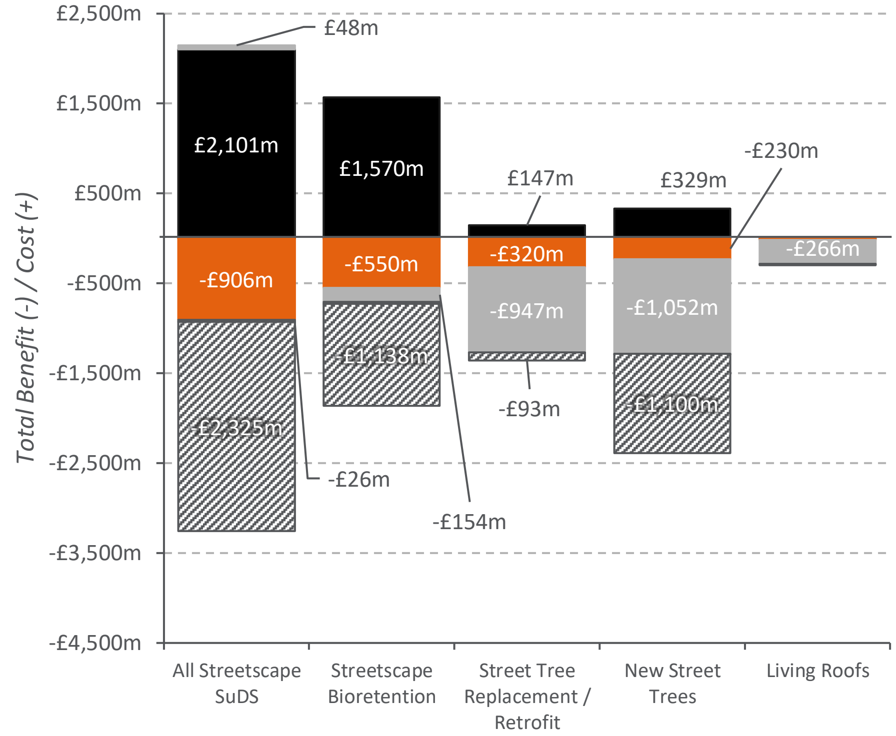


Figure 33 – Total Cost (CAPEX) and Value, Full Realisation of SuDS Opportunities

Key:

CAPEX (Average)
Flood Damage Reduction
Wastewater Headroom
Natural Capital, Environmental Benefits
Natural Capital, Socio-Economic Benefits

The results in Figure 33 demonstrate that the true value of Distributed SuDS is distributed largely across its intangible socio-economic benefits, and to a lesser degree flood damage reduction.

The total value of all benefits shown in Figure 33 have been converted to benefit-cost figures shown in Figure 34, split by flood damages, creation of wastewater headroom, and natural capital. This benefit-cost metric is a significant influencing factor in demonstrating the full 'value' of investment in SuDS, specifically the distribution of benefit across the various potential beneficiaries.

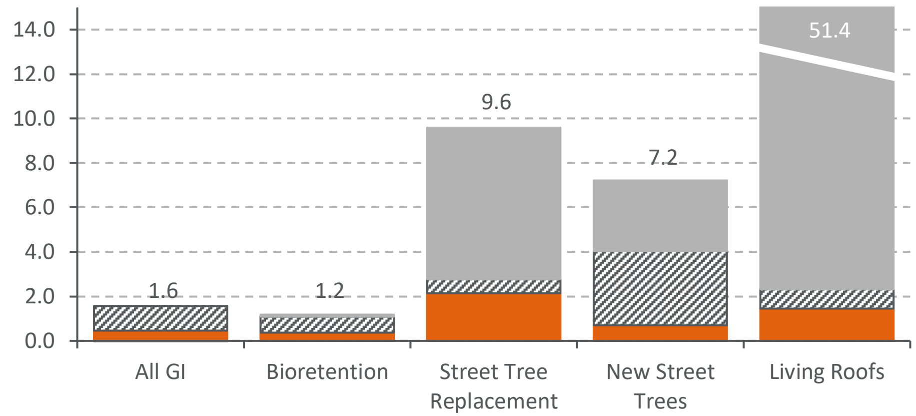
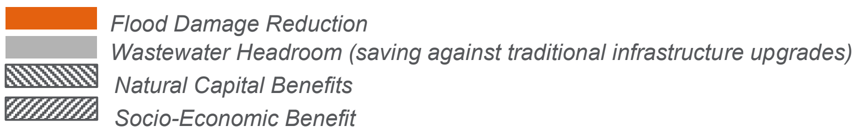


Figure 34 – benefit-cost Ratios, Full Realisation of SuDS Opportunities

Note: y-axis capped at £15

Key:



The results demonstrate that a positive benefit-cost (i.e. > 1) could be achieved with any non-optimised SuDS investment. The highlights the intrinsic value of investing in blue-green infrastructure as a general approach to improve urban landscapes, irrespective of the specific flood risk benefit that they can generate. This is not-withstanding a recognition that the benefit-cost values exhibit significant variation, indicating the ability to target more cost-effective investments.

The split of the contributing benefits to the total benefit-cost figures also demonstrates that investment in un-optimised Distributed SuDS would likely only generate an average benefit-cost of 0.75, dropping as low as 0.35, based purely in flood damages.

6.7.3 Optimised Investment

The calculation of economic value in Section 6.7.2 provided an evaluation of total benefits of Distributed SuDS at the catchment scale, assuming an 'even' or non-optimised approach to identification and delivery. It also is predicated on the eventual long-term realisation of all SuDS opportunity identified across the study area (See Section 6.1.3). This level of investment is highly unlikely to be realised in practice, even when considering a long-term timeframe. That assessment was purely done to understand the general value of Distributed SuDS and provide an un-optimised baseline understanding to compare to the optimised realisation levels evaluated in this section.

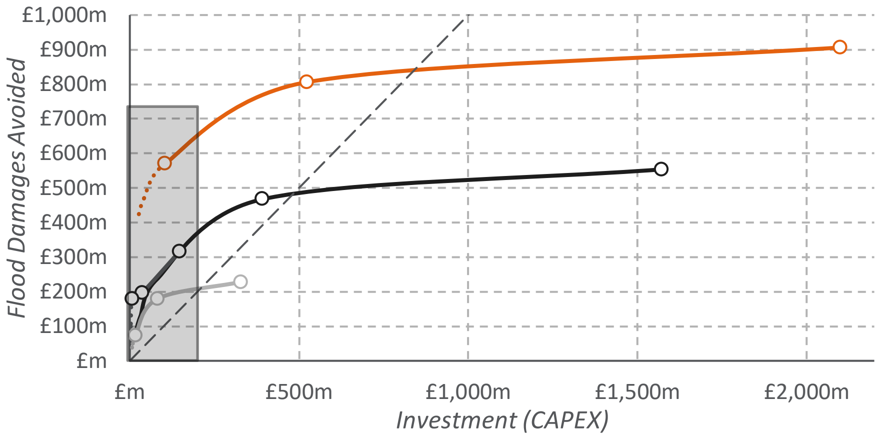
The optimisation process and development of the realisation levels used to derive the values in the following sections is outlined in Section 6.2.2.2.

6.7.3.1 Investment vs Flood Damage Reduction

The evaluation of relationships between optimised investment for flood damages avoided only is shown in Figure 35.

The profile of the investment vs. benefit curve for all the SuDS scenarios demonstrate the potential to avoid the majority of flood damages through a smaller optimised investment. The curve shapes provide direct proof that the optimisation process is robust.

The results also show that non-optimal SuDS opportunities could entail significant investment without much tangible benefit.



Note: Grey box indicates extent of enlarged area shown / dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

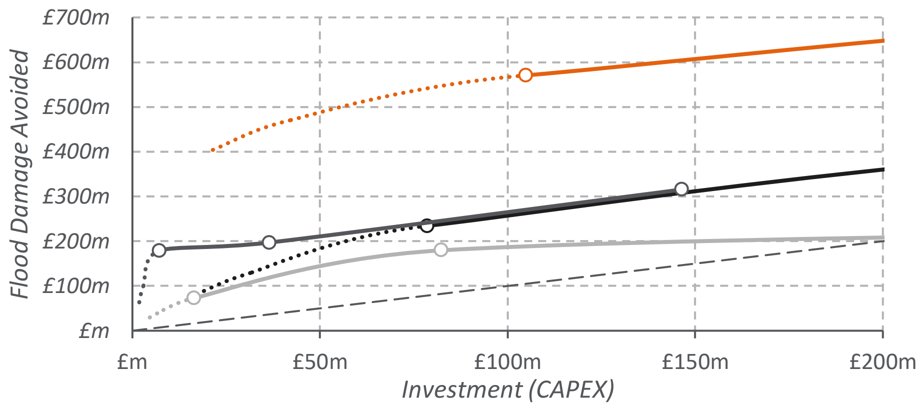


Figure 35 –CAPEX vs Flood Damages Avoided Benefit only

Note: Dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

Key:

Streetscape Bioretention
Street Tree Retrofit / Retrofit
New Street Trees
All Streetscape SuDS
Break even benefit-cost (i.e. £1 per £1)

The evaluation of relationships between optimised investment for all benefits is shown in Figure 36, including the flood damage avoided figures for the All Streetscape SuDS scenario (shown in Figure 35) for reference.

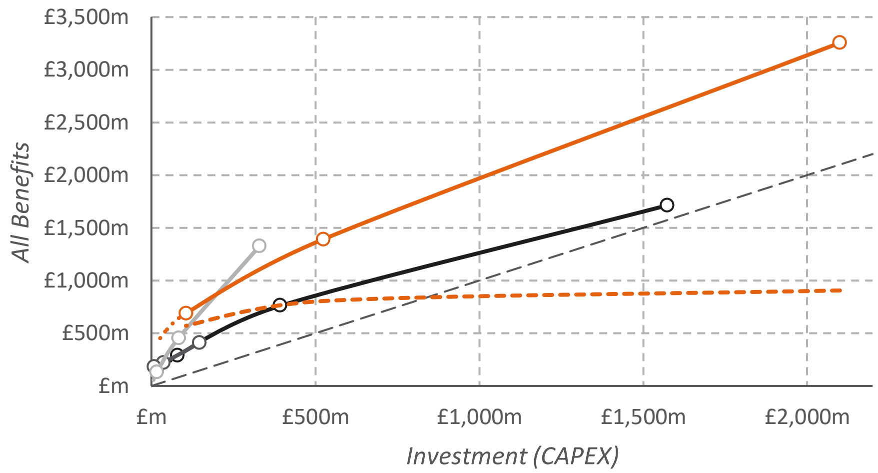


Figure 36 - CAPEX vs All Benefit

Note: Dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

Key:

Streetscape Bioretention
Street Tree Retrofit / Retrofit
New Street Trees
All Streetscape SuDS
All Streetscape SuDS (Flood Damages Avoided Figures for Reference)
Break even benefit-cost (i.e. £1 per £1)

As would be expected the value of investment is more linear, due to the dominance of Natural Capital benefits for both the optimal and non-optimal SuDS opportunities. This supports the justification to invest in Distributed SuDS without the need to optimise the realisation of opportunities, if investment is driven by non-flood partners.

The three scalable unit metrics for flood damage reduction, devised for Figure 32, have been presented for the different realisation levels in Figure 32, to show the impact of optimisation on unit value.

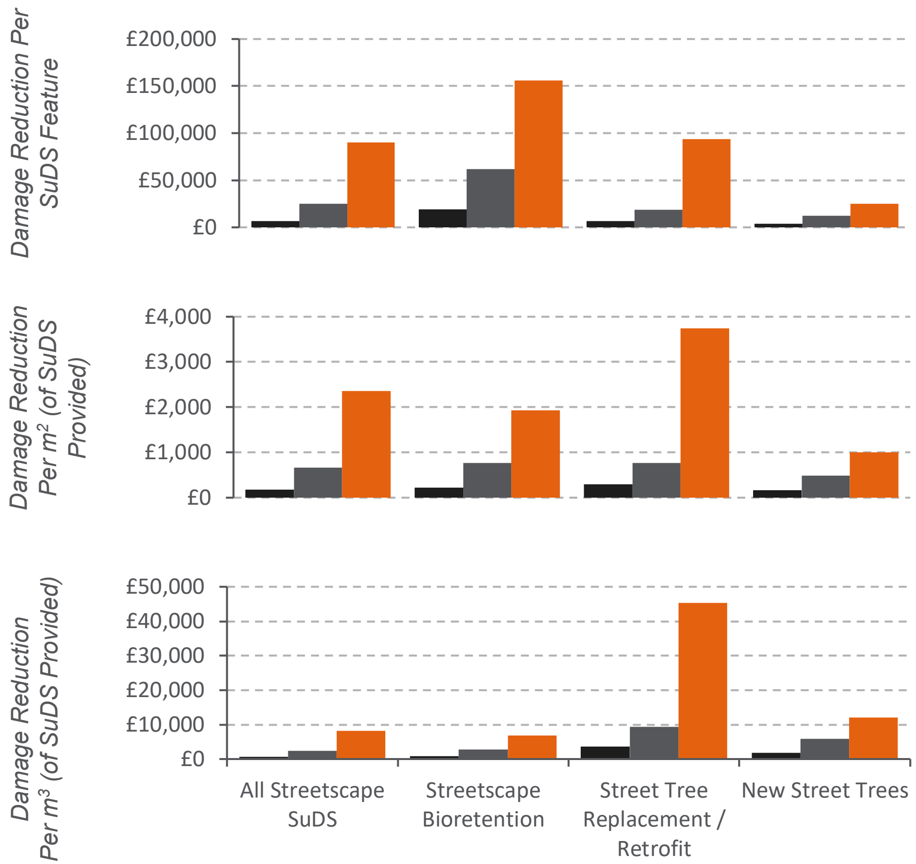


Figure 37 – Realisation Level Flood Damage Metrics

Key:

Non-optimal
25%
5%

6.7.3.2 Benefit-Cost

The figures in Section 6.7.3.1 are presented as benefit-cost in Figure 38 and Figure 39.

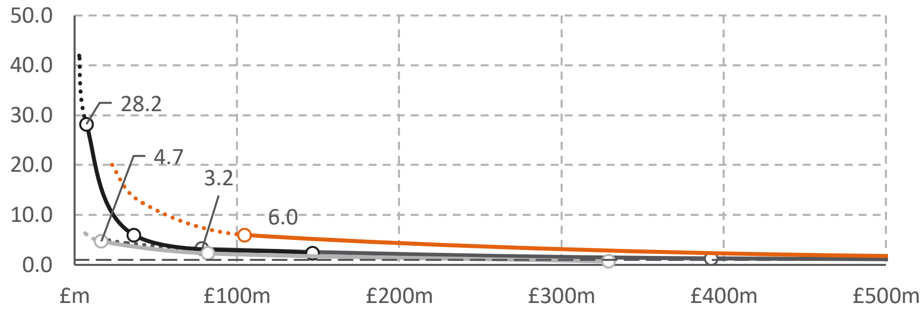


Figure 38 – Optimised benefit-cost, Flood Damages Avoided Benefit Only

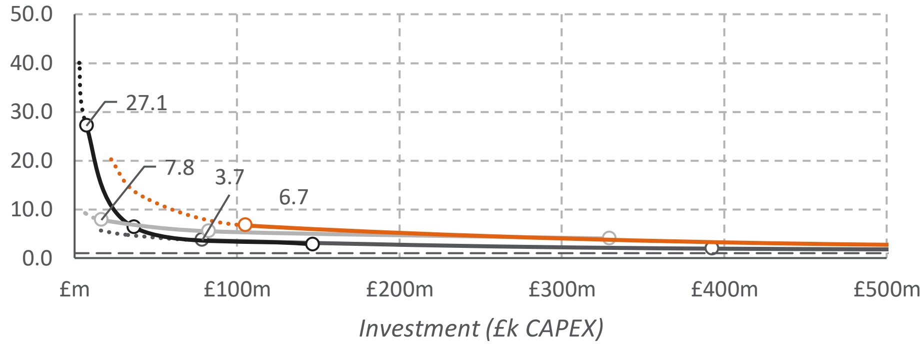


Figure 39 – Optimised benefit-cost, All Benefit

Note: total investment is capped at £500m / the values labels are shown for the 5% realisation levels / dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

Key:

Streetscape Bioretention
Street Tree Retrofit
New Street Trees
All Streetscape SuDS
Break even benefit-cost (i.e. £1 per £1)

The use of flood damages to optimise investment is evident in the results, with the All Benefits results showing very a comparable relationship.

To provide some additional confidence in the figures and understand the impact of catchment type benefit-cost the Stage 1 All Distributed SuDS figures (See Figure 11) have been compared to the Stage 2 data, shown in Figure 40.

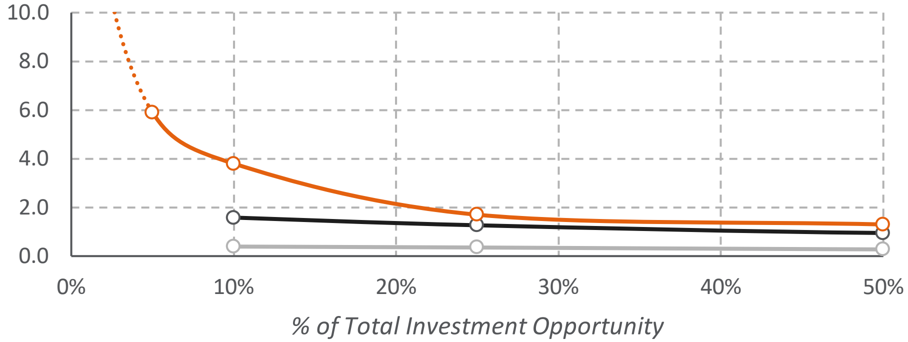


Figure 40 – Stage 1 vs Stage 2 Optimised benefit-cost, Flood Damages Avoided Benefit Only

Note: % of total investment opportunity capped at 50% / Stage 1 benefit-cost results have been proportionally adjusted to remove the OPEX component and ensure a fair comparison (since this has not been included in Stage 2)

Key:

Enfield Town Centre
Moore Brook Culvert
Stage 2 Catchment

The profiles show a relatively comparable benefit-cost ratio profile between Enfield Town Centre catchment and Stage 2 catchment for 25% realisation level and higher. More optimal investment diverges substantially, although the lack of Stage 1 realisation levels more optimal than 25% inhibits a more robust comparison.

6.7.4 CAPEX & Natural Capital Value Uncertainty

The uncertainty associated with estimated CAPEX and generated Natural Capital can a seen as a major blocker to the more widespread consideration of SuDS as an alternative approach to more traditional 'tried and tested' methods. This denotes the necessity to account for this uncertainty, to provide empirical proof of value under more pessimistic estimations.

The benefit-cost values derived and presented in Figure 39 in Section **Error! Reference source not found.** have been re-calculated up to the upper and lower extent of the CAPEX costs and Natural Capital value estimates (as defined in Section 6.3). The subsequent range of values are shown in Figure 41.

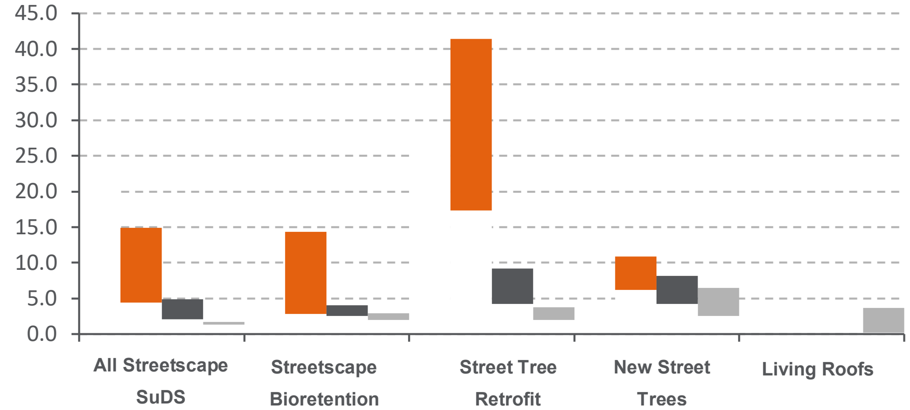


Figure 41 – Uncertainty Range of benefit-cost Value, All Benefit (£ per £1)

Note: Only the non-optimal range has been evaluated for Living Roofs

Key:

Non-optimal range
Top 25% range
Top 5% range

The largest uncertainty ranges are associated with the more optimal locations, although the New Street Trees scenario is relatively consistent. Significantly the All Streetscape SuDS scenario maintains an encouraging benefit-cost of at least 5.0 for the top 5% most optimal sites irrespective of uncertainty, providing tangible evidence of the investability for £105m of Distributed SuDS opportunities.

6.7.5 FCERM GiA Partnership Funding

Determining whether a Distributed SuDS approach could secure FCERM GiA funding is crucial under the current funding framework, especially with the recent approval of the FCERM 2020 strategy and funding.

The flood damages data for the Streetscape SuDS scenarios have been used to calculate the raw PF scores (using the EA Partnership Funding Calculator 2020), the primary level metric the EA use to justify a proportional or full application of GIA funding. The results of this evaluation are shown in Figure 42.

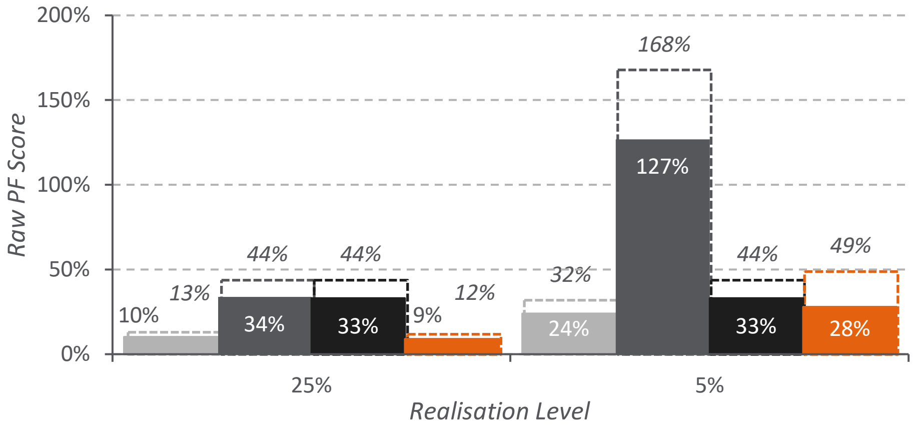


Figure 42 – FCERM GiA Raw PF Scores

Key:

Central Lower (CAPEX Estimate)

Streetscape Bioretention
Street Tree Retrofit
New Street Trees
All Streetscape SuDS

The results demonstrate that the Street Tree Retrofit 5% realisation level could be eligible for full FCERM funding, equating to an investment of £10m to generate £179m in flood damages avoided. All other scenario scores are less than 50%, indicating that based on flood damages avoided equivalent or slightly higher additional contributions would be necessary to secure funding.

The results associated with the lower CAPEX estimates show a marked increase in the PF score, but not significant enough to notably improve the chances of secure full FCERM GiA funding. It does demonstrate the value of accurate CAPEX estimation, specifically for long-term strategic planning since each percentage increase could substantially reduce the additional contributions required.

Comparing the Raw PF scores with the flood damages avoided (See Figure 43) highlights the potential challenges in generating a case for full FCERM GiA funding, specifically for Streetscape Bioretention and New Street Trees (based purely on flood damage reduction).

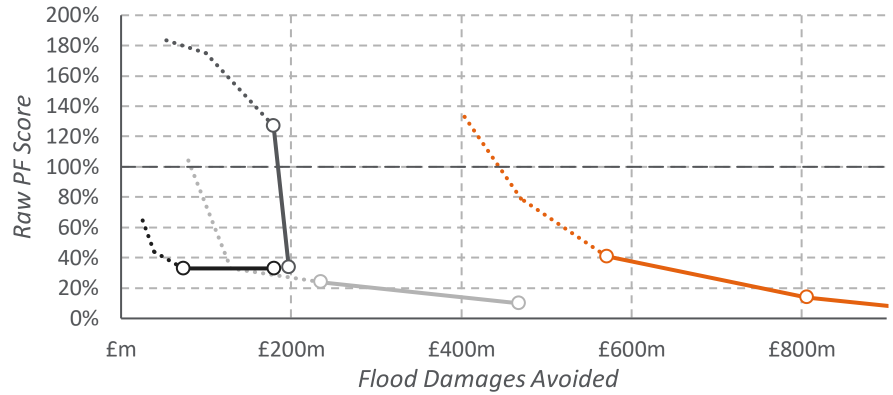


Figure 43 – FCERM GiA Raw PF Scores vs Flood Damages Avoided

Note: Dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

Key:

Streetscape Bioretention
Street Tree Retrofit / Retrofit
New Street Trees
All Streetscape SuDS
Raw PF Score = 100%

Considering the realisation levels less than the 5% indicates the potential to secure a much higher proportion of funding, subject to the depreciation of uncertainty. The curve for the All SuDS Scenario indicates that £440m in flood damages avoided could be eligible full funding, representing 49% of the total potential benefit.

These figures demonstrate the effective ability to generate a robust case for partial FCERM GiA funding (30-40% on average). Decreasing the additional contributions required to generate the adjusted PF score of 100% will likely require the development of more effective optimisation processes and / or more focused model evaluations to remove uncertainty.

6.7.6 Sewer Headroom benefit-cost

Benchmarking Distributed SuDS (as a long-term strategy) against a more traditional approach to creating the necessary headroom that long-term population growth will require (as TW are obligated to invest in) is a key measure to justify investment. The benchmark selected is the more common 'business as usual' approach of constructing network storage facilities.

6.7.6.1 Long-term Benefit

The calculated volume of water removed for each SuDS scenario (as explained in Section 6.6) was used to determine the equivalent CAPEX costs if provided by storage tanks. A TW storage CAPEX calculator was used, ensuring robust and consistent CAPEX costs were created to enable valid comparison of CAPEX cost per dwelling, which is shown in Figure 44.

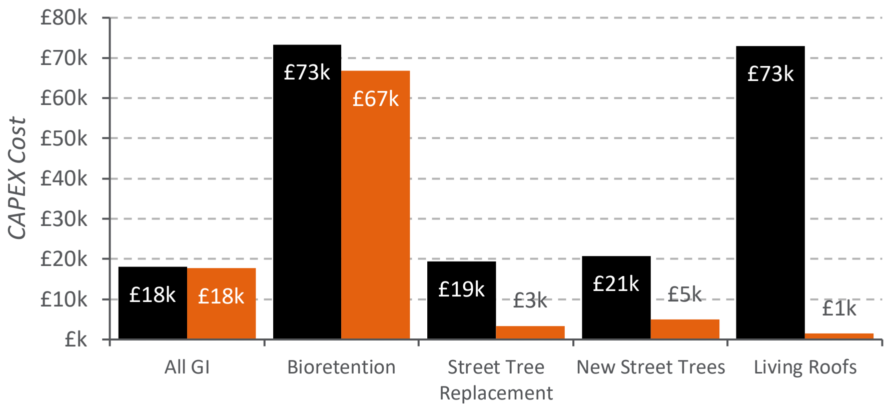


Figure 44 – CAPEX Investment Per Dwelling

Key:

Storage Tank Average CAPEX per Dwelling
Distributed SuDS Average CAPEX per Dwelling

All the SuDS Scenarios evaluated demonstrated that a Distributed SuDS approach can generate headroom capacity at a lesser CAPEX than using in-network storage facilities. The street tree SuDS and living roofs scenarios demonstrate the most significant cost savings, ranging from 85-95%.

Given the significant benefit that optimisation has on benefit-cost for flood damages (see Section 6.7.3) the results shown in Figure 44 are likely to represent a conservative estimate of benefit, although do represent the creation of headroom across the whole study area. However, generating headroom along whole trunk sewer lengths (as would be necessary to support major development) would likely require a minimum investment threshold due to the interconnected nature of the wastewater network.

The results indicate that a non-optimised Distributed SuDS strategy would be unlikely to deliver more headroom capacity than approximately 120k dwellings across combined wastewater catchments of Beckton STW and Crossness STW. This headroom is also geographically tied to specific trunk sewer lengths and catchments areas, as shown in Section 6.6.2.

6.7.6.2 Optimised Benefit

For the All Streetscape SuDS scenario the headroom capacity and benefit-cost ratios have been derived for the realisation levels, shown in Figure 45.

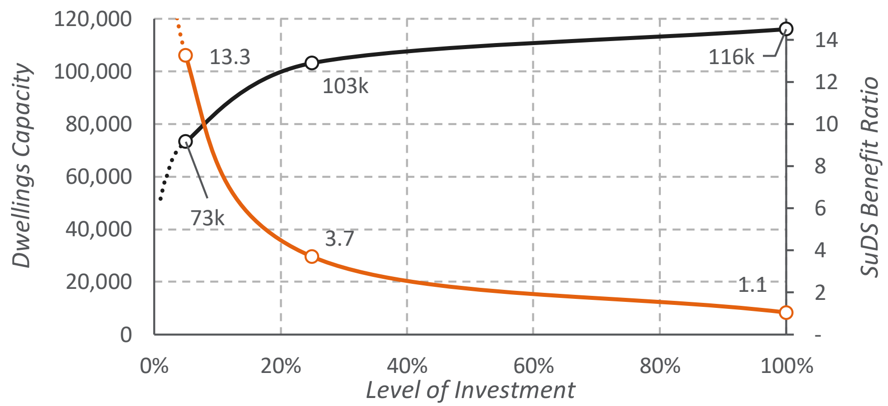


Figure 45 – All Streetscape SuDS, Realisation Level Headroom Created

Note: Dotted lines indicate data uncertainty < 5% realisation level (See Section 6.2.2.3)

Key:

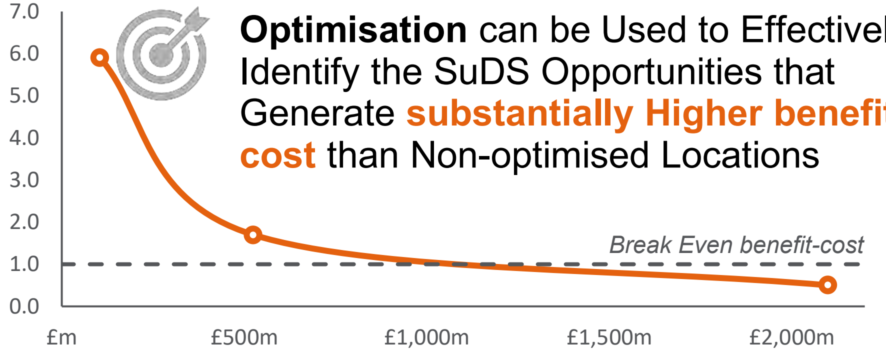
Dwellings Capacity
SuDS benefit-cost Ratio

When delivering much more focused areas (i.e. <= 5% realisation levels) the Distributed SuDS CAPEX savings could be more significant, up-to 50%. It should be highlighted that these locations may not be where development is going to occur, which would diminish the value of this cost saving. Constructing storage facilities can appear to be more flexible in where they can be constructed, enabling TW to address capacity issues more rapidly. Countering this is the recognition that the Distributed SuDS CAPEX cost is likely to be shared amongst various flood risk and management authorities, with TW only bearing a proportion of the SUDS costs shown in this section.

Comparing the values in Figure 45 as CAPEX cost per dwelling figures (aligning with Figure 46) provides evidence of the value of focusing on the optimal locations, shown in 6.6.2.

It is recognised that the optimisation undertaken to generate the realisation levels was undertaken based on flood damage information (See Section 6.2.2.2), not network capacity. Although locations that suffer from flooding tend to be indicative of areas lacking in network capacity (as they are likely overwhelmed by surface runoff) a method to optimse Distributed SuDS to create headroom in specific areas of the networks could further demonstrate value. This is discussed further within the recommendations in Section 1.1.

7 SUMMARY OF OUTCOMES



Optimisation can be Used to Effectively Identify the SuDS Opportunities that Generate **substantially Higher benefit-cost** than Non-optimised Locations

(All Streetscape SuDS Scenario Data)

SuDS Opportunities *(ordered by most effective SuDS Features)*

Flood Damage Reduction *(proportion of total possible)*

5% of Most Optimal SuDS Features Represent…

£35 Million Capital Investment in SuDS *(On Average per London Borough)*

Could generate…

£190 Million in **Flood Damage Reduction**

£40 Million in **Natural Capital Value**

Natural Capital Value Increases the Benefit-Cost Ratio from **0.4 to 1.6**

(Average of un-optimised Streetscape SuDS Scenarios)

All SuDS Opportunities (un-optimised)…

£700 Million Capital Investment in SuDS *(On Average per London Borough)*

Could generate…

£300 Million in **Flood Damage Reduction**

£800 Million in **Natural Capital Value**

Creation of **Wastewater Network Capacity** for between **116,000 and 180,000 additional dwellings**

Requiring **Comparable or Less CAPEX** than Typical Strategies to Create the Same Capacity

(Beckton & Crossness STW Catchments)

£3 Million in Street Tree SuDS Improvement Could Secure **Full FCERM GiA Funding**

(On Average per London Borough)

Project Already Secured **£600,000** in Short-term **Local Levy Funding**

The key technical outcomes from the project are outlined below:

Flood Mitigation Value - Distributed SuDS can provide extensive flood risk mitigation value and **deliver significant reductions in flood damages**, achieved through both the number and scale of opportunities available (realised over a long-term commitment to delivery) and a focus around the most optimal SuDS sites.

Natural Capital Value - The socio-economic benefits calculated outstrip all other benefits, including flood damage reduction, by up-to an order of magnitude for some scenarios evaluated, demonstrating the underlying holistic **value of SuDS as a key component of investing in green infrastructure**.

Catchment Commonality - Some correlation was demonstrated between the various Evaluation Scenarios across different catchments, which was encouraging, but not considered statistically reliable. This means that the inherent **variability in catchment and network complexity prevents the reliable inference of 'benefit' for a non-modelled catchment**.

Value of Optimisation – The significant variation in the benefit-cost ratio for Distributed SuDS across the realisation levels evaluated demonstrates the **importance of location and SuDS feature type on the value of any investment.** Optimisation will help achieve at least a positive benefit-costs ratios, but in many cases orders of magnitude higher than non-optimised approaches.

Relevance of Modelling – The use of 1D-2D hydraulic models to evaluate flood mitigation value of different SuDS Scenarios is a critical stage in identifying the most cost-effective SuDS strategies and **should become an essential element of the planning process**, to ensure adequate return on investment.

Sewerage Network Capacity - Distributed SuDS could be implemented as an **affordable alternative 'green' strategy** (or component of a strategy) to generate sewerage capacity to accommodate future growth, by facilitating long-term reductions in sewer flow through cost-effective funding partnerships.

FCERM GiA Funding - The economic evaluation has proven that optimised investments in Distributed SuDS **can substantially improve the likelihood of securing full FCERM GiA funding**, or part funding with demonstration of evidence of value to incentivise potential beneficiaries to provide additional contributions.

Cost Uncertainty – Although the inherent challenges in estimating CAPEX and Natural Capital remains a major issue for confidence, the **most optimal SuDS sites show positive benefit-cost ratios (sufficient to secure FCERM GiA funding) irrespective of the uncertainty bands**.

FCERM GiA Funding - A small-scale Distributed SuDS approach was successfully demonstrated to have **secure FCERM GiA funding**.

8 CONCLUSIONS & RECOMMENDATIONS

This study was conceived to address a general challenge around the investability of SuDS, guided by several interrelated and open-ended objectives. The conclusions cover a correspondingly wide range of key outcomes, resolutions to problems encountered, and residual issues that need to be taken forward into future work.

The conclusions and recommendations outlined in this section are aimed at helping to frame water sector discussion around taking practical and achievable next steps:

- Addressing residual uncertainty and limitations in the processes and methods developed in this study, specifically recognising that planning for SuDS will be inherently iterative in nature, incorporating new innovative techniques and utilising more advanced predictive capacity in future
- Assisting the LLFAs (plus TW and TfL) in identifying and formulating SuDS strategies for the next 6-year programme of FCERM GiA funding
- Provide guidance on a potential London-wide framework that could be employed to provide a more robust structure to support the LLFAs in realising the SuDS strategy ambitions and integrating needs and constraints across the various flood management authorities
- Catalysing more effective stakeholder collaboration to grow awareness and justify cross-department communication

It is recognised that a major takeaway from this work may be around the derived values, specifically the unit CAPEX, natural capital and benefit metrics. A schedule of key project metrics is provided in Appendix C and Appendix D.

8.1 Conclusions

8.1.1 Significance of Location on Flood Mitigation

It is clear from the results of the hydraulic modelling that the specific distribution / localisation proposed SuDS features (or clusters of features) has a significant bearing on benefit-cost, and in turn the investability. The various scenarios in Stage 1 performed very differently, most notably due to catchment proximity (discussed in Section 5.6.1). The distribution of SuDS features within the central or upper catchments (based on elevation) appears to be the most dominant factor in flood risk mitigation, almost irrespective of the type and SuDS feature type.

The same conclusion cannot be directly drawn for Stage 2, potentially due to the flatter and larger catchments which are not representative of clear hydraulic catchments based on elevation. The calculated flood damages avoided do show very clustered benefit, with the majority of benefit being realised through a relatively small proportion of the total SuDS opportunities (See Section 6.7.2.1).

8.1.2 Relevance of Hydraulic Modelling & Optimisation

In terms of technical practicality this study has proven that hydraulic modelling of Distributed SuDS can be highly effective, with appropriate planning and data management. The modelling approach has been subject to continual evolution throughout the project and there remains opportunity to further improve general efficiency and enable a more precise optimisation process that could be driven by any ‘benefit’ or collection of benefits.

The differences in the results for comparable scenarios (i.e. conceptually the same) between the different catchments and stages illustrate that the manifested benefits of Distributed SuDS are intrinsically dependent on the specific characteristics of each catchment. Urban and topographical variation significantly influenced the comparative benefit for the Stage 1 scenarios.

The significance of location (discussed in Section 8.1), especially for Stage 2, further justifies the requirement for hydraulic modelling for most catchments, especially large catchments, where Distributed SuDS are being considered.

8.1.3 Potential for Long-term Flood Damage Reduction

The hydraulic modelling has provided clear and tangible evidence of the overall value that Distributed SuDS could generate for the study area, and in concept across the majority of Greater London. The Stage 2 evaluation calculated that approximately £900m flood damage reduction could be generated (across three London boroughs). An indicative extrapolation across the whole Greater London area (based on area) equates to reductions of around £18b, and although representing an obvious over-estimate (given variation of urban landscape and density) it does provide justification in principle for the magnitude of potential benefit.

The proportion of the calculated flood damages that could be reduced following the realisation of all Distributed SuDS opportunities is shown in i.e.

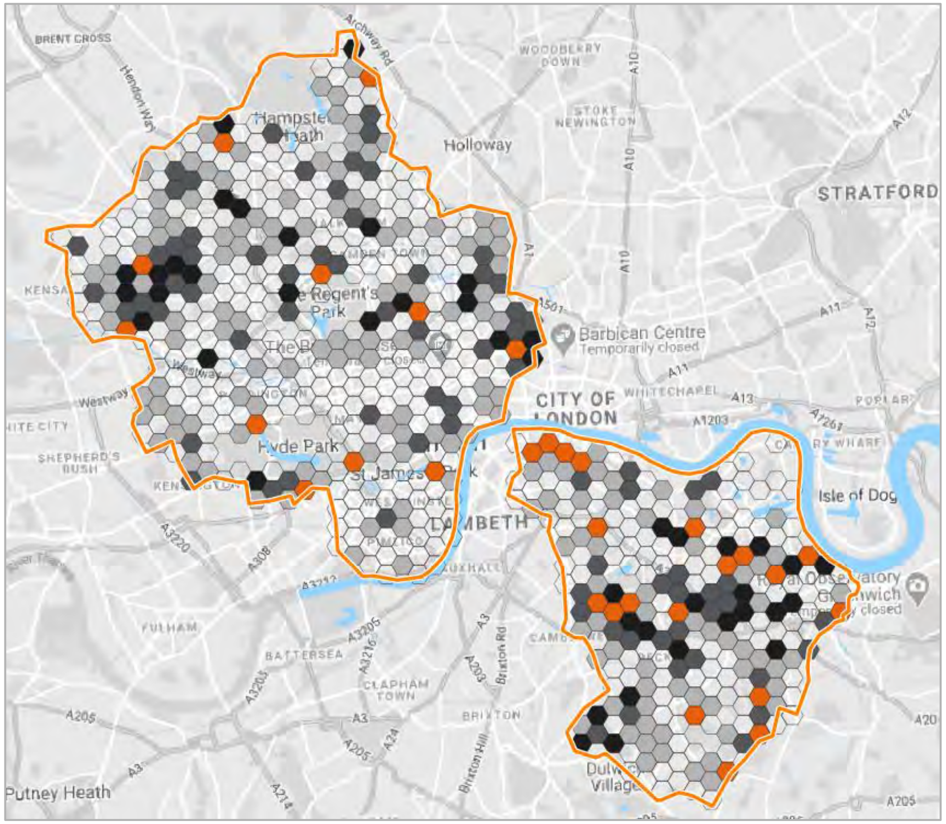


Figure 47 – All Streetscape SuDS Opportunities, Proportional Flood Damages Avoided (1 in 30-year event)

Key:

- 80%
- 60%
- 40%
- 20%
- <20%

To provide some local context to the hex grid results (in Figure 47) the raw modelling results have been presented for two specific benefitting locations in Figure 48 – All Streetscape SuDS 25% Realisation Level, Flood Mitigation Potential Around Kilburn Area and Figure 49.

Figure 48 – All Streetscape SuDS 25% Realisation Level, Flood Mitigation Potential Around Kilburn Area

Figure 49 – All Streetscape SuDS 25% Realisation Level, Flood Mitigation Potential Around Willowbrook Estate Area

Key:

- *Flooding prevented (i.e. 100% reduction)*
- *Substantial flood mitigation (>50% flood depth reduction)*
- *Residual flooding (0% - <50% flood depth reduction)*

8.1.4 Addressing Long-term Strategy Sewerage Capacity Issues

Although the optimisation process in Stage 2 did not specifically account for the needs of the sewerage network in terms of headroom (although flood damages could be considered a pseudo proxy for a lack of sewerage capacity) the magnitude of headroom that could be created is large enough to claim as a tangible benefit.

The results have shown that there is obvious benefit to key trunk sewers across the catchment irrespective of where SuDS are implemented (See Section 6.6.2). The evaluation of headroom across the realisation levels demonstrates the value of optimisation, even though its process is not tailored to maximum headroom benefit. Furthermore, a large-scale Distributed SuDS strategy could be realised for a comparable long-term CAPEX to traditional approaches (See Section 6.6).

Ultimately investing in creating headroom will be dependent on future demand, a product of residential and commercial growth, climate change, and sewer degradation (i.e. increased infiltration). With growth, headroom need will be very localised, based on long-term projections and local plans. This localisation will require a similar focus on the location for delivering Distributed SuDS, a need that may necessitate selecting areas that do not generate the highest benefit-cost for other stakeholders / beneficiaries, requiring TW to become primary funders.

One remaining uncertainty of this comparison is OPEX, which has not been considered in this study (See Section 6.3). A Distributed SuDS approach may require more frequent and intensive maintenance, increasing the effective TOTEX and suppressing any benefit-cost superiority over storage tanks.

8.1.5 Realisation of Catchment-scale Benefit Only Possible through Long-term Multi-partner Investment

The primary focus of the study has been to explore approaches that optimise the flood benefit, since this in-turn supports any bids for government funding. It has however been recognised that significant partnership funding contributions will, in most cases, be essential to secure funding and that flooding may not be a key factor in the decision-making process. Moreover, the ability to integrate SuDS into the ongoing public improvement / re-development and highways works will likely drive a large proportion of any proposed approach to Distributed SuDS.

It is expected that alternative SuDS strategies more suited to a broader range of potential investors should be considered in future, seeking to identify a more common level of benefit to secure maximum investment. A sole focus on flood risk benefit will likely levy greater financial burden on the flood risk authorities, even when the wider benefits can be proven to be extensive, just not used as an equal part of the selection process.

8.1.6 Ability to Secure Full FCERM GiA Funding

The economic assessment in Stage 1 demonstrated that some of the SuDS Evaluation Scenarios generated sufficient benefit-cost ratios to secure full funding via the current FCERM GiA model, due to flood damages avoided alone. Potentially more important, the reduction in properties within the OM2 'Very Significant' and 'Significant' risk bands is considered substantial (given the nature of Distributed SuDS).

Conversely the viability of FCERM GiA funding in Stage 1 was inhibited by the inability to derive the most optimal SuDS scenarios, without introducing uncertainty over the causality of benefit (See Section 6.2.2.3). The evaluations did show benefit-cost and PF score trends (See Figure 38 and Figure 43) that highlight the potential to secure full FCERM GiA funding, if this uncertainty can be addressed (See Section 8.2.5).

8.1.7 Relative Magnitude of Natural Capital Benefits

The monetised value of Distributed SuDS shown in this study is largely dominated by Natural Capital without any investment optimisation, effectively relegating flood damage benefits to a secondary consideration (if total net value of all benefits was solely used to justify investment).

The balance between flood damage reduction and natural capital is shown in Figure 50.

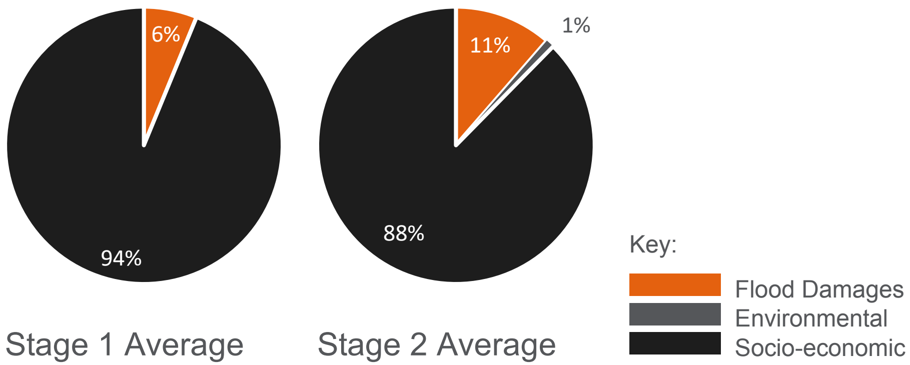


Figure 50 – Flood Damage Reduction / Natural Capital Value Proportional Split for All Streetscape SuDS Opportunities

The distribution of value across the various Natural Capital benefits is also heavily skewed towards social and wellbeing, specifically amenity, health and traffic calming. This skew is generally attributed to the following:

- High value associated with preventing traffic accidents
- General applicability of traffic calming SuDS to predominantly residential catchments with a large volume of these features included for most scenarios
- General applicability of street trees within residential catchments
- High costs of healthcare in the UK

The relative minority of most environmental benefits is partly attributed to the lack of accountability for catchment-scale value and contributions realising regional environmental drivers (e.g. groundwater water quality, biodiversity targets, wildlife corridors etc.). This would require a more extensive and regional assessment of spatial value which could be used to enhance or weight value depending on location.

The significance of this diversity of potential benefit should be a catalyst for incentivising funding commitments / contributions from a broader portfolio of potential investors. This breadth of investments is likely to be an essential component of resilient and sustained long-term investment in Distributed SuDS, due to the following primary reasons:

- Funding flexibility considering variations in future climate change / growth pressures and changing socio-environmental issues, and evolving
- More adaptable to intermittent and gradual changes in legislation / policy around SuDS, flood risk management, and availability of government funding

8.1.8 Impact of Cost Estimation on Uncertainty

The estimation of cost is a critical element of the calculation of value, and uncertainty can diminish how robustness of projected benefit-cost and the justification for investment. The significance of uncertainty has been accounted for in the use of upper and lower bands for the derivation of CAPEX (See Section 6.3.4) and Natural Capital (See Section 6.4.2).

The range of uncertainty is evident in Figure 41, where the range of benefit-cost ratios varies by around 100% to 350%. This is reflected, to a lesser extent due to the omission of Natural Capital benefits, in the potential to secure FCERM GiA funding (See Figure 42) that shows PF score increasing by around +30% to +75% using the Lower CAPEX estimates.

Given the range of uncertainty the benefit-cost ratios calculated for both optimised and non-optimised scenarios is held above 1.0. This demonstrates that Distributed SuDS provide a positive return on initial investment without the need to optimise investments, proving their inherent raw value (when accounting for all benefits).

8.1.9 Effectiveness of Different SuDS Features

The development of the different SuDS Scenarios was primarily aimed at understanding the conceptual net benefit of different SuDS feature types, which may be used to influence policy and further research. It has been recognised that a long-term commitment is far more likely to result in a blend of SuDS features types, more representative of the All Streetscape SuDS Scenarios.

The results from both stages of the project provided tangible evidence that a composite of different SuDS feature types will typically generate the most significant net catchment benefit. There is however a significant variation across the different SUDS features types, in terms of value and benefit-cost. An MCA assessment of the Stage 2 scenarios is shown in Figure 52.

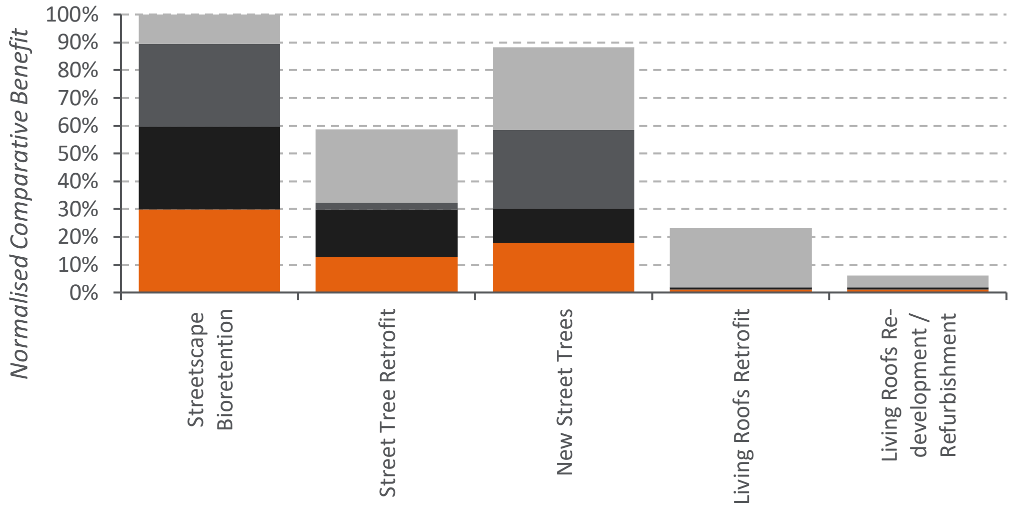


Figure 51 – Stage 2, All Streetscape SuDS Scenario, SuDS Feature Type Proportion

Note: The normalisation of the comparative benefit is explained in Appendix B

Key:

Magnitude of Opportunity (total area of catchment)
Flood Damages Avoided
Natural Capital Value
Magnitude of Sewer Headroom Created

Streetscape Bioretention and New Street Trees provide the most substantial contribution across the four metrics. Living Roofs and Rainwater Planters may demonstrate more attractive benefit-cost ratios (See Section 6.7.2) but the overall magnitude of benefit from the available opportunities is markedly muted in comparison.

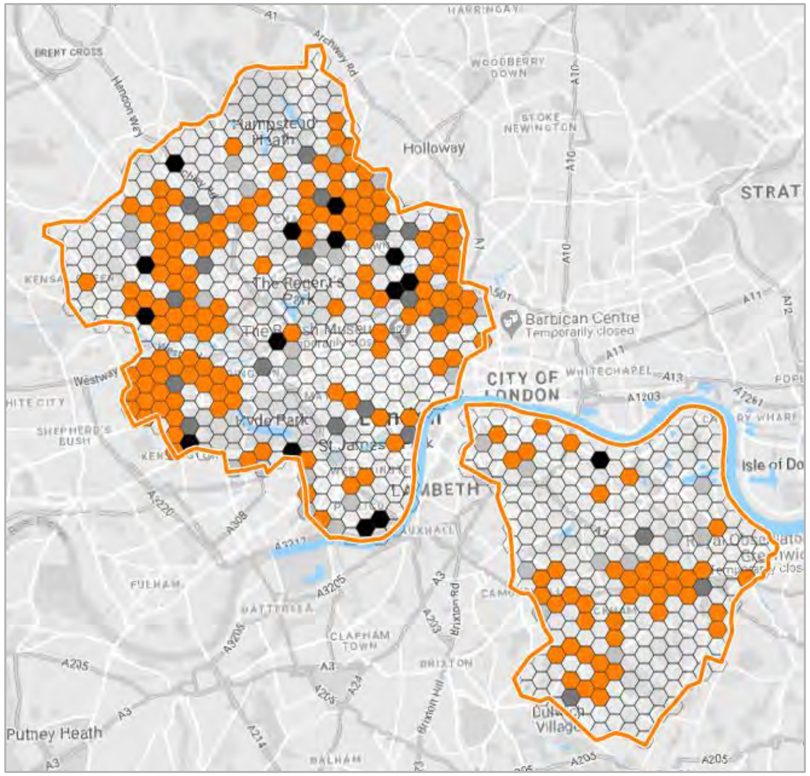


Figure 52 – Stage 2, Distribution of Optimal SuDS Feature Type (Top 25%)

Key:

Mixture of Features
Streetscape Bioretention Only
Street Tree Retrofit / Retrofit Only
New Street Trees Only

8.2 Recommendations

Several recommendations are proposed to enhance and translate the key outcomes of this project into practical and programmable steps towards developing long-term actionable strategies to implement Distributed SuDS:

Engagement of Wider Community of Stakeholders via Socio-Economic Value

This project has highlighted that multi-disciplinary collaboration and water authority partnering appears to be essential to enable the realisation of the demonstrated benefits of a long-term commitment to Distributed SuDS. The PSG does include a diverse array of responsible organisations but is largely limited to flooding and water management practitioners, which does inhibit the wider engagement. To drive investment the level of engagement and awareness needs to be greatly increased, incorporating key policy makers and investment managers.

To maximise effective engagement (and long-term retention of engagement) it would be pragmatic to be facilitated from a position of overarching influence and authority. This is likely to be the GLA, who already take a policy lead on GI.

The primary goal of engagement will be to leverage funding from any London administrative body or authority where it can be demonstrated they are a financial beneficiary of Distributed SuDS. This demonstration will require the robust calculation of benefit for both the short and long-term.

8.2.1 FCERM GiA Business Case Process Improvements

The simplification and / or better alignment of the current (and future) FCERM GiA process, specifically to support investment in Distributed SuDS, would represent a pragmatic adjustment to funding governance to greatly improve Distributed SuDS investment prospects. To realise the benefits from what is effectively an 'essential' long-term financial commitment to Distributed SuDS any revision to the current process would need to:

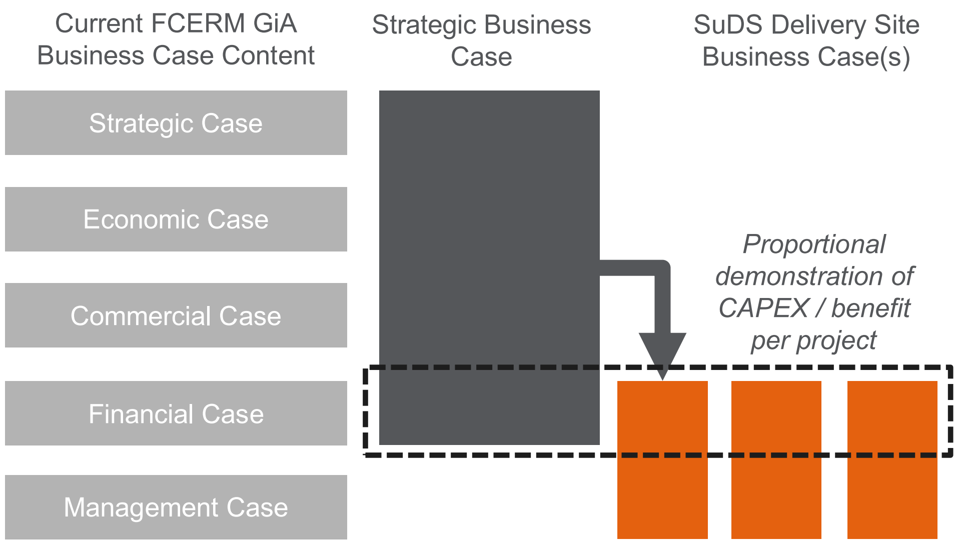
- **Improve the Business Case Process Efficiency** – necessary to cope with significantly larger volumes of submission (associated with individual stages of long-term proposals)
- **Repeatable & Transferable Across Catchments / Authorities** – Process improvements need to ensure easy transference and application, enabling authorities to quickly formulate the documentation for numerous individual SuDS projects without unnecessary repetition
- **Resilient to Regulatory / Governmental Policy Fluctuations** – Consideration of how the long-term proposals can be accepted and administered beyond normal governance timeframes

The core recommendation is that the current FCERM GiA process is split into two stages (for Distributed SuDS):

1. **Strategic SuDS Business Case** - Outlines the long-term technical and commercial case across major catchments / local authority areas, providing the underpinning approval for EA investment in Distributed SuDS. The document should contributions to achieving the long-term objectives outlined in the proposed Strategic Distributed SuDS Case for London (See Section 0)
   - ***EA NPAS / NPAB / LPRG Approval*** *(>£500k) - covering demonstration of long-term positive benefit-cost / benefit-cost, wider Natural Capital benefits, general design approaches, and an outline commercial and management framework*

   The business case template should follow the 5-BC template
2. **SuDS Delivery Site Business Case(s)** – Streamlined OBC covering specific SuDS site design details, financial arrangements, partnership funding, procurement, and delivery management, relying on the overarching commercial and management approvals within the Strategic SuDS Business Case
   - ***Area Flood and Coastal Risk Manager Approval*** *(<£500k) - covering the specific details and financial arrangements, likely requiring additional small-scale evaluation of benefit-cost / benefit-cost*

The SuDS Delivery Site Business Case stage should not have to present a detailed financial case, since the net financial viability / benefit would effectively have been established on the EA approval of the Strategic SuDS Business Case.



It should be possible to align the CAPEX for parts or whole SuDS programmes of works with future short to medium-term public highways works and re-development projects, to reduce CAPEX and maximise benefit-cost. This will require acceptance of more flexible delivery timeframes, with EA funding needing to be 'locked' to the project.

The Strategic Business Case will need to detail the current and prospective funding partners necessary to generate additional financial contributions, which will typically be essential to achieve the adjusted PF score of 100% to secure EA FCERM GiA funding. This may need to include confirmation of an 'Agreement in Principle' with proposed funding partners, providing an indication of funding prospects over the long-term, how management of the relationships will be undertaken, and projections of their funding commitment to provide the EA.

A further logistical issue will be the current inability to claiming OM2 benefits more than once for a property. One of the long-term strategic benefits of Distributed SuDS is the ability to iteratively mitigate SuDS through gradual implementation of opportunities. In many locations, properties may move risk bands multiple times as new SuDS features are constructed locally or upstream. The inability to claim more than once could substantially suppress their true economic value, reducing the PF score and reducing the likelihood of securing FCERM GiA funding in future.

Accomplishing this recommendation will require direct consultation with the EA and DEFRA, to secure conceptual 'buy-in' based on the demonstration of potential outcomes and co-creation of the technical content of the final process.

8.2.2 London SuDS Evaluation & Delivery Framework

Although conceptually suitable for direct application across most catchments / London Boroughs, the methods developed in this study should not be considered fully transferable without an underpinning framework in place. The methods detailed in this report represent a first version, and should be subject to improvement through continual innovation, advances in GIS / hydraulic modelling techniques / software, and the collation of more SuDS case studies.

It is recommended that a progressive London SuDS Evaluation and Delivery Framework is instated, formulating the methods, processes and economic requirements necessary to underpin a long-term investment is Distributed SuDS. The exact operating principles for this framework and policy-related amendments would need to be addressed through multi-agency consultation, likely led and owned by the GLA. Such a framework would also create a measure of consistency (data and methods) across the London boroughs, which is likely to become critical in enabling the proposed revisions to the FCERM GiA funding process (See Section 8.2.1), specifically by providing the EA with a 'common' understanding of the generation of value and benefit-cost to facilitate efficient and repeatable business case approval.

The key structural elements should include the following:

- **Technical Evaluation Framework** – process workflow guidance on identifying & optimising SuDS opportunities, aligned with the minimum FCERM GiA funding requirements (See Section 8.2.1)
- **Access to Supporting SuDS Data & Assumptions** – centralised repository of London focused SuDS information that can used during the evaluation and funding stages (supplementing locally available data)
- **Stakeholder Engagement Forum** – managed collaboration during the evaluation of SuDS opportunities and identification of potential funding partners

- **Opportunistic Delivery Works Programme** – centralised programme of short to medium-term public highways works & re-development projects, accessible to identify locations for opportunistic SuDS delivery that can be referenced within FCERM GiA funding bids
- **Strategic SuDS Realisation Case for London** – strategic evaluation and presentation of the benefit-cost of SuDS at a regional scale / level, incorporating spatial Natural Capital information and long-term growth expectations (See Section 0)

The framework should define a structured approach for London Boroughs to identify SuDS projects for submission for FCERM GiA funding under the revised approach (See Section 8.2.1). The process will be dependent on available funding and GLA governance, but an outline recommendation for a 3-step process is shown below:

1. **Regional Opportunity Assessment** – large-scale GIS assessment of SuDS opportunity sites, flood damages, and Natural Capital, undertaken to establish the total potential benefit of Distributed SuDS opportunities (used to inform the Strategic SuDS Business Case outlined in Section 8.2.1)
2. **Local Delivery Economic Evaluation** – derivation of optimised / preferred SuDS locations and alignment with public highways works & re-development projects, formulating a long-term programme of SuDS delivery
3. **SuDS Delivery Projects** – identification of parcels of SuDS sites for submission within a SuDS Delivery Site Business Case (as outlined in Section 8.2.1

A key catalyst for action and commitment will be the effective cross-pollination of information between the various authorities and stakeholders, to foster a supporting and engaged community of local SuDS 'experts' (covering investment planning, strategic assessment, calculation of benefits, design, and implementation). The supporting SuDS data and information should provide a robust and valuable resource to facilitate the technical evaluations, implemented in a way so as to drive efficiency and mitigate the impact of uncertainty on funding commitments (specifically private contributors). Its influence would grow with each new successful SuDS Dispersed case for funding and / or completed project.

The core elements would be:

- **London CAPEX & OPEX Figures** – transparent case-study based register of key CAPEX unit and features costs, including local borough adjustments and uncertainty ranges
- **Natural Capital Guidance** – collated evidence base to enable each borough to derive benefit based on their key issues / requirements

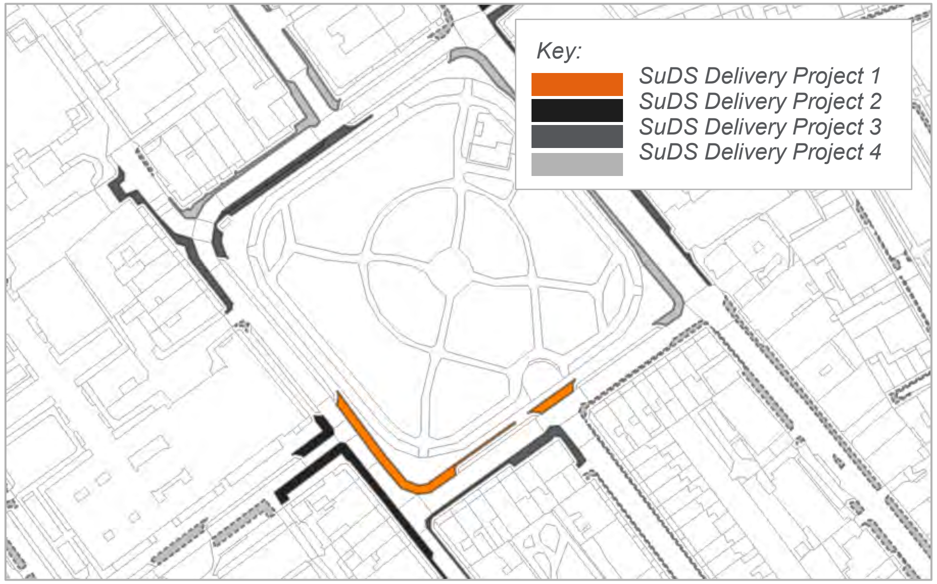


Figure 53 – Conceptual Demonstration of SuDS Delivery Projects Identified as part of a Local Delivery Economic Evaluation

8.2.3 Strategic Distributed SuDS Case for London

The strategic and commercial case for investment in Distributed SuDS is not just related to the needs and opportunities for specific catchments or local authority administrative areas. The evaluation and definition of London-wide flooding, socio-economic, and environmental needs and opportunities would provide a regional strategic context to the development of an Outline Business Case.

This strategy would entail a fully inclusive consideration of all factors potentially affecting proposals for SuDS, covering the following primary areas:

- **Social** – demographical variations to help prioritise the enhancement of urban amenity, land value, improved health through increased walking etc.
- **Community** – local community plans which include recommendations for greening and improvements to the urban aesthetic, community engagement schemes, local environmental / ecological improvement initiatives etc.
- **Public Open Space** – location and quality of existing green space, improvement programmes etc.
- **Transport / Traffic** – distribution of traffic issues, traffic calming initiatives, spatial data on accidents etc.
- **Hydrological** – spatial data to understand the likely hydrogeological constraints and ground suitability for SuDS
- **Environmental / Ecological** – extent of biodiversity challenges, local schemes / initiatives, water quality improvement projects etc.
- **Urban Regeneration** – planned and committed regeneration projects / programmes
- **Flood Risk** – high-level assessment of flood risk, property impacts, and flood damages
- **Drainage Systems** – spatial understanding of drainage system capacity and critical assets

The data and information collated should be presented in a geospatial format to provide a geographical focus. This would allow individual authorities, who are preparing a business case for funding, to efficiently interrogate their catchment / area whilst retaining context against the whole of Greater London.

Most data and information would be sourced from responsible London authorities and organisations (covering the points above). Some of the key existing policy and strategies that would be form the basis of this document are likely to include:

- Healthy streets (GLA)
- London Environment Strategy
- London Plan (inc. Opportunity Areas)
- Natural Capital Account for London
- Mayors Transport Strategy 2018
- BGS Infiltration SuDS map (BGS)
- London Wildlife trusts

8.2.4 TW Strategic Growth Opportunity Assessment

The scale of headroom creation that could potentially be created at a comparable benefit-cost to more traditional approaches presents a significant opportunity for TW to justify a greater investment in SuDS, to supplement LLFA commitments and FCERM GiA contributions. The benefit-cost figures presented in this report could be improved further with work to develop an optimisation framework focused solely on drainage headroom. This could facilitate a greater awareness of TW needs in different catchments, becoming an influencer on investment decision making, and provide further justification to the strategic element of a business case for funding.

This assessment would need to be focused on providing discrete location-based information on the current and future headroom 'need' and the projected benefits that Distributed SuDS could generate. Deriving this understanding would require a strategic level-assessment utilising on high-level 1D modelling to provide an effective schedule of opportunities and indication of where the greatest return on investment is likely to be realised.

This assessment would become a key element of the Strategic SuDS Realisation Case for London, underpinning individual business case submissions. It would also serve to provide TW with empirical evidence of the net value of SuDS to clarify long-term commitments (i.e. AMP cycle budgets) and their SUDS policy.

8.2.5 Optimisation Process Improvement

It has been recognised throughout the study that optimising investments in Distributed SuDS is critical in securing funding by maximising benefit-cost. It is recommended that further work is undertaken to remove or reduce uncertainty from the limitations of the optimisation process proposed in this study (See Section 6.2.2.3). Each evaluation of SuDS opportunities undertaken by local authorities should consider various options, proposing a method that builds upon the concept proven in this study.

At present, three alternative approaches have been considered suitable to address the issues partially or wholly around uncertainty and causality:

Simplified Full Opportunity Assessment

The most logical approach to optimise opportunities is to apply a general scenario-based approach, where every effective combination of SuDS feature type and location is 'tested'. This approach was initially considered for this project but later discounted due to the anticipated scale of modelling and analysis.

A far more simplified 1D or 2D model would be recommended to apply this method using the common computing / processing power and likely project resources, potentially many models covering different sub-catchments. Effective management of prediction data and automation of the analysis would also be important. If this method could be successfully formulated it would likely generate the most accurate picture of the optimal implementation of Distributed SuDS, at an individual feature level.

Delineation of Wetspot SuDS Opportunity Catchments

This method could be applied as a standalone approach or used to supplement the Simplified Full Opportunity Assessment, providing an initial screening to reduce the number of models and scenarios.

Flood mapping would be used to derive watersheds for each flood wetspot, defined using a metric such as a minimum number of properties flooded or flood depth threshold. The net benefit-cost of all the Distributed SuDS opportunities within each watershed would be evaluated, enabling the selection of the most optimal cluster of Distributed SuDS by comparing all the watersheds. This approach would simplify the overall modelling process and provide a more focused assessment, based on predicted flooding locations. It would also enable weightings to be applied, based on flood frequency, historical evidence and political pressures. Its limitations, which are similar to those made for the process in this study, are around the inability to understand benefit at multiple locations downstream since SuDS features would be tied to the wetspot watershed that they are located in.

Use of Neural Networks / Machine Learning Techniques

A more advanced approach to the Simplified Full Opportunity Assessment would be to use neural networks to seek a more efficient path to identifying the optimal locations. This would require advanced technical capability and is likely to be logistically unachievable (at present) without incurring a disproportionate development cost.

Appendix A

Register of Supporting Technical Notes

SuDS Features Technical Note

10016816-ARC-XX-XX-DE-RP-0002-01-SuDS Features, Technical Note.pdf

SuDS Evaluation Scenarios Technical Note

10016816-ARC-XX-XX-DE-RP-0003-01-SuDS Evaluation Scenarios, Technical Note.pdf

CAPEX Estimation Technical Note

10016816-ARC-XX-XX-DE-RP-0004-01-SuDS CAPEX Estimation, Technical Note.pdf

Natural Capital Accounting Technical Note

10016816-ARC-XX-XX-DE-RP-0005-01-Natural Capital Accounting, Technical Note.pdf

Hydraulic Modelling Technical Note

10016816-ARC-XX-XX-DE-RP-0006-01-Hydraulic Modelling, Technical Note.pdf

Appendix B

Normalisation of Comparative Metrics

To enable a clear and consistent comparison of all the metrics across all scenarios, the majority of assessment values have been ‘factored’ from 0% - 100%. A scenario with a 0% factorised metric has the lowest benefit of all the scenarios within the comparison, while a scenario with a 100% factorised metric has the highest benefit, with all others scaled accordingly. The calculation is defined as follows:

$$Mf = \frac{\big(M - Min(M1 \ldots Mn)\big)}{Max(M1 \ldots Mn) - Min(M1 \ldots Mn)})$$

Where M = metric value / M f is the factorised value

When reading and interpreting the plotted results it is important to note that any scenario metric with the lowest benefit will be shown with no bar (i.e. 0%). In these cases, it is likely that this scenario is generating some benefit, but when compared to all other scenarios it performs the lowest.

This result of the factorisation process is demonstrated in Figure 54.

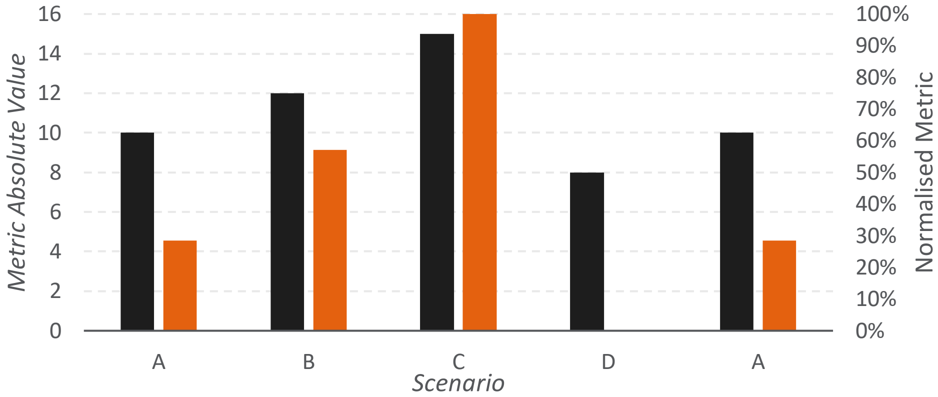


Figure 54 - Example of Factorisation

Key:

Metric Absolute Values
Factorised Metric

Appendix C

Stage 2, Comprehensive Economic Valuation - CAPEX Cost Metrics

SuDS Feature Type	SuDS Costs		Non-SuDS Costs		SuDS Cost Savings		Total SuDS Material Costs		Design, Mobilisation & Site Costs				Total / Site				Units
									Direct Procurement		Opportunistic Delivery		Direct Procurement		Opportunistic Delivery		
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	
Streetscape Bioretention	£69	£207	£218	£703	-£64	-£191	£223	£719	£84	£647	-£6	£18	£307	£1,366	£218	£737	per m^2
New Street Tree	£3,676	£4,569	£49	£147			£3,725	£4,717	£1,397	£4,245	-£93	£118	£5,122	£8,962	£3,632	£4,835	per tree
Street Tree Replacement	£2,205	£2,742	£29	£88			£2,235	£2,830	£838	£2,547	-£56	£71	£3,073	£5,377	£2,179	£2,901	per tree
Living Roof	£81	£128					£81	£128	£0	£1	-£0	-£1	£20	£89	-£37	-£67	per m^2
Rainwater Planter	£150	£175					£150	£175	£38	£123			£188	£298			Per planter

Notes:

SuDS Costs *- soil, vegetation, kerbing etc.*

Non-SuDS Costs *- standard kerbs, pedestrian access paving etc.*

SuDS Cost Savings *- Costs associated with material elements not needed within a SuDS design (i.e. tarmac, paving slabs, kerbs etc.)*

Total SuDS Material Costs *- SuDS Costs + Non-SuDS Costs + SuDS Cost Savings*

Design, Mobilisation & Site Costs, Direct Procurement *- Estimated cost lift (as % of Total SuDS material costs), assuming feature designed and constructed solely by water management authority(ies) under capital investment*

Design, Mobilisation & Site Costs, Opportunistic Delivery *- Estimated cost lift (as % of Total SuDS material costs), assuming feature function integrated into a wider urban regeneration / highway / property re-development scheme (procured and funded by non-water management authority)*

Total / Site *- Total CAPEX: Total SuDS Material Costs + Design, Mobilisation & Site Costs*

Direct Procurement *– See Section 6.3.3*

Opportunistic Delivery *– See Section 6.3.3*

Lower / Upper *– See Section 6.3.4*

Appendix D

Stage 2, Comprehensive Economic Valuation - Natural Capital Value Metrics

Unit Benefits (tabulated)

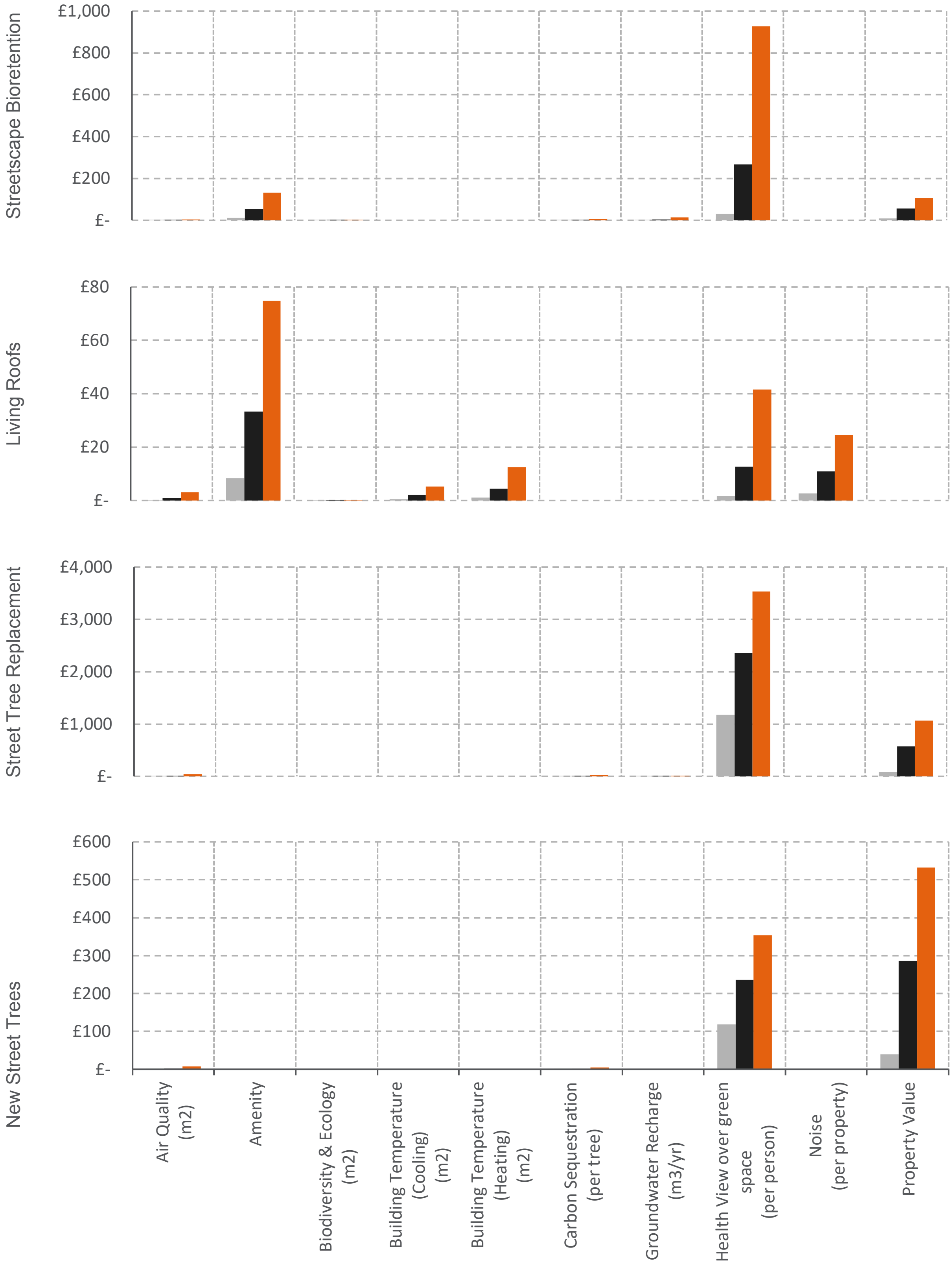
SuDS Feature Type	Uncertainty Band	Air Quality	Amenity	Biodiversity & Ecology	Building Temperature (Cooling)	Building Temperature (Heating)	Carbon Sequestration	Groundwater Recharge	Health View over green space	Noise	Property Value	Traffic Calming	Urban Heat Island	Total
Streetscape Bioretention	Lower	<£1	£13	<£1	-	-	<£1	<£1	£31	-	£8	£370	£8	£430
	Central	£1	£53	<£1	-	-	£2	£4	£267	-	£57	£987	£16	£1,388
	Upper	£3	£131	<£1	-	-	£7	£14	£926	-	£106	£3,332	£23	£4,543
New Street Tree	Lower	<£1	£8	<£1	<£1	£1	-	-	£2	£3	-	-	£8	£22
	Central	£1	£33	<£1	£2	£4	-	-	£13	£11	-	-	£16	£80
	Upper	£3	£75	<£1	£5	£12	-	-	£42	£25	-	-	£23	£186
Street Tree Replacement	Lower	£1	-	-	-	-	£1	<£1	£1,179	-	£78	£270	£60	£1,589
	Central	£7	-	-	-	-	£6	£4	£2,358	-	£571	£719	£141	£3,807
	Upper	£41	-	-	-	-	£22	£14	£3,537	-	£1,065	£2,426	£256	£7,361
Living Roof	Lower	<£1	-	-	-	-	<£1	-	£118	-	£39	-	£95	£253
	Central	£1	-	-	-	-	£1	-	£236	-	£286	-	£243	£767
	Upper	£8	-	-	-	-	£4	-	£354	-	£532	-	£475	£1,373

Notes:

All values in per m^2 / m^3 equivalent

New Street Tree / Street Tree Replacement based on average tree canopy of $25m^2$

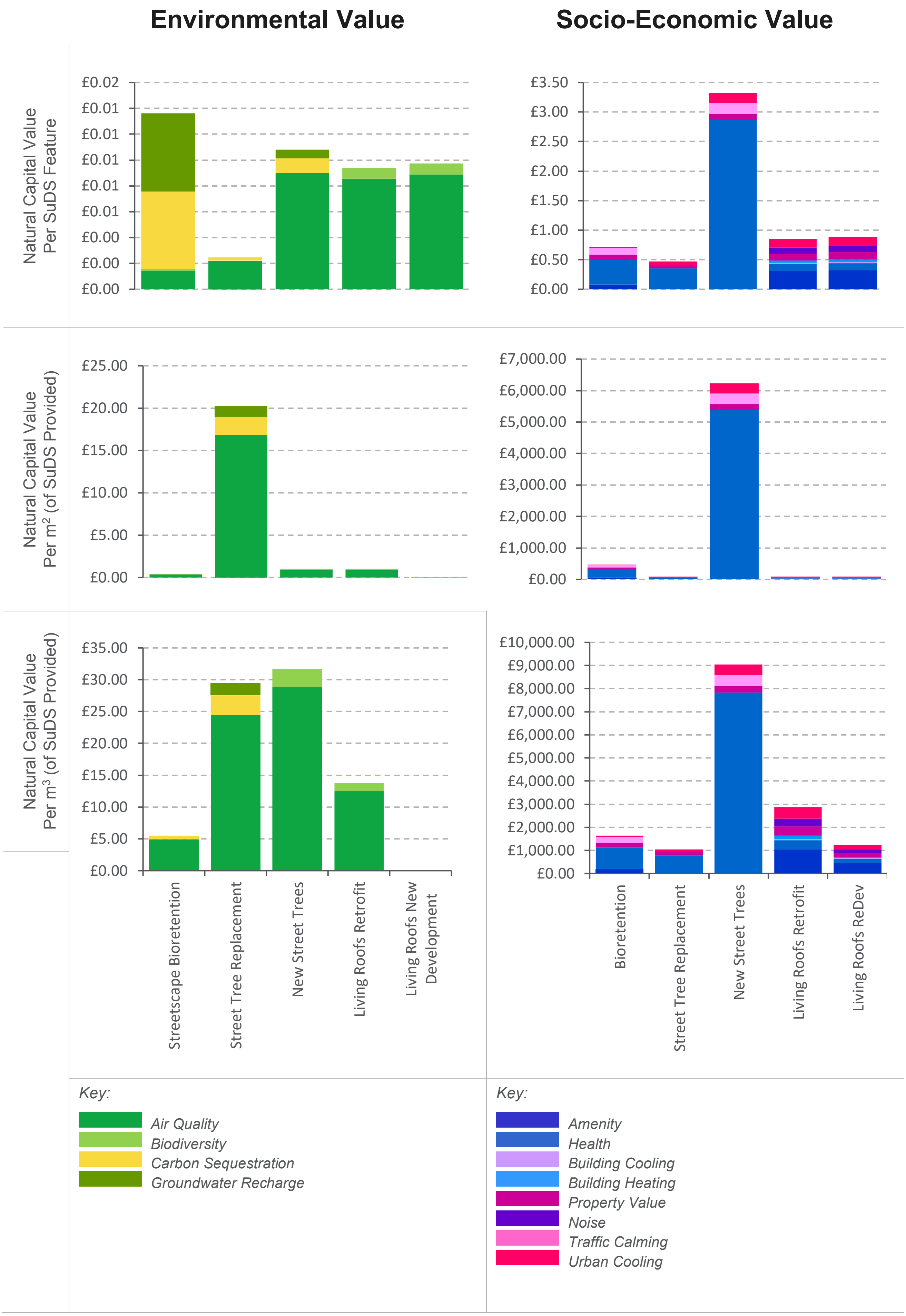
Unit Benefits (plotted)



Key:

Appendix E

Stage 2, Comprehensive Economic Valuation - Natural Capital Value of SuDS Evaluation Scenarios


Environmental Value
Socio-Economic Value
Natural Capital Value Per SuDS Feature
Natural Capital Value Per m² (of SuDS Provided)
Natural Capital Value Per m³ (of SuDS Provided)
£0.02
£0.01
£0.00
£3.50
£3.00
£2.50
£2.00
£1.50
£1.00
£0.50
£0.00
£25.00
£20.00
£15.00
£10.00
£5.00
£7,000.00
£6,000.00
£5,000.00
£4,000.00
£3,000.00
£2,000.00
£1,000.00
£35.00
£30.00
£10,000.00
£9,000.00
£8,000.00
Streetscape Bioretention
Street Tree Replacement
New Street Trees
Living Roofs Retrofit
Living Roofs New Development
Bioretention
Living Roofs ReDev
Key:
Air Quality
Biodiversity
Carbon Sequestration
Groundwater Recharge
Key:
Amenity
Health
Building Cooling
Building Heating
Property Value
Noise
Traffic Calming
Urban Cooling

Arcadis UK

34 York Way
London N1 9AB

T: +44 (0) 20 7812 2000

arcadis.com