Environmental Policy Consulting

Sustainable Drainage Systems on new developments

Analysis of evidence including costs and benefits of SuDS construction and adoption

Final Report
For the Welsh Government

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Executive Summary

Introduction

The Welsh Government commissioned Environmental Policy Consulting to assess the performance of SuDS on new developments, including costs and benefits, compared with conventional drainage approaches. The purpose of this assessment is to inform potential policy changes that could be made to accelerate the use of SuDS on new developments in Wales.

Such policy changes could include commencement of Schedule 3 of the Flood and Water Management Act 2010. This would establish a SuDS Approving Body (SAB) within lead local flood authorities, with SAB approval required before construction of drainage systems can commence on new and redeveloped sites. Provided appropriate national standards are met, the SAB would be required to adopt and maintain the approved SuDS that serve more than one property.

Approach

The approach adopted in this project, which was undertaken between October and December 2016, was based around four main tasks:

1. Review of evidence – 34 recent case studies were analysed in detail, with these selected as potentially including quantifiable costs and benefits for both a SuDS scheme and for a comparable conventional approach.
2. Engagement with stakeholders – 24 interviews were undertaken, focusing on different perspectives, experiences and expectations in relation to the use of SuDS on new developments. These interviews were supplemented by additional consultation and engagement with experts to identify and verify useful data and information.
3. Additional evidence gathering – supplementary data, evidence and information was collated from a range of sources, largely to ensure that, as well as the economics of SuDS, the project fully considered issues around adoption, maintenance and funding.
4. Analysis – economic analysis focused on monetised capital and operational costs and benefits for schemes at different scales (small – less than 10 units; medium – 10 to 100 units; large – over 100 units) where both a SuDS-based option and a more conventional solution had been identified and considered.

Key findings

The key findings from the collated information are as follows.

i. SuDS are already used extensively on new developments in Wales. However, these are variable in quality and performance, and there is currently a preponderance of 'hard' SuDS (largely comprising underground measures and attenuation ponds), with fewer 'landscaped' (vegetated) SuDS that can potentially deliver multiple benefits.
ii. At present, the key barrier to greater uptake of good quality, landscaped SuDS is uncertainty around adoption and ongoing operation and maintenance. A variety of adoption and funding arrangements are currently used, and these are arrived at by different means.
iii. Different SuDS schemes in different places have very different costs and benefits. However, based on the evidence obtained, the capital costs of SuDS solutions are lower than the capital costs of comparable conventional solutions. This differential can be very significant and depends primarily on the size of the scheme and the SuDS components used.

iv. Operational and maintenance costs also tend to be lower for SuDS. However, there is more variability here and some important caveats to this, primarily related to the type of measures and management regime used.

Results and discussion

The capital and operational costs and monetised benefits (mean and standards errors) of SuDS and conventional schemes at different scales are shown in Figures E1, E2 and E3.[1]

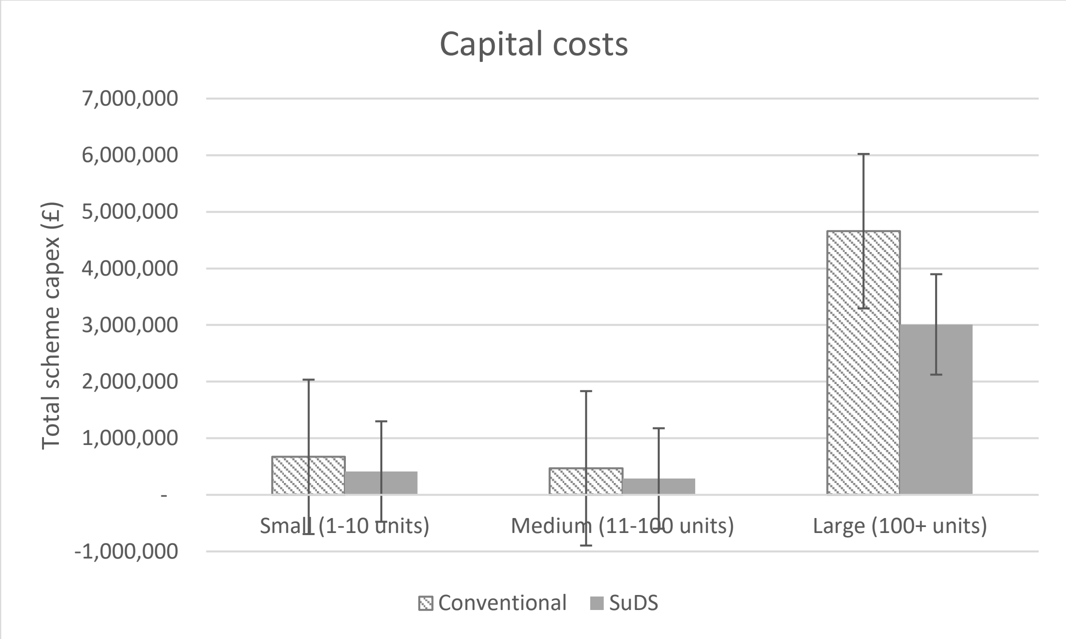

Figure E1: Capital costs of conventional and SuDS schemes

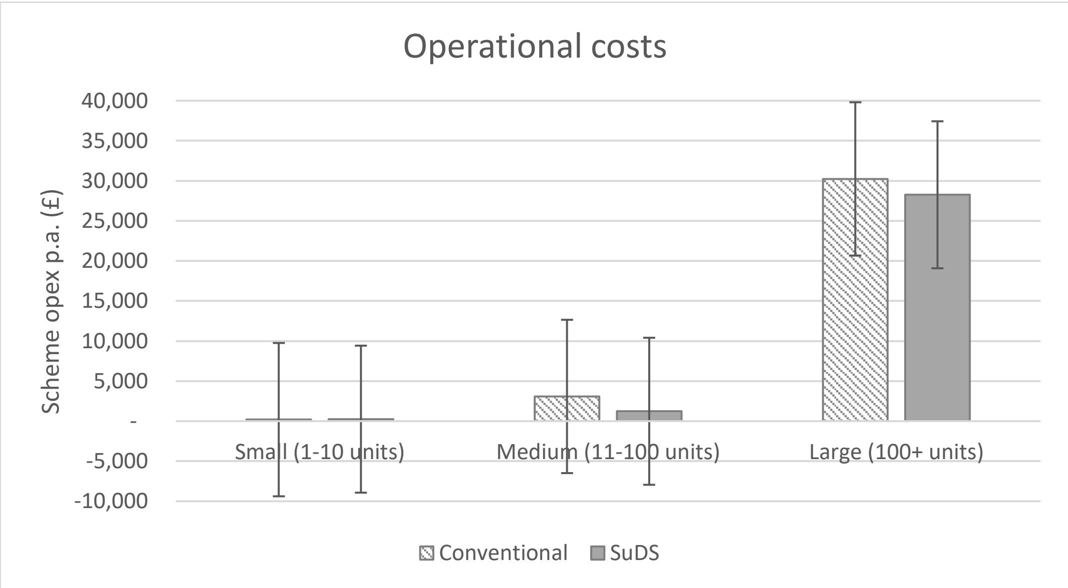

Figure E2: Annual operational costs of conventional and SuDS schemes

[1] In each case, n=5 (small), n=13 (medium), n=12 (large)

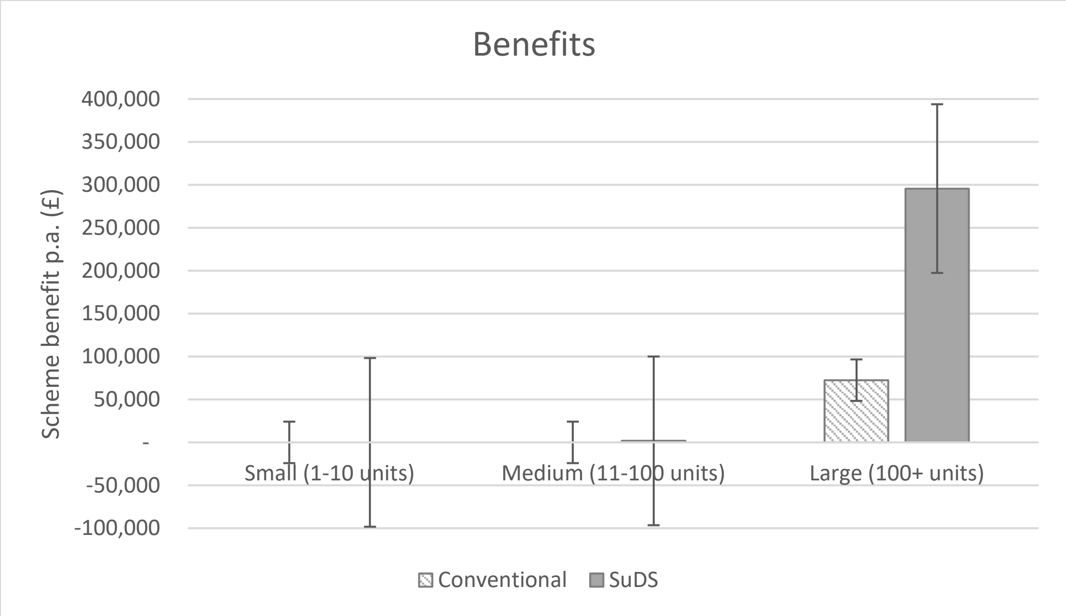

Figure E3: Annual benefits of conventional and SuDS schemes

There are a number of gaps in the data supporting the analysis above. In particular, information related to small developments is very limited. Even for medium developments, information relating to operational costs and benefits is scarce. There is much more data available for large developments, and for capital costs generally.

Nevertheless, the figures do highlight a number of important points.

i. Based on the evidence considered here, the capital costs of landscaped SuDS solutions are lower than the capital cost of comparable conventional solutions at every level. On average, our analysis suggests that the use of SuDS could save Wales over £9,000 per new home in capital costs alone.
ii. Of those schemes examined in detail, the operational costs of landscaped SuDS solutions are also lower than the operational cost of comparable conventional solutions at every level.
iii. In terms of costs per household, there are, as would be expected, capital cost economies of scale for both conventional and SuDS schemes, with capital costs per household falling significantly as the scale of development increases. However, these economies of scale are less pronounced for operational costs. Nevertheless, the operational costs per household for large developments are generally lower than those for small and medium developments.
iv. Although the number of data points is more limited (because most schemes do not assess or record benefits), it is clear that there are real and significant benefits associated with the use of landscaped SuDS, and that the benefits of SuDS solutions are significantly higher than the benefits of comparable conventional solutions. Further, wider benefits related to health, amenity and other areas could be very significant, even when compared to more traditional benefits like flood risk reduction and water quality.
v. Per household, there is a different picture to costs. Unlike costs, benefits per household are greater for larger developments than for small and medium developments. This may be because certain benefits only accrue above a certain scale. Our analysis suggests that the use of SuDS could generate benefits of well over £300 per household per year on large developments.

Although the analysis suggests that there is a strong economic case for SuDS on new developments, it is important to note that costs and benefits often fall on different groups. Any change in policy is therefore likely to result in both winners and losers, and additional mechanisms may be needed to appropriately compensate those who could be worse off.

Uptake, adoption, operation, maintenance and funding

SuDS are not simply an alternative to piped drainage systems. SuDS provide financial and other outcomes that far exceed those from using conventional drainage, but many of the benefits relate to service provision beyond the duty to '*effectually drain*' an area. SuDS benefits comprise human and ecosystem health, aesthetic, recreational and environmental quality enhancements. Currently the town planning, institutional and responsibility frameworks in Wales, as elsewhere in the UK, are not ideally set up to exploit and maximise the wider SuDS benefits, as these frameworks have been established primarily to manage surface water to avoid flooding and water pollution. Funding has focused on only these outcomes. This is why there has been limited uptake of SuDS so far. The clear benefits from using SuDS often accrue to organisations and individuals who are largely unaware of, or remote from, the management of surface water, like health authorities. Hence, those responsible for the capital funding of SuDS and for the funds for necessary long-term maintenance and operation to sustain these wider benefits, need to be effectively funded in a way that recognises and supports the delivery of SuDS benefits. Across the UK, not only in Wales, the lack of understanding of the need to ensure effective institutional arrangements and to provide funding in a way that supports the delivery of the widest range of benefits brought by SuDS, has so far resulted in a mixed, confused and largely ineffective approach that has failed to ensure the best outcomes for society as a whole. A single body or organisation, such as a SAB, would be best placed to ensure that SuDS are used effectively if resourced adequately. Establishment of such an organisation would also require a review of the current arrangements for town planning, flood and water management to ensure that these support the necessary approach.

Conclusions and recommendations

The main conclusions from the work undertaken and presented here are as follows.

1) The overall capital costs of well designed, good quality landscaped SuDS solutions are always less than those for conventional solutions. In most cases, overall operational and maintenance costs are also lower. Notwithstanding poor or incomplete data, this is a clear and consistent finding.

2) SuDS are not just an alternative to conventional drainage solutions. They can provide significant and multiple benefits, and have particular potential to help Wales meet well-being and wider sustainability goals. Although the arrangements for the way in which water and surface water systems are managed in Wales has evolved in the last decade and there are still many players with diverse responsibilities, all key stakeholders support the role that SuDS can play in achieving these aims.

3) Across the 110,000 new homes planned for Wales by 2021, our analysis suggests that the use of landscaped SuDS on new developments that are compliant with required standards could save Wales nearly £1 billion in capital construction costs and generate benefits of over £20 million per year.

4) Costs and benefits vary according to location, ground conditions, scale of development, the type and range of measure employed and other factors. The biggest advantages for SuDS seem to be associated with the following:

   a. SuDS need to be planned at the earliest stage of the planning process and integrated with general landscape design and maintenance;
   b. SuDS on or near the land surface are far more cost-effective than below-ground proprietary systems;
   c. Working in the broadest possible partnership offers the greatest potential to maximise benefits and lever additional funding; and
   d. The significant role of 'champions' in obtaining 'buy-in', managing relationships using voluntary agreements, and in promoting successful delivery and continuing functioning of SuDS.

5) There is broad and widespread support for commencement of Schedule 3 or a similar process that would make good quality SuDS, which are compliant with national standards, mandatory on new developments. Further, it appears unlikely that such a process would increase costs or hamper or slow down development. However, it would need to be accompanied by a clear but flexible process covering planning, adoption and responsibilities for long-term maintenance, supported by a continuous and sustainable income stream to ensure security of funding. **In short, commencement of Schedule 3 is necessary but not sufficient on its own to facilitate uptake of good quality SuDS on new developments.**

6) Although information and evidence related to SuDS has improved significantly in recent years, some key gaps in knowledge or in readily accessible information remain, including
   a. Monitoring of performance, especially longer-term (e.g. flows, volume, quality, environmental outcomes)
   b. Quantification and monetisation of the costs and benefits of *SuDS compared with conventional systems*, particularly for smaller schemes
   c. The need for a comprehensive SuDS Register (size, location, quality, adoption agreements used, costs, performance, benefits, etc.)
   d. A clearer understanding of how SuDS can fit within a natural capital framework, such that they can be treated as assets rather than liabilities.

7) Nevertheless, despite a clear vision for the future of Wales and a strong policy framework that seeks to enhance the welfare of future generations, taking responsibility for the long-term adoption and maintenance of SuDS, within an integrated water management framework, remains a risk for any organisation and, in common with the rest of the UK, a major challenge for Wales.

8) To realise the full benefits of SuDS, new models of funding may be required. These should be based on an improved understanding of who benefits, and may include a greater emphasis on the 'beneficiary pays principle', under which households, road users and others that benefit from SuDS may need to make larger contributions than at present, or existing revenues redirected to better align with the actual costs and better understood benefits.

9) Regardless of whether or not Schedule 3 is commenced, it is clear that the town planning processes need to be effective and timely and include all parties as consultees. We have found that 'drainage' proposals are often vague at the outset of the approvals process (see Woods-Ballard et al, 2015 for an outline of the process) and (largely due to pressures and complexities of site layout) are not defined by developers until too late in the process. The consequence is that the use of SuDS is often not possible due to the fixing of site details for

other reasons – layout of houses, roads etc. SuDS need to be co-designed with the other surface features of a site. In addition, it means that reliable estimates of maintenance costs and any commuted sums cannot be determined early in the design and planning process due to the lack of detail about the SuDS. This leaves questions of adoption to the very end of the process and little room for manoeuvre to get the best outcome for this.

Recommendations are primarily aimed at the WG for consideration and informing possible consultation options around commencement of Schedule 3.

1) In order to realise the benefits of SuDS and for consistency with the goals set out in the Well-being of Future Generations (Wales) Act 2015, the WG should take account of the information and analysis presented here in taking forward SuDS in Wales, including the use of appropriate policy levers and legislation.

2) In developing an approach to the public consultation exercise which will accompany any proposed changes in policy, the WG should consider the following issues.
    a. The need for policy options which provide a clear framework and process for adoption, and for the provision of incentives and sustainability of funding to ensure the long-term operation and maintenance of SuDS. This should consider how the use of incentives could be developed which support the beneficial use and funding of SuDS, consistent with the beneficiary pays principle and encompassing all surface water sources (including highways).
    b. Whether, in order to build the evidence base for SuDS, there is a need to consider developing guidance to support assessments and recording of the expected or actual performance, capital/O&M costs and benefits of SuDS in a consistent and transparent way.
    c. Likewise, whether there is a need to establish and maintain a register of SuDS in Wales.
    d. The possibility of convening (potentially in partnership with a body such as CIRIA) a 'SuDS Summit' to communicate examples of emerging or established good practice, and to provide a forum for identifying and developing partnerships for delivering SuDS.
    e. How SuDS can be consistently treated as assets rather than liabilities (e.g. by adopting a natural capital framework) in order to support delivery of multiple benefits.

3) In parallel to the consultation process, the WG should consider how the town planning process can be reformed to require that 'drainage' and appropriately designed, approved and adopted SuDS are adequately considered and formally accommodated from the outset and at all stages in development proposals. All parties with an interest in SuDS should be made statutory consultees to this process.

4) The SuDS Advisory Group in Wales should establish a sub-group to set out a process map and accompanying guidance that encompasses design, planning, construction, commissioning, adoption, O&M and decommissioning. This should either be defined in terms of a single adopting body (SAB or otherwise), or set out to inform the diverse and various potential adoptees as seen across the UK.

5) Greater priority should be placed on effective regulation and inspection of SuDS. Experience from SuDS use in Scotland has shown that an effective regulation and inspection regime is required to ensure good practice is enforced and SuDS conform to the guidance set out in e.g. the CIRIA SuDS Manual.

Glossary

Term	Meaning
Capex	Capital expenditure
Circular economy	Alternative to traditional linear economy (make, use, dispose), in that resources are used for as long as possible, so the maximum value is extracted from them whilst in use, then value is recovered and materials reused at the end of each service life.
CIRIA	Construction Industry Research and Information Association
CIWEM	Chartered Institution of Water and Environmental Management
Commuted sum	A sum payable by a developer to a maintenance organisation for future maintenance of SuDS
IWCM	Integrated water cycle management
LCA	Life-cycle assessment
Natural capital	The world's stocks of natural assets which include geology, soil, air, water and all living things. It is from natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible.
Opex	Operational expenditure
O&M	Operation and maintenance
NRW	Natural Resources Wales
SAB	SuDS Approval Body
Schedule 3	Part of the Flood and Water Management Act 2010 that relates to sustainable drainage (SuDS)
SuDS	Sustainable drainage systems
WaSC	Water and sewerage company
Whole-life cost	Refers to the total cost of ownership over the life of an asset. Also commonly referred to as "cradle to grave" or "womb to tomb" costs.

1. Introduction

1.1 Background

Schedule 3 of the Flood and Water Management Act (UK Government, 2010) relates to provisions for sustainable drainage (SuDS). These include the establishment of a SuDS Approving Body (SAB) to be set up within lead local flood authorities (LLFAs), with SAB approval required before construction of drainage systems can commence on new and redeveloped sites. Provided appropriate national standards are met, the SAB will be required to adopt and maintain the approved SuDS that serve more than one property.

A decision on commencing Schedule 3 will require an Impact Assessment, setting out the need for, and impact of, any change in policy. This should assess and present the likely costs and benefits (monetised as far as possible) and the associated risks of a proposal that might have an impact on the public, private or third sector.

Consideration of the most effective way of embedding SuDS principles in new developments was a commitment in the Water Strategy (Welsh Government, 2015a). Environmental Policy Consulting Ltd (EPC) was commissioned by the Welsh Government (WG) to provide evidence on the costs and benefits of SuDS on new developments, so that a decision can be made on whether their use should be mandatory.

There is general agreement that current approaches are not leading to optimal solutions and outcomes, and that further support for SuDS, potentially with legislative backing, is required. Options will be developed by the WG but could encompass the following.

i. Continued support for best practice, but non-statutory, SuDS standards. This is the current situation in Wales.
ii. Commencement of Schedule 3 to the Flood and Water Management Act 2010 (with no amendments to those provisions, and the prospect of any future changes wholly contingent on evidence based on practical issues arising further to implementation).
iii. Enhanced planning focus (similar to the approach in England), with local authorities seeking compliance with the non-statutory standards for the design, construction, operation and maintenance of SuDS in Wales through the planning system.

This report sets out the evidence obtained and analysed by EPC in relation to the above. It is aimed primarily at the Welsh Government, but will also be of interest to other parties involved in the construction, adoption and use of SuDS on new developments.

1.2 SuDS and their benefits

The reference point in this report for the definition of SuDS is that set out in the Flood and Water Management Act (2010).[2]

> *"Sustainable drainage" means managing rainwater (including snow and other precipitation) with the aim of—*
>
> *(a) reducing damage from flooding,*
>
> *(b) improving water quality,*

[2] The Flood and Water Management Act covers other elements relevant to SuDS, including the designation of Lead Local Flood Authorities (Section 27) and local flood risk management strategies (Section 10).

(c) protecting and improving the environment,

(d) protecting health and safety, and

(e) ensuring the stability and durability of drainage systems.

Essentially, the SuDS approach "*is about slowing down and reducing the quantity of surface water runoff from a development site to manage flood risk and reducing the risk of that runoff causing pollution. This is achieved by infiltrating, slowing, storing and treating runoff on site and, where possible, on the surface rather than underground. Water then becomes a much more visible and tangible part of the development that can be enjoyed by those who live and work there or choose to visit*" (Woods-Ballard et al, 2015).

The SuDS approach is potentially a radical shift in the way in which surface water is seen and managed in the UK. The first edition of the SuDS Manual (Woods-Ballard et al, 2007) set out to explain how to use SuDS to manage surface water problems. The second edition in 2015 takes a more holistic approach (moving well beyond considerations of water quantity only) and recognises the opportunities from surface water, with the potential to benefit society in many ways.[3] Despite this, planning and other systems in place in the UK still see surface water as a '*problem to be solved'* (e.g. Bide, 2014).

However, SuDS (particularly 'landscaped' SuDS – those encompassing above-ground planting and landscaping) offer significant opportunities, in terms of multiple benefits beyond surface water management. These are reflected in the WG's recommended standards (Welsh Government, 2016) and the updated SuDS Manual (Woods-Ballard et al, 2015). They correlate with both the well-being goals and the sustainable development principles contained within the Well-being of Future Generations (Wales) Act 2015 (Welsh Government, 2015b).

As noted above, a decision on commencement of Schedule 3 would need to be based, in part, on a more complete understanding and assessment of the benefits of SuDS, including those listed in Figure 1 below, many of which are currently not well understood or undervalued.

[3] This is consistent with concepts such as Water Sensitive Urban Design (WSUD), an approach which integrates water (including stormwater) management into urban design. The 2015 Water Strategy for Wales included a commitment to "*work with others both nationally and internationally to identify how the WSUD approach could be used in Wales*". The use of SuDS, and the multiple benefits that can be derived through their use, is entirely consistent with WSUD principles to reduce water use, minimise flood risk and improve water quality. As such, this report, and consideration of policy options related to SuDS on new developments, helps to fulfil this commitment.

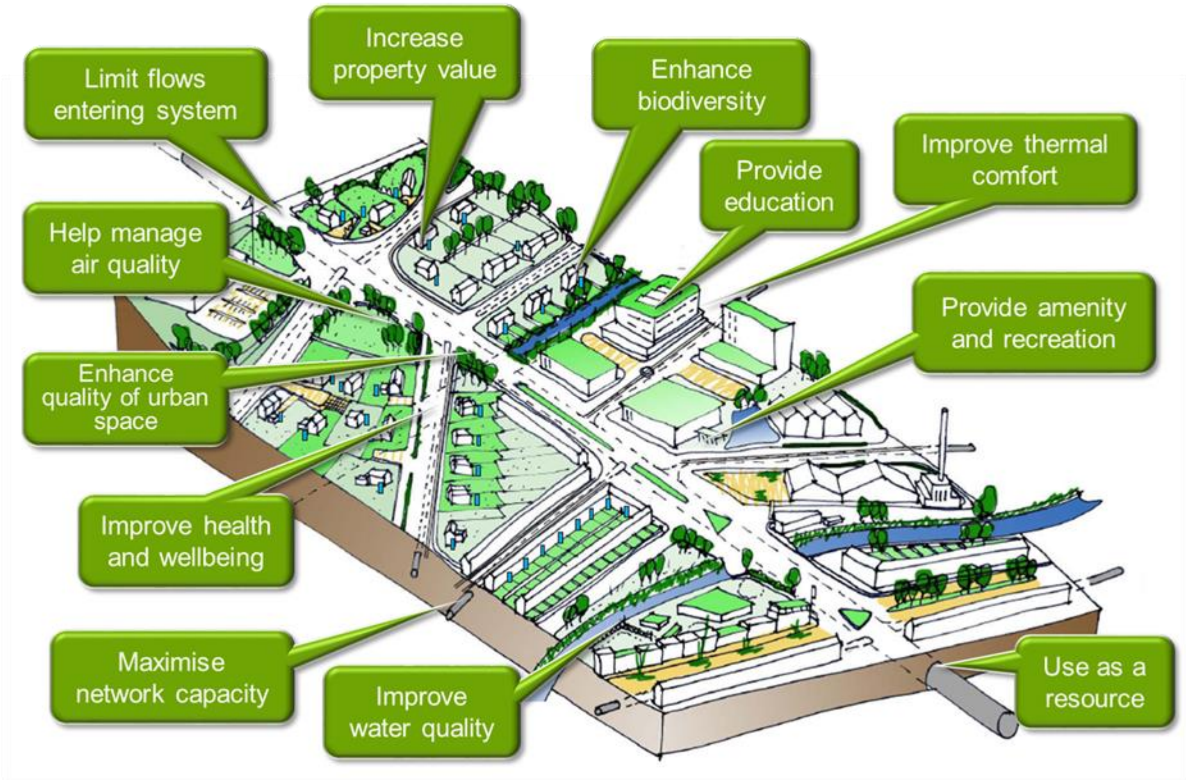

Figure 1: Potential benefits of SuDS (adapted from Woods-Ballard et al, 2015)

1.3 Drivers of SuDS in Wales

In the course of this project, we have identified a wide range of direct and indirect drivers for the inclusion of SuDS on new developments in Wales, these also relate to some of the benefits delivered by well-designed SuDS. These are shown in Table 1.

Table 1:Drivers of SuDS in Wales

Type of driver	Driver	How it supports SuDS
Political / regulatory (national)	The Well-being of Future Generations (Wales) Act 2015	Sets out well-being goals and sustainable development principles which align with SuDS approach. Decisions affecting natural resources in Wales should seek the best overall outcome, taking account of economic, social and environmental factors and the underpinning resilience of ecosystems. The SuDS approach can contribute to achieving six of the well-being goals, namely (1) Prosperous Wales, (2) Resilient Wales, (3) Healthier Wales, (4) More equal Wales, (5) Wales of cohesive communities, and (6) Globally responsible Wales. The Act places duties on public bodies (including local authorities, health boards, Natural Resources Wales (NRW) and others) to think more about the long-term, work better with people and communities and each other, look to prevent problems and take a more joined-up approach. The benefits potentially created through the use of SuDS can contribute to all of these objectives.
	The Planning (Wales) Act 2015	Section 2 imposes duties requiring "*sustainable development*" consistent with SuDS features on new developments. Also makes water companies statutory consultees on new developments, enabling drainage considerations to align with planning more explicitly.

	The Environment (Wales) Act 2016	Part 1 is about the sustainable management of natural resources which includes surface water and biodiversity. The Act introduces nine principles for the sustainable management of natural resources including, taking account of the resilience of ecosystems and the benefits that natural resources and ecosystems provide – relating to the well-being goals. The Act requires the production of a *State of Natural Resources Report by Natural Resources Wales*, the first of which identifies six opportunities to deal with the challenges identified. These include Green Infrastructure in and around Urban areas and maintaining, enhancing and restoring floodplains and hydrological systems. The Natural Resource Policy Consultation identifies three priorities: • Accelerating green growth by increasing resource efficiency, renewable energy and supporting innovation. • Delivering nature-based solutions to improve resilience and the benefits derived from natural resources. • Improving community and individual well-being by taking a place and landscape based approach Under Section 6 of the Act, a public authority must seek to maintain and enhance biodiversity in the exercise of functions in relation to Wales, and in so doing promote the resilience of ecosystems, so far as consistent with the proper exercise of those functions. A public authority must take account of the resilience of ecosystems, in particular the following aspects: (a) diversity between and within ecosystems; (b) the connections between and within ecosystems; (c) the scale of ecosystems; (d) the condition of ecosystems (including their structure and functioning); (e) the adaptability of ecosystems.
	EU Water Framework Directive	Notwithstanding post-Brexit uncertainty around extent and timing of compliance, this enables SuDS to be included in river basin management plans, helping to meet the requirements of the Directive.
	Flood and Water Management Act 2010	Gives effect to the WG's Environment Strategy for Wales and the Strategic Policy Position Statement on Water. Includes Schedule 3 and other provisions for sustainable drainage.
	Air quality standards (Wales) Regulations 2010	SuDS can play a role in reducing air pollution in all four designated 'clean air zones' in Wales, which have illegally high pollution levels.
	Water Strategy for Wales	Non-binding but sets out strategic direction for water policy over the next 20 years and beyond. Highlights role of water as one of Wales' greatest natural assets and an integral part of Wales' culture, heritage and national identity.
	Social & Env Guidance to Ofwat (2013)	Urges Ofwat to encourage innovative, catchment-based solutions by companies, including use of SuDS.
	WG Programme for Government 2016-2021	Sets out the government's programme to drive improvement in the Welsh economy and public services, delivering a Wales which is prosperous and secure, healthy and active, ambitious and learning, united and connected. Identifies green infrastructure as opportunity to address poverty, housing and infrastructure drivers, whilst meeting broader longer term objectives.
	Welsh Housing Quality Standards	New homes constructed for Registered Social Landlords (housing associations) for both social housing and sale on the open market (RSLs) must construct property in line with the Standards, which

		must be "*located in attractive and safe environments*", use "*soft and hard landscaping with planting in protected areas*" and provide "*adequate, practical and maintainable communal areas*".
	Parliamentary committees	Whilst focused primarily on England, EFRAs "Future flood prevention" report (Nov, 2016) says "*all flood risk management bodies must understand better the contribution that sustainable drainage systems (SuDs) and green infrastructure such as ponds and swales can make to protecting communities from flooding*". National Audit Office and the Committee on Climate Change have also produced several reports promoting the benefits of SuDS.
	EU Urban Waste Water Treatment Directive	Adopted in 1991, the objective is to protect the environment from the adverse effects of urban waste water discharges and discharges from certain industrial sectors. It concerns the collection, treatment and discharge of: • Domestic waste water • Mixture of waste water • Waste water from certain industrial sectors
	EU Bathing Water Directive	Revised in 2006, this requires Member States to identify popular bathing places in fresh and coastal waters and monitor them for indicators of microbiological pollution (and other substances) throughout the bathing season.
	EU Floods Directive	In force since 2007, this requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. The Directive also reinforces the rights of the public to access this information and to have a say in the planning process.
Political / regulatory (regional / local)	Flood risk management strategies	SuDs can play an important and significant role in helping to reduce flood risk and support flood risk management. Wales is 'ahead of the game' in these respects (Ellis & Lundy, 2016).
	Local development plans	By mitigating barriers to planning consent, the use of SuDS can expedite construction of 110,000 or so homes scheduled in Welsh LDPs for delivery between 2006 and 2021. However, SuDS are still viewed by some as a barrier to housing growth due to unfamiliarity with their usage.
	Technical Advice Note (TAN15)	Provides guidance which supplements the policy set out in Planning Policy Wales in relation to development and flooding. Covers the use of development advice maps to determine flood risk issues, how to assess the flooding consequences of proposed development and action that can be taken through development plans and development control (management) procedures to mitigate flood risk when planning for new development. TAN 15 is in the process of being updated and a revised version is expected in 2017.
	Building Regulations (2010)	Particularly relevant is Approved Document H, which includes guidance related to drainage, including rainwater pipes, soakaways, etc. Based on hierarchy of: • Discharge via infiltration (including collection and reuse) • Discharge to watercourse • Discharge to sewer
	S42 Flood and Water Management Act 2010 – Mandatory adoption of foul sewers or lateral drains communicating with the public sewer	This introduced mandatory adoption of foul sewers and lateral drains communicating with the public sewer. This and the related Welsh Ministers' sewer standards emphasise the contrast with the lack of equivalent provision for SuDS systems.

	network	
Political / regulatory (international)	Global Climate Leadership MOU	Wales is a party to the MOU (Memorandum Of Understanding), which SuDS approach is consistent with and would help achieve.
Economic	Economic growth	SuDS can play an important role in helping to grow or regenerate areas, including deprived areas.
	Lower cost	SuDS are potentially cheaper to construct and maintain than conventional drainage systems.
	UK National Ecosystem Assessment (2010)	Provides a framework for understanding and capturing the contribution of SuDS to ecosystem service provision.
	Natural Capital Committee and Protocol	Provides framework for considering SuDS and local authority green space as an asset that can provide a return, rather than a liability.
	Abstraction reform	SuDS can help make more water available for abstraction, providing market-based opportunities for water.
	Public health	Can support health agenda, including strategic objectives of Public Health Wales, which include: Working in a different way to improve our health; and Influencing policies to help improve and protect your health.
	Life-cycle assessment and the circular economy	Opportunity to compare costs and benefits of SuDS against conventional solutions from a whole-life perspective, and to consider role of water and drainage in a fully integrated economy.
Technical	WG non-statutory standards for SuDS	Planning authorities expect SuDS on new developments to achieve compliance with standards, though they are not mandatory.
	Integrated water cycle management	Brings together range of national and local stakeholders, encouraging and enhancing integration of water management across Wales.
	National Infrastructure Commission for Wales (planned for 2017)	SuDs can support objectives of Commission, which will advise on decisions around all economic and environmental infrastructure in Wales including energy, transport, water and sewerage, drainage, digital communications and flood management.
	Water industry 21st century drainage project	Looking at future models for drainage management generally, and ways to deliver drainage in most sustainable and cost-effective way. SuDS expected to play a key role in this.
	CIRIA SuDS Manual	Key reference document for defining situations in which SuDS should be used and standards to meet.
	Drainage strategy frameworks/plans	These should be developed by sewerage undertakers in line with regulatory guidance (Ofwat, 2013) and be consistent with key principles, namely: partnership, take account of uncertainty, risk-based, whole-life costs and benefits, be dynamic, innovative and sustainable.

Clearly, there are many complex and interconnected drivers for SuDS. Those responsible for delivering outcomes against these drivers are similarly varied, although public bodies, in particular local authorities, oversee many of the political and regulatory drivers. Other important organisations include the Welsh Government, Natural Resources Wales, Ofwat and the water industry.

1.4 Project objectives

The principal aim of the project is to assess the performance of SuDS on new developments, including costs and benefits, compared with conventional drainage approaches. This should take account of recent evidence of constructing SuDS on new developments in the UK, as well as internationally, and good practice principles for the use of SuDS.

The project should also review the implications for the stakeholders involved or potentially involved; responsibilities, opportunities and the wider implications of how, when and where the use of SuDS can support the wider legislative framework around the well-being of future generations and sustainable development.

The outcome of the work will inform and support WG's impact assessment regarding whether or not to commence Schedule 3 or an alternative non-statutory approach, and inform the efficacy of SuDS on new developments more generally.

1.5 Project scope

The main considerations in relation to the scope and limitations of the project are as follows.

i. Whilst the focus of the project is the application of SuDS on new developments, information associated with retrofit situations has been considered and utilised where it is particularly relevant and lessons can be learnt. This includes, for example, the effectiveness of SuDS in slowing or removing flow from the system, and the associated benefits.
ii. Developments primarily comprising both residential properties and non-residential units are considered. In the former situation, trends to densify housing areas in the last decades have meant that the open space that would be available for surface SuDS is often absent from the inner areas, restricting options, although SuDS can be used in dense areas as illustrated by the Stamford case study described in Appendix 1. Lack of space for SuDS is exacerbated today by the many planning authorities who do not recognise that SuDS can provide the requisite green space required in planning approvals. In commercial areas, SuDS are often seen as a means of providing attractive landscapes and in some places, such as the BID in Victoria London, this has led to the retrofitting of SuDS to enhance surroundings.
iii. A primary focus on the economics of SuDS inevitably brings in issues around adoption and responsibilities for ongoing maintenance, since uncertainty around these is generally cited by developers and others as being the key barrier to delivery of SuDS. As such, it is not possible (or desirable) to completely disentangle economic issues from those related to ownership, responsibility and associated legislation.
iv. We have sought to maximise consistency and minimise the potential for overlap with the parallel WG project, *the effectiveness of drainage and sewerage regulations in Wales*, due to report in 2017. This review will highlight gaps, ambiguities and overlaps and inform recommendations on the shape of new or amended legislation. It will also explore the powers, duties and liabilities of stakeholders and how they align with legislation to see how this legislation works in practice, and whether it helps or hinders those working in the industry. Whilst the project is looking much more broadly than SuDS, some overlap is nevertheless inevitable.

Further information on the key caveats and assumptions we have made during this project is provided in Section 2.5.

2. Approach

2.1 Overview of approach and key steps

An overview of the approach adopted in the project, in order to achieve the objectives set out in Section 1.4, is shown in Figure 2. Each of the four key steps is described in more detail below.

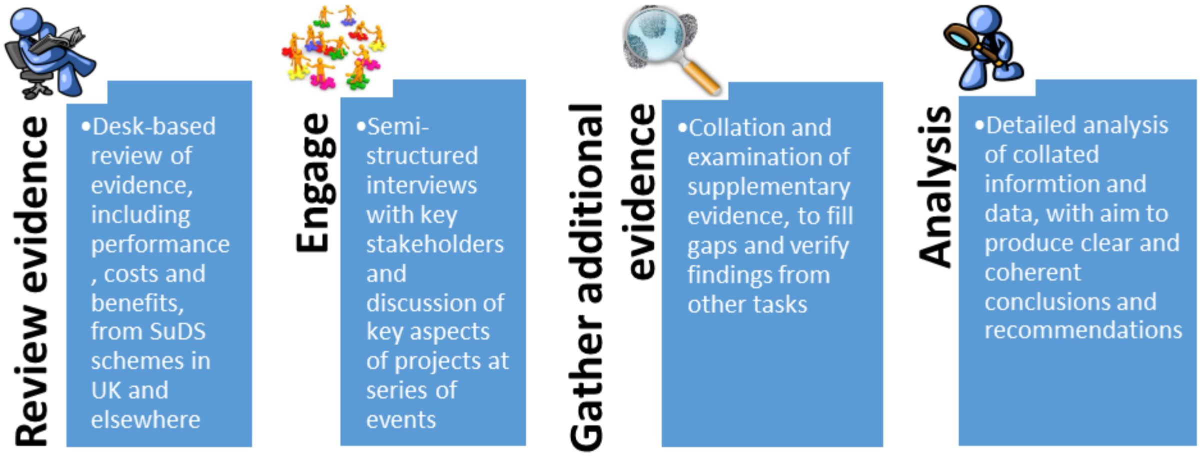

Figure 2: Overview of approach

2.2 Review of evidence

The purpose of the review was to identify and assess case studies most relevant to the economics of SuDS on new development in Wales.

A total of 34 case studies (27 from the UK and 7 from other countries) were identified from a range of sources, including:

- Susdrain (http://www.susdrain.org/case-studies/);
- Published papers from academia, government, policy organisations, etc.;
- Grey literature (not controlled by commercial publishers) from business, industry and other organisations; and
- Directly provided by stakeholders.

The case studies all come from the last ten years (when, following publication of the SuDS Manual, national standards for SuDS effectively emerged) and are listed in Appendix 1. They were reviewed in detail against the criteria shown in Table 2. In particular, we sought to identify as many case studies with quantifiable costs and benefits for both a SuDS scheme and for a comparable conventional approach.

Table 2: Criteria for assessing case studies

Element of analysis	Term/criteria	Definition
Context	Background	Preliminary context to the case-study
	New build/retrofit	Whether the SuDS are designed and/or applied to existing infrastructure or as part of a planning proposal.
	Scheme size	The area of which the SuDS system/component is designed to manage
	Catchment	The watershed delineation where the case-study is located
	Waterbodies	The receiving watercourse of the SuDS scheme
	Land-use	The dominant management and modification of natural environment (e.g.

		residential, industrial etc.)
	Soil-type	The characteristics of the areas soil, UK soil observatory data
	Geology	The characteristics of the areas geology, British Geological Survey data
	Slope	The characteristics of the areas altitude and gradient
	Rainfall	The standard average annual rainfall (SAAR), determined from Flood Estimation Handbook (FEH)
	Management train(s)	Identifies if the case-study involves multiple components working in source, site and regional mechanisms
	Funding	Identifies the amount and source of funding for the implementation of SuDS, if available
Scheme Details	Drivers	The key reasons for the considerations of SuDS at the site, e.g. surface water flooding problem etc.
	Components	The elements of the SuDS scheme, including the individual SuDS measures within the management train
	Management	Identify the methods by which stakeholders manage the site
	Stakeholders	Determine the key players and responsibilities of those involved in constructing, owning and maintaining the SuDS system
Assessment	Framework	The broad method of assessment, e.g. using CIRIA Benefits of SuDS Tool
	Baseline	The 'pre' development situation, identifying existing context in terms of flood risk, water quality pressures, lack of green space etc.
	Options	The different SuDS or alternative schemes (e.g. traditional engineering) schemes (as well as a 'do nothing' option) considered
	Costs considered	The types of costs considered in the assessments, e.g. capital, whole life costs etc.
	Benefits considered	The elements of the SuDS square, and beyond, assessed in terms of qualitative, quantitative or monetised benefits
	Quantification	The method applied to quantify any costs and benefits
	Valuation	The method used to value the quantified values determined from cost to benefit, translated to pounds sterling.
	Timescale	The longevity of the assessment (start and end date), if applied, to determine the reliability of the data and accuracy of whole life costs.
	Uncertainty	Often a range or percentage, considers uncertainty of SuDS providing benefits outlined. Also, illustrated in theoretical studies in terms of confidence.
	SuDS principles	Case-studies will be related to the SuDS principles that aim to deliver multiple, sustainable benefits, to work with natural processes where possible.
Results	Performance	The quantified outcomes of the scheme in terms of performing the functions for which it was designed.
	Costs	The monetised costs of the scheme, considering the whole-life-costing approach where evidence is available
	Benefits	The quantified or monetised benefits of the scheme
	Robustness and flexibility	Applies more conclusively to those implemented case-studies, considers the adaptation in practice and function of the scheme to provide benefits
	Lessons learnt	The key elements to inform the policy/practice for the Welsh Assembly and Schedule 3 of the Flood and Water Management Act
Relevance to Wales		Each case-study has relevance to Wales, however, this is of varying degrees displayed based on a scale of somewhat relevant, relevant and highly relevant. This is based on the SuDS schemes components that can be transferred to a Welsh context (climatologically and ground conditions), as well as the practical and political motives and lessons.
Additional comments		Any further comments associated with case-study.
References		Compiled from both grey and academic literature, including personal communication, and presented with relevant links.

Following the assessment of the 34 case studies, ten were selected by the project team as providing a particularly useful and broadly representative picture of the type and scale of issues, costs and benefits collated. These were incorporated into a template and are reported in Appendix 2.

2.3 Engagement with stakeholders

The main purpose of engaging with stakeholders was to provide a deeper understanding of the key issues related to the project. Additional aims were to verify information emerging from the review of evidence, and to identify and elicit any further data or information that could prove useful.

There were three main elements to the stakeholder engagement element of the project.

i. Semi-structured interviews

A total of 24 interviews were arranged and carried out in October and November 2016, each lasting between 30 and 60 minutes. These focused on different perspectives, experiences and expectations in relation to the use of SuDS on new developments. The specific areas covered were:

1. General experience with respect to SuDS on new developments
2. Use of SuDS standards (e.g. those published by WG in 2016)
3. Success factors for SuDS on new developments
4. Evidence relating to performance, costs and benefits
5. Funding and partnership working
6. Preferred policy options for SuDS
7. Evidence requirements for informing decisions
8. Future challenges
9. Opportunities for aligning SuDS with wider objectives
10. Any related on ongoing work/projects we should be aware of

A list of organisations from which interviewed individuals were drawn, and the names and roles/titles of those individuals, is included in Appendix 3.

ii. Additional consultation

To supplement the formal interviews, we also contacted a number of other individuals and organisations known to be active in the area. These were drawn from consultancy, academia, English local authorities, international experts and those involved in related work or research (e.g. the 21st century drainage project). We specifically asked for any data or information they could provide around the costs and benefits of SuDS.

iii. Events

The final stakeholder engagement element of the project included attendance and presentation at a number of relevant meetings (e.g. Welsh Government SuDS Advisory Group) and events. Again, the main aims were to identify additional useful data and to identify or verify information.

2.4 Gather additional evidence

Whilst the review of evidence and stakeholder engagement tasks provided a wealth of rich and diverse data and information, this was not comprehensive in terms of meeting the project objectives. In addition, it became clear relatively early on in the project that, as well as the economics of SuDS, a greater focus on issues around adoption, maintenance and funding was required.

As a result, the project team sought to identify and incorporate evidence related to these areas. This evidence came from two main sources.

i. Existing published and unpublished data, information and literature related to adoption, maintenance and funding.[4]
ii. Further discussions with key stakeholders and experts actively engaged in and working on these areas.

2.5 Analysis

All the data and information collated from the review and engagement tasks were recorded in excel spreadsheets. The project team collectively analysed this information, supplemented by the additional evidence, to identify patterns, common issues and key points. Economic analysis focused on monetised capital and operational costs and benefits for those schemes where both a SuDS-based option and a more conventional solution had been identified and considered. The spatial and temporal distribution of costs and benefits was also considered, since impacts can fall on different groups, and vary over time.

Quantified estimates of costs and benefits were developed for schemes at different scales, specifically:

- Small developments (less than 10 units);
- Medium developments (between 10 and 100 units); and
- Large developments (greater than 100 units).

To supplement and help verify scheme-level cost information, we also examined component cost information. This drew on several sources (e.g. Royal Haskoning, 2012b; Environment Agency, 2015).

All costs and benefits were uplifted to 2015 prices using the Bank of England inflation calculator[5].

2.6 Caveats and assumptions

The main caveats and assumptions related to the analysis undertaken are as follows.

i. We have not reviewed the technical merit of the evidence (including case studies) presented. We therefore assume that the solutions and schemes reviewed are compliant with relevant standards.
ii. Information relating to quantified and monetised costs and benefits was not available or forthcoming in many cases. For costs, this is generally because either the information is bound up with broader landscape and development design and cost information, or because it is held by sub-contractors, commercially confidential or subject to stakeholder

[4] This builds on previous work in this area, for example the guidance related to the costs and benefits of SuDS collated and summarised on the susdrain web site, http://www.susdrain.org/delivering-suds/using-suds/the-costs-and-benefits-of-suds/guidance-on-cost-benefit-analysis.html
[5] http://www.bankofengland.co.uk/education/Pages/resources/inflationtools/calculator/index1.aspx

sensitivities.[6] For benefits, it is generally because these have not been formally considered or assessed.

iii. Whilst there is a wealth of information related to the cost of individual SuDS schemes (e.g. Transport for London, 2016; West Country Rivers, undated), in the majority of cases there is no direct or simple comparison with conventional approaches. This lack of a comparator makes the information redundant from the perspective of making an economic case for SuDS, and meant that this information could not be used directly to inform the project.

iv. The data and information we have been able to collate for this project is generally on a 'total scheme' basis. As such, the analysis undertaken is not based on the costs and benefits of individual SuDS components. Information on the costs of such components, and the factors that impact these costs (e.g. ground conditions) is available elsewhere (e.g. CIRIA, 2015; Environment Agency, 2015; Royal Haskoning 2012b).

v. In some cases, cost information has been extrapolated or estimated after construction, whilst in others information on costs and benefits is largely theoretical (i.e. the scheme has not been built). Whilst neither case invalidates the information collated, it does mean that biases could be introduced and that the findings are subject to a degree of uncertainty.

vi. Information on costs other than capital (capex) and operational (opex) costs (e.g. administration, design or planning costs) is, at least currently, rarely available separately. These costs may be significant (particularly to the consenting or adopting organisation), and provision to meet these costs would need to be considered if legislative or other changes are made. However, many of these costs are capitalised and, given the lack of clear evidence currently, we assume that the majority of these costs are subsumed within broader capital and operational cost categories.

vii. Costs and benefits will vary for a number of reasons, largely related to the specific design, characteristics, location and quality of the scheme. As such, the estimates provided here should not be used to guide the assessment of any specific scheme. They are designed to be used at a macro level to inform policy decisions.

The combined impact of the points above is that there is not as much robust and comparable data on costs and benefits as we would like. As such, the analysis undertaken and the results presented in Sections 3 and 4 should be treated with caution. Nevertheless, they are based on the best evidence currently available, and the patterns and consistency we have found across the different elements of the project suggest that the findings are likely to be reliable.

[6] This is consistent with the CIWEM 'Big SuDS Survey' (to be published early in 2017 in order to inform the UK Government's forthcoming review of SuDS), which suggests that the majority (>75%) of SuDS schemes do not record cost information.

3. Key findings

3.1 Key findings from review of evidence

Some clear messages emerged from the analysis of the 34 case studies listed in Appendix 1 and the top ten detailed in Appendix 2.

v. The capital costs of the SuDS solution were lower than the capital costs of the comparable conventional solution in every case. This differential was as high as 45 per cent and the size of the cost saving seems to relate primarily to the size of the scheme and the SuDS components used.

vi. Operational and maintenance (O&M) costs were also lower for SuDS. However, there are some important caveats to this.
   a. Maintenance (when required) is generally more complex (and therefore more expensive) for 'underground' SuDS. Invasive activities on underground pipes and gullies (e.g. de-silting) require a contractor, whilst tasks necessary to maintain surface SuDS (e.g. litter picking and grass cutting) can be included in the overall upkeep of the green space.
   b. Maintenance costs depend on the design, with 'passive' approaches, integrated with existing landscape maintenance, resulting in lower costs.
   c. SuDS maintenance costs are often overestimated at the project outset. This may be due to risk aversion inherent in delivering SuDS, the development and the application of commuted sums, or because adopting bodies (especially local authorities) face difficulties in attempting to 'ring fence' maintenance budgets for SuDS. This can undermine future benefits.

   Given the relative lack of information on O&M costs from the case studies, further evidence related to these is presented in Section 3.3 below.

vii. The inherent flexibility of SuDS can reduce the cost of unforeseen events. For example, the Hopwood MSA and Railfreight Terminal schemes have included valves and penstocks in the SuDS management train designs. This has saved on clean-up costs for unexpected contamination events. Additionally, if it is necessary to rehabilitate the area, SuDS on or near the surface require less invasive remediation techniques in comparison to below ground or conventional systems. One sewerage undertaker provided an example of a sewer flooding problem where the solution was to work in partnership with the highways authority to extend an existing detention basin/swale to provide the additional storage. This would not have been practical with a shaft tank.

viii. SuDS provide a wider range of benefits than conventional drainage. Valued benefits tend to focus on flood risk mitigation, increased property prices (e.g. Coventry) and cost savings associated with reduced stormwater disposal charges (e.g. Lamb Drove) or energy use (e.g. Greener Grangetown). However, in the majority of cases, benefits are not assessed or monitored following completion of the scheme.

ix. Partnership working at an early stage (involving ecologists, landscape architects and others), as well as clarity over long-term ownership, are important factors in achieving good design, maximising benefits (e.g. Roundhay Park) and providing potential funding opportunities.

A summary of the key points from the ten case studies considered in more detail is shown in Table 3.

Table 3:Overview of SuDS across the case studies evaluated

Case study	Location	Key summary points
1	Lamb Drove	Changes from initial proposals had resource implications suggesting it is necessary to include the confirmation from all the key stakeholders and organisations early in the process including the Master Planning stage and start of the Development Plan. The SuDS scheme effectively had to be retrofitted around the existing designs for the site layout. However, key benefits relate to installation of water butts and avoidance of stormwater charges £30/yr/household (2011). Capital costs £5,645 (2006), compared to £5,960 (2006) for conventional drainage. At £1,340/yr (2011) SuDS maintenance is cheaper than conventional drainage. Uncertainty around adoption also meant there were delays in the SuDS scheme (particularly the permeable paving) being maintained. However, this did not impact on performance.
2	Dunfermline Eastern Expansion	Total costs = £1,270,511 Total benefits = £1,935,397
3	Coventry, Retrofitting Green Streets	Total costs = £121,000, Total benefits = £1.5 billion (over 40 yrs). Retrofit and based on large (optimistic) assumptions, so of limited use, but does highlight potential scope and scale of benefits.
4	Stebonheath Primary School	All of the works were within the boundary of the school on the private drainage system, under private agreement with the local authority. This is a new way of working for DCWW as water and sewerage companies usually rely on using statutory powers to undertake works. Following the completion of the defects period, the system has been handed back to the local authority for long term operation and maintenance from 2015.
5	Glasgow City Centre (retrofit)	The estimated benefits of the option are always greater than the costs. The central estimate after confidence is applied gives a benefit cost ratio if 2.3. This is 1.3 under low sensitivity and 3.7 under high sensitivity.
6	Hopwood Motorway Service Area	Estimated capital costs of the SuDS were £56,000. Maintenance costs were cheaper than anticipated and activities have been reviewed since. However, long-term business plans need to be considered before the construction of SuDS to ensure an annual budget is set-aside specifically for maintenance. The annual budget has now reduced to £350 and the scheme, although now less pristine than originally, is still functioning as planned.
7	Red Hill Primary School (retrofit)	SuDS can be used for educational means – bringing water to the surface for use in safe, fun and instructive ways. SuDS are cheaper than traditional drainage, despite the different requirements for runoff rates.
8	Railfreight Terminal	SuDS were considered to save capital costs and the decision has been vindicated with a saving of £321,171 in comparison to conventional drainage. The significant cost reduction enabled more investment to be placed in features that directly contribute to the functioning of the facility.
9	Figtree Place (Australia)	If policies are adopted to encourage Water Sensitive Urban Design (WSUD) and many such projects are completed, then substantial urban infrastructure cost savings to the community are likely to materialise. SuDS used for water harvesting and use could be advantageous, saving on costs per property.
10	Puget Sound (USA) (retrofit)	Total capital costs of construction = $120,000 - $20 million per year, depending on the extent of spending on storm-water-related damage and storm-water-management programs across the Puget Sound region. Total capital spend in Phase 1 was $138 million (an average of $36/capita/year) to meet the 1995 NPDES permit requirements. Implementing best management practices (BMPs) in the planning stages of development projects found to be the most effective means of mitigating and avoiding storm-water consequences.

3.2 Key findings from engagement with stakeholders

The main points from the stakeholder engagement part of the project are highlighted in Table 4. This is organised around the ten areas covered in the interviews and described in Section 2.3.

Table 4:Key findings from stakeholder engagement

Area	Key summary points
What is happening now?	• SuDS widely used but variable in quality – whilst most, if not all, parties are in favour of SuDS, the planning process, building control issues and a general lack of oversight and competence mean that components used are limited (e.g. permeable paving), SuDS are not built as designed and that sub-standard SuDS (e.g. pipe to below ground attenuation facility) turn out to be the norm. • A key problem is that, largely due to site layout pressures and complexities, drainage details are often considered at end of planning process, when there are limited opportunities and space for good quality, surface (or near surface) SuDS. • The lack of a statutory requirement and uncertainty over adoption means developers are generally reluctant to install SuDS, citing issues such as cost, space, maintenance, health and safety. • Differing design standards and a proliferation of supplementary guidance from a number of local authorities in Wales leads to confusion, with systems designed for different purposes (e.g. some components designed to meet a 1 in 30 year storm event, whilst others designed to meet a 1 in 100 year storm), and dual systems being installed as a result. • Land use planning is critical, and many new developments are not in the best place from a flooding/drainage perspective. • A range of adoption and funding arrangements have been used (but are absent or unclear in many cases).
Success factors for SuDS on new developments	• Has to perform as designed (well-designed and managed). • Clarity and certainty (ownership, responsibilities, adoption). • Consider drainage and land use at outset/design stage. • Embed in local development planning and engage early across local authority departments. • Link with broader policy objectives (well-being, biodiversity, transport, etc.). • Involve communities and external stakeholders. • Strong leadership or 'champions'. • Use of innovative designers, engineers and other consultants • Education and information (planning committees, developers, residents, etc.). • Availability of expertise, resource and ongoing funding. • Robust economic case.

Costs of SuDS	• Limited evidence – costs often sensitive, confidential or bundled together (into broader development capital costs, or into general landscaping)
	  ◦ Suggestion that developers may inflate estimated cost of SuDS to maximise contribution from housing associations.
	• Landscaped SuDS generally cheaper than conventional systems (lots of examples)
	  ◦ Location and context specific (smaller sites (<50 units) often not cost-effective)
	  ◦ Need to consider other costs (e.g. consultation, spoil removal)
	  ◦ Large range for maintenance costs – often over-estimated using guidance to calculate commuted sums, but sometimes under-estimated
	  ◦ O&M costs are dependent on behaviour of occupiers/users of drainage system, and effective engagement can help reduce these costs
	  ◦ Costs increase the later they are considered in planning and design
	  ◦ There remains a perception that SuDS are more expensive, especially from 'whole-life' (including maintenance) perspective.
	  ◦ SuDS are particularly attractive from a cost perspective where they negate the need for off-site capacity upgrades, by reducing discharge flows/volumes.

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In some cases (e.g. self-cleansing oversized sewer storage or box culverts), O&M costs of conventional solutions may be negligible/lower than SuDS, and/or may have other advantages (e.g. less/no land take). Conventional solutions are likely to be favoured in these circumstances.
Harder (predominantly underground) SuDS are often more expensive.
New development SuDS are almost always cheaper than retrofit, where flows may be combined and need to be separated (but this is case dependent and is particularly so in urban areas).
If adoption and responsibility for maintenance issues are resolved, more SuDS will be built and costs will come down.

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<tr><td>Benefits of SuDS</td><td>

Information sparse (not collected/needed)
Benefits from SuDS are varied and accrue to different stakeholders
Main benefits are flood risk reduction and avoided pumping costs
Wider benefits (amenity, education, health, etc.) important in some cases
Larger schemes lead to proportionately greater benefits.
<u>Who</u> benefits is key question.

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<tr><td>Funding</td><td>

Funding depends on cost element it relates to (explored further in Section 4.4), standards used and adoption route
Local authority (commuted sums or sinking funds)
Difficult to estimate
Generally not possible to ring-fence, so sums ‘disappear’ into general funds
Varying approaches and time periods
Question over long-term sustainability
Private management companies
Use is now widespread
Risk of orphan SuDS (lack of competence and companies often fold)
Sewerage undertaker - wastewater charges spread across customer base
Future options generally encompass taxation (general/local), wastewater charges. Some more innovative approaches are being trialled or considered, including
Maintenance charges
Tenure bonds
Fees (e.g. application, maintenance)
Surface water rebate/reduced infrastructure charges
Collaborative funding (e.g. Highways, Landfill Communities Fund, health agencies)
Key is <u>reliable</u> future income stream over life of the maintenance activities

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<tr><td>Preferred way forward</td><td>

Strong preference for mandatory approach, including mandatory adoption of assets which connect to the public sewer network
Would provide clarity and consistency
Current planning approach not satisfactory (leads to inconsistency, use of harder, underground SuDS, etc.)
Must be linked to removing right to connect to the sewer (via S106 of Water Industry Act)
Would need to clarify role and spatial scale of SAB
Range of potential routes for adoption
Local authority, sewerage undertaker, drainage authority, highways, private company, SAB, NRW, etc.
Must be consistent & accompanied by resources, funding & clarity on responsibility, particularly if SAB services are to be provided by local authorities
Amendments to planning regime, e.g. to require planning authority to consider SuDs within proposed development and at preliminary approvals stage
Preference for one-stop-shop, but is this possible within current arrangements, given that many of the key actors operate at different administrative and geographical levels?
Need to retain flexibility – not all local authorities/sewerage undertakers/developers are the same with different definitions, standards and policies being utilised

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Evidence gaps/needs	• Monitoring of actual performance against expectations (e.g. flows, volumes, quality) • Guidance in some areas, e.g. technical standards, standing water in open spaces, examples of good SuDS designs • SuDS Register – how many, where, quality, etc. • Long-term maintenance/whole-life costs (including risk/consequence of failure) • Benefits of SuDS, including water quality and wider benefits • Links between, and guidance on, SuDS and green infrastructure • Rural SuDS and links to land use/catchments • Leisure, business, commercial developments (including application, consenting, adopting process)
Key challenges	• Lack of clear, strong (ideally statutory) driver and process for adoption • Different approaches across lead local flood authorities at present, and between England and Wales • Lack of capacity/resources/expertise in designing SuDS for multiple benefits • SuDS perceived as a liability, e.g. by some local authorities, with ongoing maintenance required (although others see them as potential assets and a source of income) • SuDS can cost more, especially if considered late or focused on hard (predominantly underground) SuDS • Wider benefits undervalued or not valued • Inadequate enforcement • Developer reticence to use SuDS and view that SuDS could inhibit housing growth • Legal position (surface water discharges to water bodies, right to connect, 3rd party land, leasehold props, etc.) • Town and Country Planning process • Highway adoption • SuDS on land designated as public open space • SuDS as fulfilling green space requirements in developments
Opportunities	• Wellbeing of Future Generations (Wales) Act provides very useful driver/hook for SuDS • Clarity & consistency from a common approach could drive large benefits • Building a ring-fenced pot for SuDS maintenance could support future benefits • SuDS can provide a range of benefits if viewed as community assets • SuDS can provide an income stream to adopters, e.g. using fees for inspection • Catchment approach/SuDS masterplans could drive multiple benefits at larger scale • SuDS both require and provide potential for better engagement across local authorities, including planners, highways, etc • Cost effective solution to delivery as part of fulfilment of the need for more housing in Wales • Align requirements for SuDs with Local Development/ Regional Development plan, and Flood Risk Management Strategy/Plan • Greater role for upland catchment management in contributing to reduced flood risk (SuDS are not only for urban areas)

In summary, a number of key points emerge.

i. There is a lack of clarity, certainty and consistency around the use of SuDS on new developments.
ii. SuDS are considered late in the development process, resulting in sub-standard or sub-optimal solutions.
iii. Different SuDS in different places have different costs and benefits.
iv. The economics (costs and benefits) of SuDS are important, but perhaps less so than other, closely related, factors, particularly clarity around adoption and ongoing responsibility.
v. There is general support for a mandatory approach, but a desire to retain flexibility.
vi. SuDS should be considered as an integral part of broader drainage and land and water management – particularly catchment management.

3.3 Key findings from additional evidence

The additional evidence we have examined supports many of the points already identified. For example, a major recent survey found that 88% of respondents in Wales believe that uncertainty around maintenance and performance of SuDS components is presenting barriers to schemes being adopted (Engineering Nature's Way, 2016). In the same survey, 41% of respondents in Wales said there should be increased regulation to manage the impact of surface water runoff on the water environment through SuDS, compared with only 12% who disagreed with this statement.

In addition, the definition of long-term responsibilities and O&M needs for SuDS are less straightforward and less well understood than for piped infrastructure (which may impact on costs). This is partly due to the many layers of planning, regulation and responsibilities around the use of SuDS (Ellis & Lundy, 2016). Also a lack of experience in the UK around how SuDS function over the long-term, and because SuDS performance may vary seasonally, especially landscaped SuDS that incorporate green or blue infrastructure. Landscaped SuDS require plant management to varying degrees depending on the SuDS measure. Also, if the multiple benefits that SuDS can bring are to be activated and sustained, there may be other requirements, such as maintaining safe access, ensuring plants grow or maintaining the aesthetic value (Berwick, 2017). In order to achieve the best outcomes from SuDS, these requirements need to be considered and planned in at the design stage.

These issues are considered in more detail in Section 5. In effect, evidence related to SuDS ownership, adoption, maintenance and operational performance is mixed and success depends on a number of factors.

- Effective design, which needs to have constructability and longer-term operation included in the design and planning perspective
- Proper and competent construction
- Ensuring health and safety is managed effectively
- Arrangements for commissioning and performance verification (maintenance period)
- Inspection and reporting requirements
- Institutional arrangements and responsibilities/duties
- Land ownership, rights and responsibilities
- Riparian and building management responsibilities
- Competence to operate and maintain in the short and longer term; which includes remediation, adaptation and replacement requirements (e.g. remedial maintenance)
- Behaviour of householders/users of drainage infrastructure, and degree of ongoing engagement with these groups

Even small variations in design can lead to substantial effects on performance regarding the control of downstream flow volumes and peaks. This is why the City of Baltimore in the USA insists on in-house SuDS design, but paid for by developers (DTI, 2006). Good design, effective construction and performance checks are all essential elements in ensuring that operation will be as good as assumed and maintenance will be minimised and effective. Whilst full scale tests on the performance of as-built SuDS are rare, recently there have been long term investigations carried out by Foogaard (2015) in the Netherlands. In the UK, a number of studies were undertaken in the 1990-2000s by HR

Wallingford and Abertay University in Scotland (Charlesworth & Booth, 2017; Woods-Ballard et al, 2015), but there have been few studies subsequently.[7]

Common problems with maintenance are outlined in Li (2015) and Blecken et al (2015). Worldwide, SuDS maintenance is not as assiduous as it should be, although this is the same for sewered assets (where the impacts of inadequate maintenance are largely hidden unless and until there is surface water flooding and/or pollution as a result). The main difference with badly maintained SuDS is that this is readily apparent due to surface water ponding/flooding, watercourse pollution and unsightly green or blue spaces. This is both an advantage, as it should prompt maintenance and reveal wrongly connected foul sewers (Ellis & Butler, 2015), and a disadvantage, as it may be cited as a reason not to use SuDS. In some instances, maintenance has been counter-productive, e.g. overzealous and incorrect use of fertilizers at BedZed in London or removal of vegetation (Shirley-Smith & Butler, 2008).

Many SuDS are resilient to poor maintenance. Al-Rubaeia et al (2016) showed that the hydraulic and water quality performance for a lake/wetland system in Sweden, especially the high pollutant removal rates (>90% of heavy metals) from runoff, were maintained even after almost 20 years of operation with little maintenance (limited to dredging of sediment from the first part of the pond four times). Others, like rain gardens, require virtually no maintenance other than annual weeding (Vineyard et al, 2015). One of the UK SuDS flagship and most researched sites, the motorway services at Hopwood, now has reportedly[8] only £350 p.a. spent on maintenance despite comprising a succession of SuDS measures. The site is privately maintained and evidence of failure as a consequence is awaited before any additional funding is allocated. In essence, good design from the outset is a key factor in minimising O&M costs later.

One of the benefits of SuDS is that they can be designed to benefit a wide range of flora and fauna and help meet the Environment Act Section 6 duties to maintain and enhance biodiversity. A small number of these species, such as water voles, are afforded special protection and future maintenance protocols would have to take these needs into account. Thus there are 'balancing' needs, with SuDS benefitting biodiversity, some species may require careful effective maintenance operations (O'Brien, 2015) and special arrangements for protection where changes are envisaged to the SuDS[9].

Responsibilities for maintenance for SuDS are a major issue in many locations with similar conditions to Wales. This includes Germany (Dierkes et al, 2015), Oregon (Thorne et al, 2015), England (Ellis & Lundy, 2016), Scotland (Duffy et al, 2013) and Sweden (Cettner et al, 2014). There are also ambiguities about drainage responsibilities, especially in the UK (Lucas et al, 2015).

Where on-site system responsibility and maintenance duties are assumed, it is important to understand and support these. As this is a relatively new concept for UK householders,[10] it may need to be reinforced regularly until the practice becomes 'normal'. Motivation for householders to adopt and maintain their own surface water systems is poorly understood and still unclear in the UK. A US study found that economic rather than environmental motives were more important where householders maintained their rainwater systems, although over a quarter of households ceased to maintain their systems after only five years (Gaoa et al, 2016). In some parts of the USA, the

[7] Partly because SuDS are not subject to Building Control checks in the same way as a conventional system prior to handover.

[8] Pers. comm. Kevin Barton, Robert Bray Associates.

[9] http://norfolkwildlifeservices.co.uk/great-crested-newt-mitigation/

[10] It is only in the last 100 or so years that property drainage has become the province of service providers and even now, many of the responsibilities for the curtilage are on the property owner, often unbeknown to them.

disconnection, or lack of connection, of property surface water drainage into main drainage systems is a reason to be proud, and households install signs in their garden to display this (DTI, 2006). In Germany, many property owners install green roofs retrospectively, motivated mainly by environmental reasons (e.g. Dierkes et al, 2015).

On a larger or community scale, the maintenance of SuDS in public areas like parks by local authorities can create opportunities for sustained benefits like public education and health, providing sufficient funding is made available (Jennings et al, 2016). This is easier now that the Department for Communities and Local Government (DCLG) has agreed that the Community Infrastructure Levy (CIL) can be used for green space maintenance, and not just for new infrastructure. Urban roads and highways provide particular potential for this and in some places (e.g. Oxfordshire) SuDS are actively promoted for developments and highway drainage together, with the highway authority adopting O&M responsibilities[11]. This requires senior buy-in to ensure all surface water is managed under a single authority (Patmore, 2014). Bridget Joyce Square in London is a retrofit example where SuDS benefit public space and a school, and maintenance is shared between the school's landscape maintenance team and the local authority's highways team[12].

There are also opportunities for community-owned and hence managed SuDS, via for example, a Trust. The 800 property Lightmoor Urban Village has the Bournville Village Trust who own and operate the extensive range of surface and proprietary SuDS, with Severn Trent Water adopting the linking pipework (Stephenson, 2008).

Worldwide, there are many variations on O&M arrangements, which depend on institutional arrangements and jurisdictions. For example, the City of Baltimore in the USA takes responsibility for the design and adoption of SuDS, using a 3-year bond arrangement from the developer to ensure effectiveness of construction and commissioning. However, the surrounding State (Maryland) has a different arrangement, whereby a broader range of management approaches are allowed.

In Scotland, a seemingly straightforward system is actually complex for developers. Under some circumstances, Scottish Water adopts certain SuDS components (known as vesting) (Scottish Water, 2014; 2015)[13]. In others, local authorities may adopt (particularly source control components), with management undertaken by private organisations. The result is that very few SuDS have actually been adopted. There are also issues with poor regulatory control for the quality of SuDS construction and the subsequent standard of maintenance. Proper and effective regulatory control is essential to ensure effective SuDS (Ashley et al, 2015).

The non-statutory SuDS standards for Wales (Welsh Government, 2016) provide a comprehensive platform on which to build the use of SuDS. Standard S6 sets out the O&M requirements and requires a maintenance plan from the outset, based on the guidance in the SuDS manual (Woods-Ballard et al, 2015). The Welsh standard specifies that maintenance as well as good design be required to be as sustainable as possible. In Scotland, maintenance access is required for all SuDS assets. This can result in a loss of aesthetic value and amenity, an example of which is shown in as Figure 3. The very wide margin is for health and safety reasons to allow for maintenance vehicles to enter the site for desludging, which is likely to occur infrequently.

[11] https://www.oxfordshire.gov.uk/cms/content/sustainable-drainage-systems-suds
[12] http://www.susdrain.org/case-studies/case_studies/bridget_joyce_square_london.html
[13] http://www.engineeringnaturesway.co.uk/news/scottish-suds-success-is-clouded-by-adoption-and-maintenance-inertia-survey-reveals/

Figure 3: SuDS pond in Dundee, Scotland (photo: Richard Ashley)

Inspection, ensuring effective functioning over the longer term of SuDS is an important and often neglected component of ensuring longevity of SuDS functionality. This is not unique to SuDS, but any failures of SuDS are generally more visible (and newsworthy) than failures in piped drainage systems. Effective and vigilant enforcement of regulation by inspection and monitoring is vital as found from experience in Scotland where 'good' SuDS are failing due to poor construction and/or poor O&M.

Understanding what funding is needed for O&M, including remedial works, adaptation and capital renewal or removal of SuDS in the UK has not been well defined. There are a number of reports and papers setting out the costs and activities based on case examples, and various guidance documents providing indicative costs (e.g. Cambridge City Council, 2009). Both HR Wallingford[14] and UKSuDS[15] have developed online tools for estimating all aspects of SuDS costs, but these require site-specific inputs. There are also tools such as that developed in Scotland for looking at the life cycle aspects of SuDS, such as the consideration of carbon in estimating the whole life costs (SUDS working party, 2009).

Using local authority cost information, Kellagher et al (2013) finds that annual O&M costs are, on average, approximately 0.5% of capital costs on average. They are typically dominated by de-silting costs (which also occur with traditional drainage systems), but can vary greatly depending on extent and maintenance of vegetative systems, and other factors.

Another important factor when considering future commitments is the notional design life of the SuDS. This is shown in Table 5. Although traditional drainage assets are designed for a 30 to 50 year life, in reality main drainage systems have been functioning for 100s of years with limited maintenance in some cases. Evidence from Ofwat and elsewhere shows that the replacement turnover of some sewers is of the order of 500-1,000 years on current rates of activity, with

[14] http://www.uksuds.com/costintro.aspx
[15] http://www.uksuds.com/

consequent failures occurring. SuDS, being mainly surface based will provoke more frequent maintenance and renewal due to their visibility.

Table 5:Notional design life of various SuDS

Measure	Design life	Component life
Green roofs	Unlimited	N/A
Simple rainwater harvesting (water butts)	Unlimited	No reliable information
Advanced rainwater harvesting	Unlimited	No reliable information.
Permeable paving	Unlimited	20-25 years before replacement of filter material, if required at all
Filter drain/perforated pipes	Unlimited	10 – 15 years before replacement of filter material
Swales	Unlimited	5 – 20 years before deep tilling required and replacement of infiltration surface (infiltration swales only, not needed for conveyance)
Infiltration basin	Unlimited	5 – 10 years before deep tilling required and replacement of infiltration surface
Soakaways	No available information	
Infiltration trench	Unlimited	10 – 15 years before replacement of filter material
Filter strip	Unlimited	20 – 50 years before replacement of the filter surface
Constructed wetland	20 – 50 years	Sediment disposal after 10-15 years
Retention (wet) pond	20 – 50 years	
Detention basin	20 – 50 years	Sediment disposal after 10-15 years
Source: Environment Agency (2015)		

There is more evidence related to the operation of 'hard' SuDS, known as proprietary systems. These are measures with clearly defined volumes, footprints and operational regimes. Whereas surface SuDS are typically designed to fit the landscape and usually operate without the sophisticated controls used by proprietary systems, although many do use flow control hydrobrakes. An example is provided below.

Proprietary SuDS treatment systems (e.g. sediment traps) need to be emptied regularly. From many years operating experience in the USA, the frequency of this is set at:[16]

$$\text{Maintenance interval} = \frac{\text{Pollutant Storage Capacity } (m^3)}{(\text{Annual pollution load } (m^3/yr) \times \text{removal efficiency } (\%))}$$

As an example of O&M costs, Box 1 shows the costs for maintaining an advanced vortex separator.

[16]Courtesy of Mark Goodger, Hydro International

Box 1: Indicative maintenance costs for an Advanced Vortex Separator *(Courtesy of Mark Goodger, Hydro International)*

1. Inspection and monitoring - £63.47 annually
2. Vacuum emptying – once per 4 years; gives a whole life maintenance cost of some £13,000 - £19,500 for a 50 year life, or £260-£390 per year.

In summary, there is as yet no definitive guidance on O&M costs for UK applications. Based on the evidence available, our best assessment of the costs of SuDS, as compared to conventional solutions, is included in Section 4.

4. Results and discussion

4.1 Analysis of costs

Using the data gathered from the review of evidence and stakeholder engagement, Figure 4 (capital) and Figure 5 (operational) show costs for the three scales of developments identified in Section 2.5. As well as the mean cost at each scale, standard errors based on values obtained from the scheme information are shown.[17]

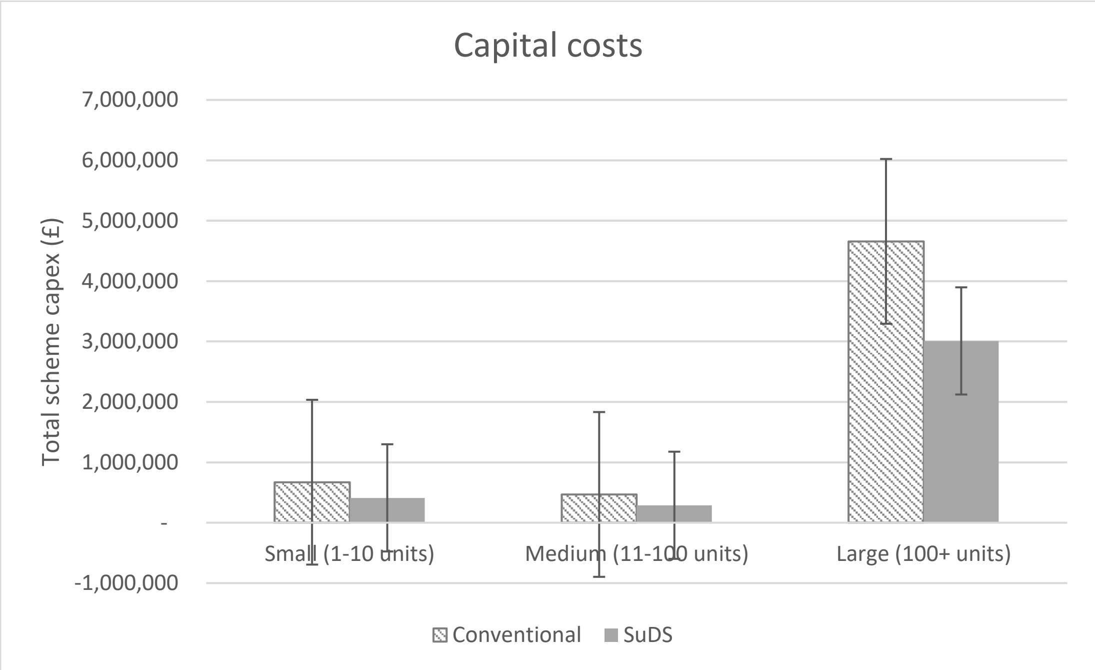


Figure 4: Capital costs of conventional and SuDS schemes

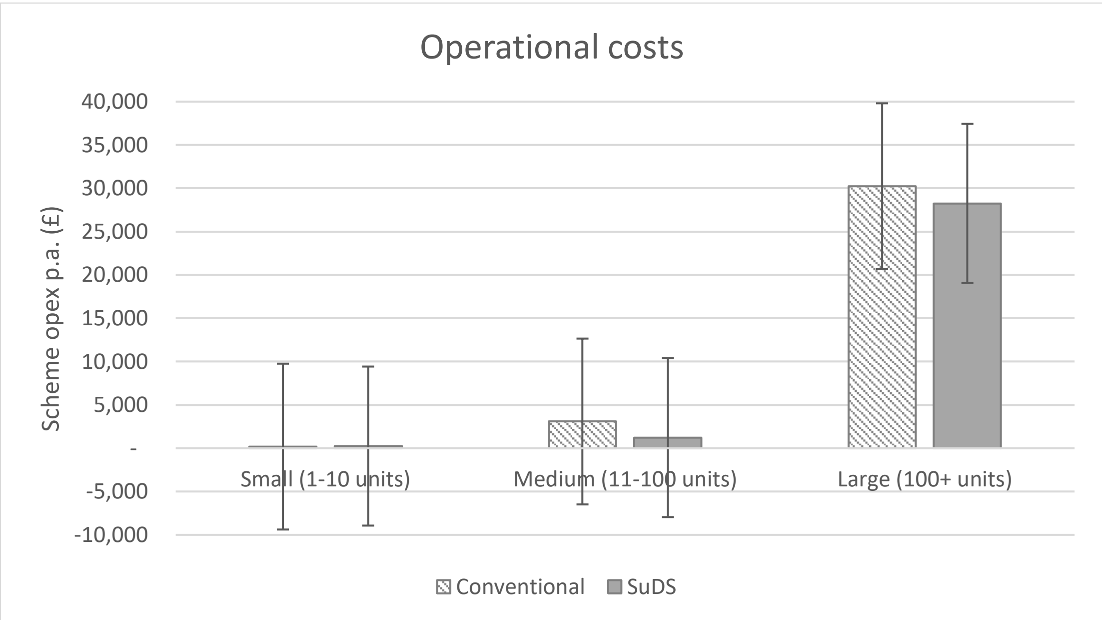


Figure 5: Annual operational costs of conventional and SuDS schemes

[17] In each case, n=5 (small), n=13 (medium), n=12 (large)

The analysis above has been supplemented by consideration of component cost information from our review of additional evidence.

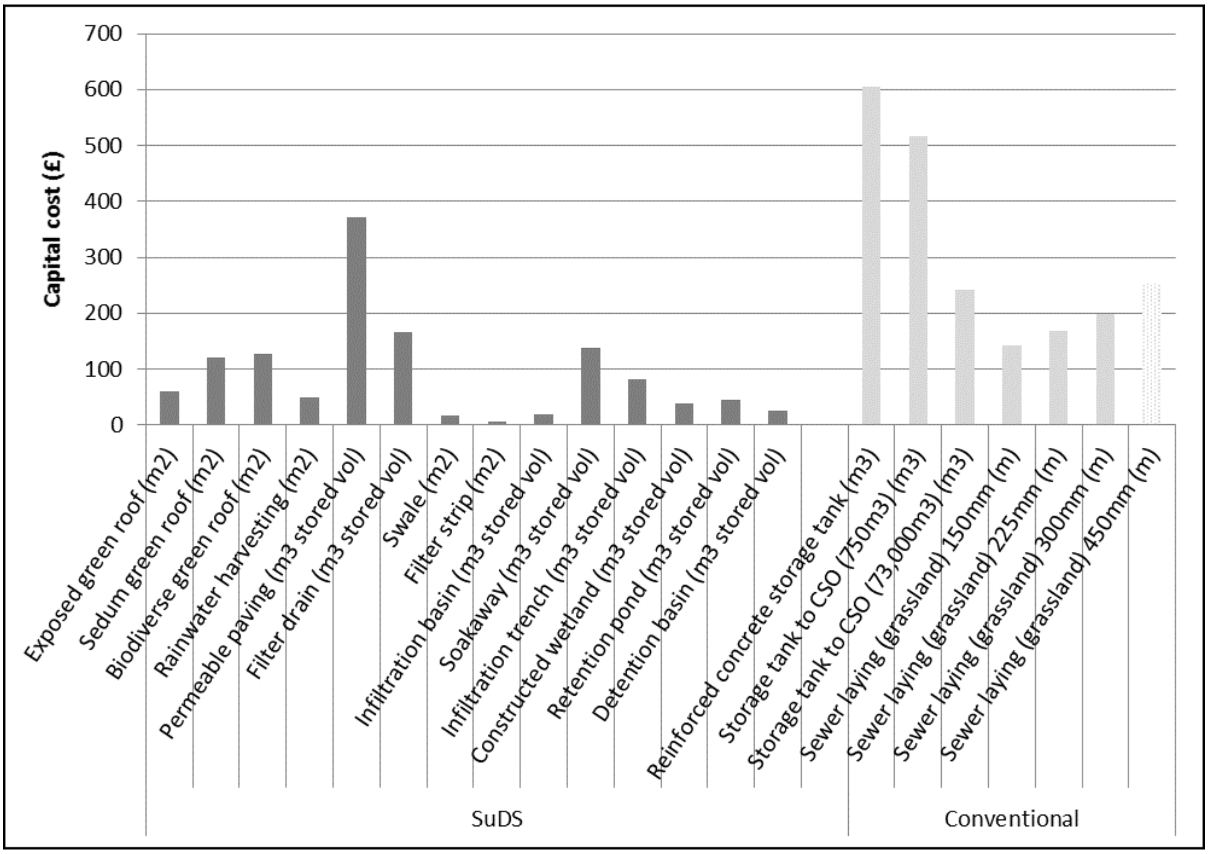


Figure 6: Component capital cost information (SuDS and conventional)

Whilst O&M cost information for the type of conventional measures shown in Figure 6 is not readily available, we have been able to identify such costs for SuDS measures. These are shown in Figure 7.

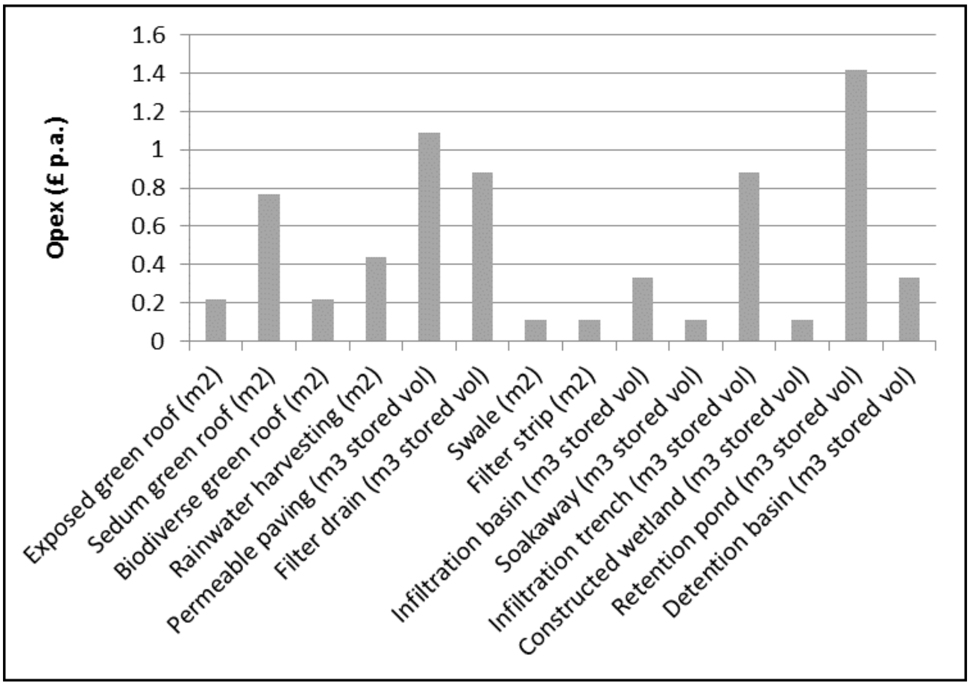


Figure 7: Component O&M cost information

Capital and operational costs can also be estimated per household. These are shown in Figures 8 and 9 (mean estimates only in each category).

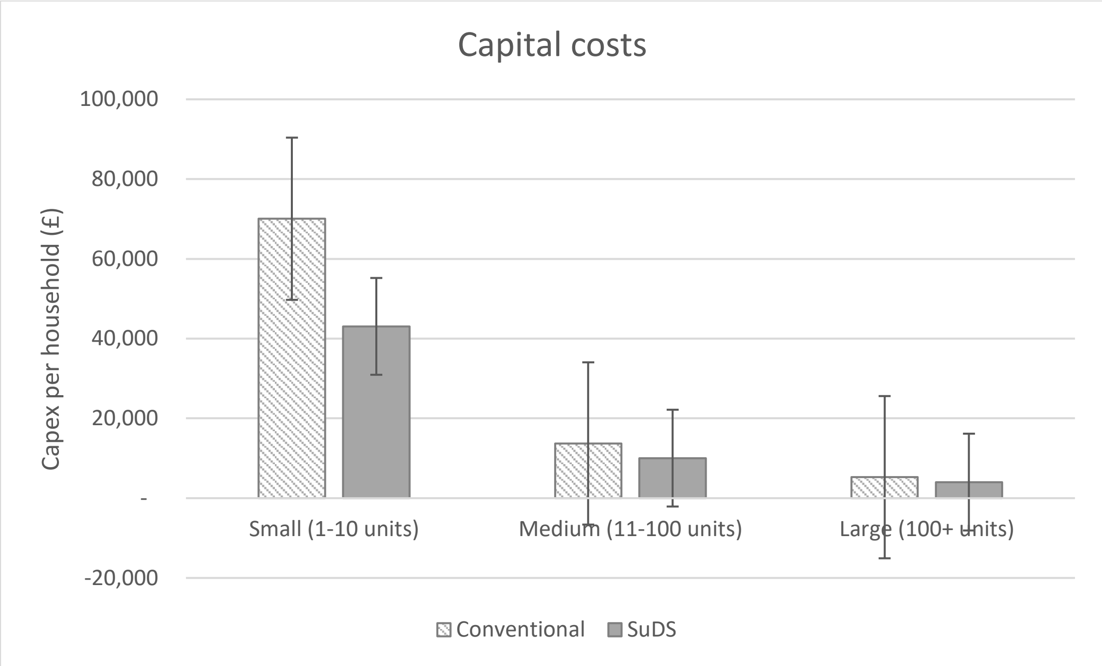


Figure 8: Capital costs of conventional and SuDS schemes per household

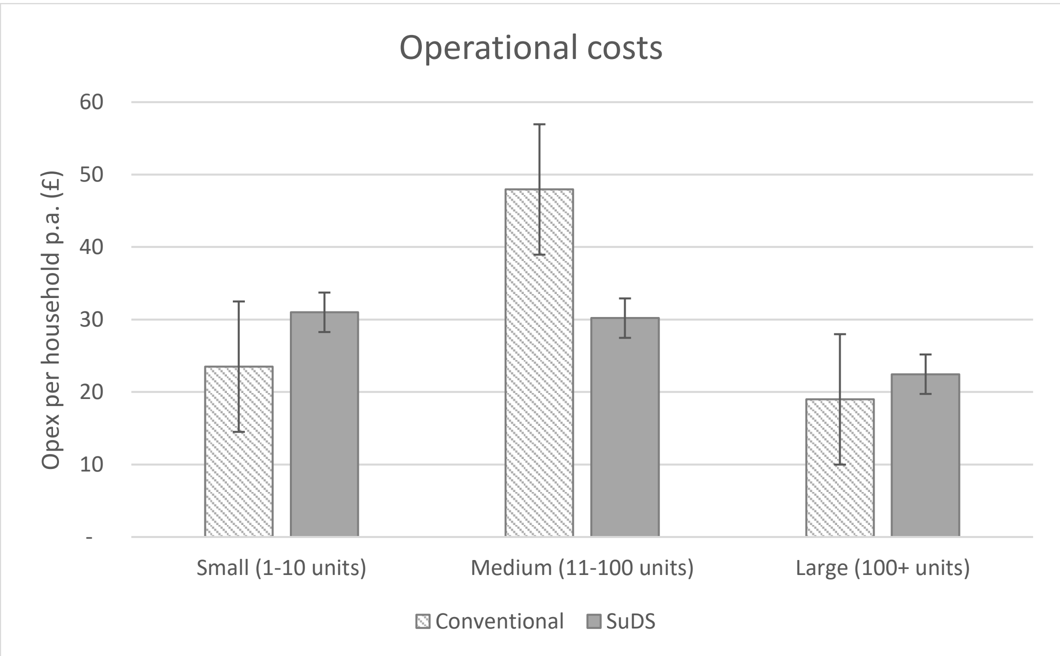


Figure 9: Annual operational costs of conventional and SuDS schemes per household

4.2 Analysis of benefits

Figure 10 shows benefits for the three scales of developments.[18] As well as the mean benefits at each scale, standard errors based on values obtained from the scheme information are shown.

[18] Although small developments are not shown, no monetised benefits were identified for any schemes in this category. There were no conventional schemes on medium developments with monetised benefits.

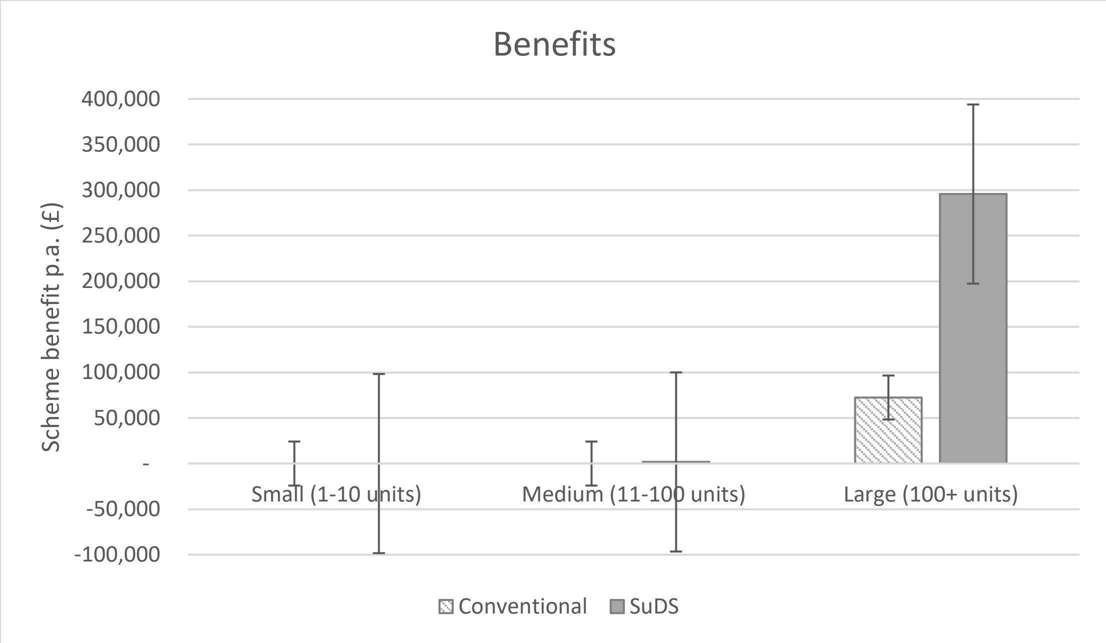


Figure 10: Annual benefits of conventional and SuDS schemes

Benefits per household are shown in Figure 11.

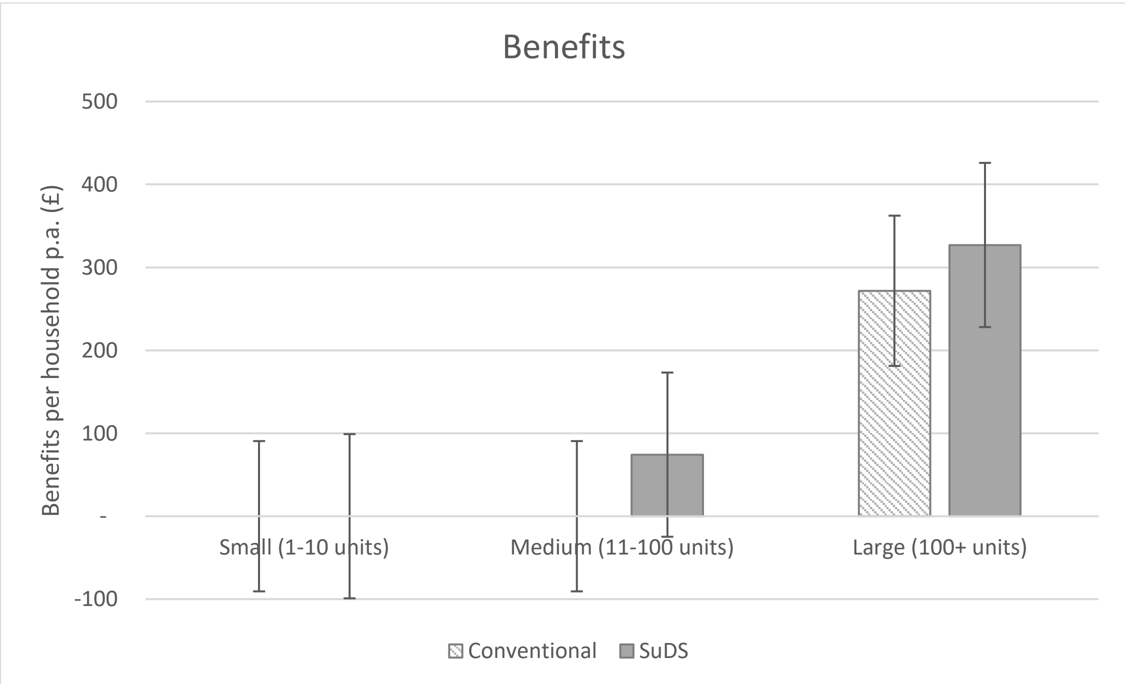


Figure 12: Annual benefits of conventional and SuDS schemes per household

Again, the information above has been supplemented by our review of additional evidence. Table 6 sets out some of the main evidence, along with the process by which benefits can be realised, according to the types of benefit identified previously in Figure 1. Many of these benefits relate directly to Wales' well-being and future generations goals. Whilst evidence is still sparse in some areas, it has improved significantly in recent years and continues to improve.

Table 6:Evidence on the benefits of SuDS

Benefit	Process	Evidence
Improve water quality and protect drinking water resources	SuDS can trap or remove pollutants, including suspended solids, metals, phosphorous and nitrates. By limiting pollution caused by discharges and spills, SuDS can reduce contamination of groundwater sources used to provide drinking water and can also provide groundwater recharge. SuDS can also reduce sediment load. Most pollution in runoff is attached to sediment particles and therefore removal of sediment results in a significant reduction in pollutant loads. Sedimentation is achieved by reducing flow velocities to a level at which the sediment particles fall out of suspension. Nutrients and metals can be removed via uptake by plants. Plants also create suitable conditions for deposition of metals, for example as sulphides in the root zone.	SuDS can reduce/remove up to 90% of pollution (West Country Rivers, undated). At Lamb Drove, there were lower concentrations of hydrocarbons, heavy metals, chemical oxygen demand, organic carbon and total suspended solids in the water compared to the nearby control site with conventional drainage. In addition, total suspended solids were found to decline through the SuDS treatment train.
Limit flows entering system and therefore maximise network capacity	SuDS can reduce runoff, improving the capacity of the conventional drainage network to deal with storm flows. This can create headroom in the drainage system, thereby helping to facilitate new development and growth.	Total outflow volume from the SuDS at West Grange, Dundee was 50% lower than from nearby tarmac. The runoff volume from the swale was on average only 6.3% of the rainfall volume. Lamb Drove showed peak discharge to be lower and flows to be attenuated compared to a nearby control site with conventional drainage. A study of three SuDS in Scotland found peak flows to be at least 50% lower than conventional drainage.
Improve health and wellbeing	Green space is linked to lower levels of human health impacts due to depression. Green roofs have a positive impact on residents' health and wellbeing in high-density areas (Yuen & Hien, 2005).	90% of residents surveyed at Lamb Drove found the aesthetics of their open space to be good or satisfactory. Depression rates are 30% lower in areas with high green space levels. The Roundhay Park retrofit SuDS in Yorkshire showed that by providing an additional 1,000 trees and 500 associated 'green space views' for dwellers the added health benefits

		would be some £3.5m.
Help manage air quality	SuDS can absorb or remove pollutants, including nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulates (PM10) and ozone (O_3).	A square metre of sedum green roof can remove 200g of particulate matter pollution per year. Each street tree and yard tree will remove approximately 92 grams of PM10 per year. (Portland)
Increase property value	People will pay more for properties in or adjacent to well-designed open spaces and local parks, which can also function as SuDS.	Well-designed open spaces and local parks (including SuDS) lead to a property price premium of around 0.5-10% (Horton et al, 2015), although the premium can be as high as 50% (RICS, 2016). Across 6,000 new builds in Wales (with an average price of £146,388[1]), this could create an annual benefit of between £4.4m and £87.8m[19].
Enhance biodiversity	SuDS can function as green corridors and provide habitat for different species. Through reducing runoff, SuDS can help increase oxygen content available to aquatic life and reduce swings in temperature.	At Lamb Drove the number of plant species increased by 4 species in the four years monitoring after SuDS installation, whereas at the control site the number of plant species decreased by 13 species. Green roofs in London have provided habitat for nesting redstarts. In Dunfermline, swans and tufted ducks have been known to breed on the SuDS ponds. Vegetation within the Upton SUDS (Northampton) has been observed as having an important ecological role in providing shelter, perches, and food, nesting and breeding sites for a wide variety of fauna. A significant number of bird species observed at Upton are associated with wetlands and river floodplain habitats. Many of these bird species are of conservation concern and have been classified as red or amber status: for example Reed Bunting (UKBAP and Red Status species) have been frequently observed in a block of *Typha latifolia* (Reedmace) in one of the larger retention ponds and may be breeding there.
Provide education	SuDS provide space for learning about wetland wildlife and the water	There are now many good case examples of 'SuDS for schools', both

[1] Average house price in Wales (Sept 2016) http://landregistry.data.gov.uk/app/ukhpi

19 However, attribution as to who accrues this increase in value is complicated – the householder, developer, and/or local area, due to a general increase in values and possible 'gentrification' (e.g. Zhou et al, 2013).

	cycle. SuDS can be built into schools, youth centres etc. children can be encouraged to get involved with managing the SuDS learning not only how the SuDS work, but about co-operation and natural processes.	newly built and retrofitted. For example, the WWT Wetland Centre at Llanelli includes a SuDS "laboratory" and hosted 5,000 school children and 1,000 adult learners in 2015-16. Business in the Community (BiTC) recently considered the benefits of SuDS to schools in Greater Manchester (BiTC, 2016).
Improve thermal comfort	SuDS can save energy for heating and cooling by shading buildings, lowering summertime temperatures, providing insulation in winter and reducing wind speeds.	New York City street trees provide annual energy saving benefit of over $85 million.[20] A green roof could save £5.20/m^2 in cooling costs per year. Chicago – Data from the City Hall's green roof indicates a stormwater runoff reduction of 50%, a significant reduction in energy use and saves the City approximately $5,500 annually on heating and cooling expenses.
Provide amenity and recreation	SuDS provide space for relaxation and exercise.	The Linburn detention basin in Dunfermline, Scotland is used by residents to play football.

4.3 Discussion

There are a number of gaps in the data supporting the analysis above. In particular, information related to small developments is very limited. Even for medium developments, information relating to operational costs and benefits is scarce. There is much more data available for large developments, and for capital costs generally.

In addition, as already highlighted in Section 2.6, care is needed in interpreting the component cost information, since the costs of SuDS components will vary due to a number of factors, and will be different for each site. Nevertheless, the general picture, shown in Figure 6, is consistent with the previous analysis.

Nevertheless, the figures do highlight a number of important points.

i. Based on the evidence considered here, the capital costs of landscaped SuDS solutions are lower than the capital cost of comparable conventional solutions at every level. On average, our analysis suggests that the use of SuDS could save Wales over £9,000 per new home in capital costs alone.
ii. Of those schemes examined in detail, operational costs of landscaped SuDS solutions are also lower than the operational cost of comparable conventional solutions at every level.
iii. In terms of costs per household, there are, as would be expected, capital cost economies of scale for both conventional and SuDS schemes, with capital costs per household falling significantly as the scale of development increases. However, these economies of scale are

[20] https://tree-map.nycgovparks.org/

less pronounced for operational costs. Nevertheless, the operational costs per household for large developments are generally lower than those for small and medium developments.

iv. Although the number of data points is more limited (because most schemes do not assess or record benefits), it is clear that there are real and significant benefits associated with the use of landscaped SuDS, and that the benefits of SuDS solutions are significantly higher than the benefits of comparable conventional solutions. Further, wider benefits related to health, amenity and other areas could be very significant, even when compared to more traditional benefits like flood risk reduction and water quality.

v. Per household, there is a different picture to costs. Unlike costs, benefits per household are greater for larger developments than for small and medium developments. This may be because certain benefits only accrue above a certain scale. Our analysis suggests that the use of SuDS could generate benefits of well over £300 per household per year on large developments.

vi. With the possible exception of permeable paving and filter drains, the costs of specific SuDS components are lower than the costs of comparable conventional measures.

Taken together, the evidence considered and presented here indicates that there is a very strong economic case for SuDS on new developments. The costs of SuDS solutions are less than the costs of conventional solutions in almost every case, often by a significant margin. As such, there is no clear need to or justification for assessing benefits. Nevertheless, explicit consideration of benefits would make the case for SuDS even stronger.

Across the 110,000 new homes planned for Wales by 2021, our analysis suggests that the use of SuDS could save Wales nearly £1 billion in capital construction costs and generate benefits of over £20 million per year.

These findings are consistent with those presented in Section 3 and with the UK Government, which stated in a recent consultation that "*all the available evidence is that sustainable drainage systems are generally cheaper to build; and maintaining them will be cheaper (or need be no more expensive) than the same cost as is required to maintain conventional drainage at present*" (Defra, 2014).

It is important to keep in mind the caveats and assumptions behind this analysis set out in Section 2.5. In particular, data is sparse in many areas, and it is often difficult to make like-for-like comparisons. However, the points highlighted above are supported and reinforced by the stakeholder engagement exercise, previous reports such as Kellagher et al (2013) and a number of anecdotal comments made to the project team. For example, one senior representative from an English local authority suggested that "*costs (of SuDS) per m^3 could end up being a quarter what it would cost to bury below ground*."

4.4 Who pays and who benefits?

As important as the size of costs and benefits is how these fall on, and are distributed between, different groups. This is particularly relevant to considerations around equity, fairness and the need to support disadvantaged groups using policy levers and tools.

From the evidence collated and analysed here, it is apparent that there is currently very little in the way of formally recorded information around incidence. However, it is possible to envisage how, for existing SuDS schemes, costs and benefits occurring at different parts of the process fall on different groups. This is shown in Table 7, which also includes an indication of the likely scale of these costs and benefits.

Table 7:Incidence of costs and benefits

Stage	Costs	Benefits	Example
Planning & design	Most costs (conceptual/outline/detailed designs, consultation & engagement, planning permission/conditions, etc.) borne by developer or planning authority. Consultees will have their own cost (e.g. pre-application enquires are commonplace).	Developer or planning authority, if this stage expedites development process.	'Enabling costs', which encompass planning and design and enable subsequent parts of the process to occur, are typically 15% of the capital costs (CIRIA, 2007), but can be as high as 30% (Ellis et al, 2003).
Construction	All costs (earthworks, materials, construction, landscaping, etc.) borne by developer.	Developer (if they can sell at premium or build faster/with fewer obstacles).	As set out in Sections 4.1 and 4.2.
Commissioning, approval & adoption	Most costs (consenting, testing, inspection and administration, etc.) borne by developer, regulators, planning or adopting authority.	Developer, and possibly local authorities/regulators, if fees (e.g. for inspection) can be levied to generate income stream.	Generally small, though charging fees for services here could be attractive model for local authorities.
Operation & maintenance (O&M)	Functional costs fall on different groups, e.g. developers (via commuted sums), households (for SuDS within property curtilage), sewerage company, adopting body, and potentially local authority if SuDS fail/are orphaned. Ultimately all costs accrue to the property owner.	Most benefits (e.g. increased property value, reduced flood risk), may accrue to householders, but others (e.g. downstream flood risk, increased network capacity, water quality, carbon, health) are wider and may need incentives for these 'bigger' policy pay-offs (a better Wales) to be realised.	As set out in Sections 4.1 and 4.2.
Monitoring	Monitoring generally not undertaken but, where it is done, most costs fall on regulators.	As for 'operation and maintenance'.	Same as O&M, where costs of monitoring are incurred.
Replacement & decommissioning	Dependent on adopting authority (e.g. developer, adopting body, local authority, sewerage undertaker, householder).	Only significant benefits expected where these are for adapting to external changes like climate by increasing resilience.	Thought to be around 35-42% of total construction costs (Environment Agency, 2015).

In relation to the incidence of costs and benefits, there are a number of important points to make. These are explored further in Section 5.

i. Since some form of drainage would always be required in new developments (whether conventional or sustainable), it is better to think about transfers of costs and benefits from one group to another, rather than absolute costs or benefits. For example, the O&M costs of (adopted) conventional drainage would generally fall on company customers of the sewerage undertaker, whilst the capital construction costs are paid by developers. Including SuDS on a new development may (e.g. through reduced O&M costs or deferred investment in increased capacity) mean that (at least some of) these costs fall instead on others (e.g. local authority or households), in turn providing a benefit to water company customers (assuming there is no redistribution of costs between the parties involved). Developers may benefit from lower capital costs, but may also benefit from increased revenue, if the inclusion of SuDS leads to higher sale prices.

ii. Related to this is the issue of additionality, and it is important to consider both costs and benefits from the perspective of 'what would have happened otherwise?' For example, some benefits attributed to SuDS may actually accrue from any type of green space, and it is therefore important to focus only on the additional benefits that SuDS features bring about.

iii. Economic theory would suggest that the most efficient allocation of resources (in this case the use of SuDS) occurs when consumers pay the full cost of the goods or services they consume, i.e. the beneficiaries of SuDS should bear the cost. Clearly, benefits fall on different groups (e.g. local benefits may accrue to developers or householders, whilst others may accrue across the catchment, the country or even globally) and some of these groups already pay (at least some of) the costs (funding is explored in more detail in Section 5). In general though, SuDS are likely to become more widespread if there is an improved understanding of the incidence of benefits and costs. It also suggests that funding for SuDS should potentially come from a range of different sources, which may be different to those for traditional drainage, depending on the nature of the benefits and associated beneficiaries.

iv. Costs and benefits may accrue over different timescales, and the incidence may similarly change over time. At least part of some benefits (e.g. carbon, health) may accrue to future generations.

v. Where O&M responsibilities for drainage on new developments are met by sewerage undertakers, regulatory intervention (e.g. by Ofwat) may be required to ensure that existing customers are not disadvantaged.

vi. Ultimately, costs will be passed through, either directly or indirectly, to the end user of a service. For example, developer costs will ultimately be paid by homebuyers, costs for local authorities by local taxpayers, sewerage undertaker costs by their customers. Of course, the end users that pay are not necessarily the same as the beneficiaries, and there may be spatial or temporal differences between these groups. In addition, some costs (e.g. highway drainage) are not currently well understood or 'visible'. These may fall on a different group (e.g. water company customers) than those who benefit (e.g. road users).

5. Uptake, adoption, operation, maintenance and funding

5.1 Overview

Across the UK there is now a presumption that SuDS should be used on all new developments that, in England and Wales, include more than 10 properties. In many countries across the world SuDS are welcomed by those who live, work and interact with surface water drainage systems (e.g. Everett, 2017). In Scotland many recent developments provide homes for residents who now see SuDS as 'normal'[21]. Dweller and user acceptability is important if SuDS are to become the normal, default and expected means of draining housing and other development sites. Section 5.2 sets out the duties of those who have SuDS on their property and/or in their community and how these duties may be discharged or delegated to others to deliver.

In many cases such duties are unknown as regards SuDS before the dweller takes up residence due to the limited experience of their use in the UK (e.g. Butler et al, 2016). However, many dwellers are equally as unaware of their duties as regards the buried piped and culverted drainage on their property; that is to accept flows from upstream and convey them safely downstream. Or to, in some cases, utilise the flows from upstream for on-site use. Many residents do use rainwater collection devices and many sewerage undertakers provide subsidies to encourage their use. There are also concerns from some residents about the relative safety of open water features especially where there are young children in the community. Ensuring safety is always a priority for public spaces and this is recognised for SuDS in the CIRIA Manual where Chapter 36 deals with health and safety issues and a checklist is given for this in Appendix B.

To be effective and to develop a public perspective that requires the use of SuDS when considering purchase of a property will necessitate engagement efforts at least in the short term in order to help develop understanding. Many people equate surface water with 'flooding' and a number of successful engagement activities have focused on the flood risk reduction benefits from the use of SuDS (e.g. Daly et al, 2015; Everett, 2017) as a means to encourage acceptance and willingness to maintain. The SuDS Manual (Woods-Ballard et al, 2015) devotes Chapter 34 entirely to community engagement in regard to SuDS and provides examples of how successful this has been in Upton for a large-scale community development and also for a much smaller retrofit scheme at Priors Farm. There is considerable evidence that public and community willingness to engage in 'living with water' as surface based SuDS require, can be attained with good demonstrations and by providing the means for better understanding. SuDS do not limit the opportunities for residents to e.g. extend their properties or pave over surfaces any more than piped drainage systems do. SuDS do, however, show very quickly where the drainage for this has not been considered properly and also where a property may have incorrectly had its' foul sewerage connected to the surface water system.

Many commercial property developers and managers have welcomed the value that SuDS bring especially as regards amenity. This is why the Business Improvement Districts in both Victoria and London Bridge in London have been able to raise the funds for retrofitting SuDS (see Digman et al, 2012). The recent use of the CIRIA Benefits of SuDS Tool (BeST) has also shown the very considerable increase in property values that SuDS provide, which piped drainage systems do not. Case studies in Yorkshire and in the Netherlands have shown that in the first year of operation large increases in property values are estimated to occur from retrofitting SuDS in urban spaces (Ashley et al, in

[21] On a 2015 visit to large and incremental developments in and around Dunfermline, a resident volunteered the information that she was interested to see what sort of drainage system the next phase of development would include as they were very happy with the SuDS that were used to drain her property and neighbourhood (Richard Ashley, Brian D'Arcy).

review). For new developments such enhanced values are not as likely as the primary benefits are from the surrounding landscape, which may, where green and blue spaces are included, be as valuable as a landscape with SuDS.

5.2 Responsibilities for adoption and O&M

The main existing duties and potential responsibilities for SuDS adoption, operation and maintenance in England and Wales are summarised in Table 8. Further details are given in CIRIA (2015a). Duties and responsibilities depend on and interact with planning duties and other responsibilities, including those related to open spaces (Bide, 2014). Some adopting organisations may be able to influence the design and planning of SuDS. If established, the SAB would have the greatest opportunity of all to both direct and manage the form and entire life of SuDS (Dwr Cymru Welsh Water, 2016).

Table 8:Existing responsibilities and possibilities for adoption and maintenance of SuDS

Organisation	Current responsibilities and effectiveness in regard to SuDS	Potential responsibilities for SuDS
Householder/ dweller or landlord/ agent	• To manage flows coming on to property and to safely pass these on (where appropriate). In practice this means maintaining drainage/surface water systems within curtilage other than where these are 'public' sewers. Also responsible for maintaining culverts and adjacent rivers up to the centre line. Any curtilage SuDS would be owned. • Many in this group are unaware of their responsibilities and often do not have the capacity to fulfil current responsibilities. • For some SuDS in Scotland householders have to agree to wayleaves and easements to allow the adopter to maintain the SuDS on their property. Such arrangements may in any case be required for traditional drainage.	• As current, but where surface SuDS are used there will also be enhanced responsibilities where these provide other benefits in addition to simply conveying the flow. • Additional education and training would be required to develop the capability for and willingness to maintain SuDS, though this may have resource/funding implications.
Sewerage undertaker	• Responsible for 'effectually draining an area'. May utilise traditional drainage systems or SuDS that are constructed by the undertaker in order to remove surface water from the public sewer network, or reduce the rate at which it enters. Have to accept flows from third parties into sewerage assets, even surface water into foul sewerage where there is no alternative. Land drainage does not form part of the definition of surface water sewage. Undertakers have powers to disconnect sub-soil water from their networks with no duty to accept it or derive income from it. • Some undertakers in England and Wales may adopt SuDS if business case is clear, and adoption of hard (predominantly underground) SuDS is already commonplace.	• Maintain existing duties. Could undertake more widespread SuDS adoption if there is a clear business case and legislative and/or regulatory amendments (e.g. covering power to adopt, land drainage, capitalising value of SuDS so they can earn a return on investment). The 2014 Water Act inserted section 114a in to the Water Industry Act 1991 to allow sewerage undertakers to build and maintain SuDS to reduce the volume of surface water entering the public sewerage system. However, no matching amendments were made to S104 relating to adoption of SuDS on new developments, which still refers to adoption of sewers only. • Have the capabilities and ability to integrate management and operation of drainage and even water resource

		systems. • Right to connect (currently conditional on planning conditions) needs to be made conditional on capacity of existing assets and undertaker needs to be one of statutory consultees for planning purposes.
Natural Resources Wales	• Has overall responsibility for coordinating flood risk management, overviews of water resources plans and setting of discharge consents with River Basin Management and other plans forming the overall strategy. Consultees for drainage/SuDS planning and design. • Also responsible for certain levels of flood risk management plans and construction large river and coastal flood defences.	• Important players in the bigger picture for catchment management and the place of SuDS therein. This should be sustained in terms of the planning processes. Although it is conceivable that poorly maintained SuDS could impact on both water quality and ecosystems, NRW will not have a direct role in SuDS O&M.
Local Authority	• In Wales (with the small exception of the 3 parks authorities), the unitary authorities are responsible for both planning and Strategic Flood Risk Assessments (as LLFAs). This is a real advantage in terms of the ability to discharge complementary (as opposed to separate) functions related to surface water management compared with England where there are a variety of types of unitary and separate authorities. For example, they can encourage the use of, and place conditions around, SuDS in local development plans. • LAs also discharge the building regulation and control functions (through Building Regulations such as Part H, see Table 1). LAs are also Highway Authorities (below) although the extent is dependent on the designation of the highway. • LAs are also the land drainage authority with a lot of the related powers that this entails. Also the Lead Flood Authority with the associated responsibilities. • Currently, many LAs won't adopt any open space.	• LAs have duty to maintain and support the health and welfare of their communities. They have a wide range of duties, some statutory, others discretionary. In many LAs the drainage function is not prioritised and in-house capacity is limited. The development planning function makes most LAs crucial in the design, planning and delivery of SuDS. Schedule 3 sets out a means to put all SuDS functions in a single place by creating a SAB, who would assume O&M responsibilities as adoptees. However, issues mainly about funding this function derailed the setting up of SABs. • An option may be the establishment of an appropriate form of unitary authorities as a collective or over-arching body with the track record and capacity to adopt and maintain. Partnerships would be crucial for this to be effective.
Highway Authority	• Highway Authorities (the Welsh Government, county and borough councils) are responsible for providing and managing highway drainage and roadside ditches on strategic roads, and must ensure that road projects do not increase flood risk or pollution. Have been interested in SuDS (and have used them for sometimes), with drainage standards and guidance including the use of SuDS in the Design Manual for Roads and Bridges. Many HAs already design and adopt SuDS, albeit primarily related to highway drainage.	• Highway drainage is currently discharged into the most appropriate assets, including public sewers. The costs of this are not differentiated and therefore are opaque for attribution purposes. HAs will continue to adopt and maintain their own assets. As indicated earlier some County level LAs are taking responsibility for all SuDS not only those draining highways.
Internal	• Although there are no IDBs in Wales, in	• Some IDB consortia in England are already

Drainage Board	England they are responsible for designated river reaches, their main objective is flood risk management and coordinating the balance between draining land and downstream protection. Many are involved in integrated approaches to water resource and flood risk management and advice on planning matters.	adopting SuDS in their areas[22]. Their adoption could be extended as there is willingness by many IDBs to expand their remit. In Wales, the IDBs are part of NRW.
Developers	• Housebuilders claim to already be using SuDS whenever and wherever possible (although these often include below ground components). This includes piped drainage systems. There is a perception that SuDS are more costly, maintenance more expensive and include long-term management, not something their customers would wish to take on. • Developers often propose SuDS as the most cost effective solution.	• It is unlikely that developers will be willing or the appropriate party to take on SuDS O&M. However, commissioning and periods of verification of functioning of all types of surface water system are their responsibility. Evidence suggests that this is often left to NHBC as insurance[23] for defects after self-certification of building regulations by the developer[24].
Property/ Housing Association	• Many developments have facilities/property managers, especially commercial and industrial areas. • Much social housing is now developed and managed by Housing Associations. New homes must be constructed in line with Development Quality Requirements under the Welsh Housing Quality Standards (see Table 1).	• Have long-term stewardship perspective and could adopt and manage SuDS or assist dwellers in O&M. Many HAs maintain the estates they manage and SuDS could comprise part of this. SuDS are also considered for renovation programmes and there has been work together with the Energy Saving Trust by Welsh HAs linking water and energy saving.
Asset/service management organisation/ resident group	• There have been both successes and failures regarding these third party managers for SuDS. SuDS should be seen as any other asset to manage. However, according to HBF, only 2 companies in England & Wales they are aware of who can properly take on board SuDS maintenance: Albion Water and Greenbelt group. Other organisations are seen as not being competent or fail, leaving stranded assets (or orphan SuDS). However, there are other organisations such as Meadfleet[25] who are recommended to be competent. • In USA, developments with on-site wastewater treatment systems only functioned properly when managed by a collective organisation. Individual plot managing by householders was a disaster.	• In principle this could work. However, there would need to be guarantees in case the management company failed or became insolvent. There would need to be a clear income e.g., estate maintenance fees. Surface water drainage charges, currently paid to the sewerage undertaker, could be used where surface water disconnection rebates exist, as in Wales. • LAs could establish a not-for-profit utility company wholly owned by one of more LAs. This model is used in many cities and States in the USA. Gwynedd Council is reportedly going down this route as an LLFA. • In Milton Keynes, the Parks Trust, originally set up by the Development

[22]e.g. Bedfordshire group of IDBs http://www.idbs.org.uk/
[23]http://www.nhbc.co.uk/Builders/ProductsandServices/BuildingControl/
[24]See https://www.gov.uk/building-regulations-competent-person-schemes. Note that the NHBC warranties have recently been changed and now specifically exclude cover against Building Regulations (Part G) Drainage. It does It does cover "underground drainage for which you are responsible" – which specifically excludes above-ground SuDS, see http://www.nhbc.co.uk/Warrantiesandcover/Buildersanddevelopers/Privatehousing-Buildmark/Policydetails/.
[25] http://www.meadfleet.co.uk/

		Corporation, adopts all open space, and is involved in the planning process. • Community Trusts have been shown to be effective, such as that for Stroud, Springhill cohousing[26].
SuDS management organisation	• Given the opening up of competition and inset possibilities regarding the monopoly held by water and sewerage companies (WaSCs), there could be management organisations as above specialising in surface water maintenance. There are already examples of this on certain estates, although the adoption of private sewers and pumping stations by the WaSCs that has now been completed has led to the failure of a number of these organisations.	• There is scope for specialist organisations such as Albion Water and Greenbelt group to take on SuDS providing the revenue stream can be defined.

Table 10 illustrates the wide range of potential players that might be directly involved in SuDS adoption, operation and maintenance. In addition to those shown, there are other options in use worldwide, for example in the USA where a municipal surface water charge may be ring fenced for SuDS maintenance; with flexibility so that if SuDS are in place the surface water charge can be reduced. In Germany disconnected properties are checked periodically to verify they are still disconnected from the main drainage and rebated accordingly. In the USA there are also schemes funded through insurance companies because of reduced flood risk.

However, adoption, operation and maintenance of any given SuDS, especially where there is a 'train' of measures, may not fall on a single body or organisation. Many SuDS, albeit providing effective delay and attenuation to runoff with pollutant reduction, can ultimately discharge excess flows into sewered assets (Highway Authorities under Section 115 of the Water Industry Act, 1991 (which is a reciprocal power which also allows the sewerage undertaker to discharge surface water into highway drains). Developers currently have a right to connect to the public sewerage system under the Water Industry Act, although Schedule 3 of the Flood and Water Management Act (2010) changes this, making any connection conditional on the developer having an approved SuDS scheme from which there may be a residual flow to the public sewer (although Highway Authorities can still refuse to accept flows from housing developments into their assets; Ellis & Lundy, 2016). There is also no requirement for the discharge rate to be controlled into the public sewer. Thus WaSCs are reliant on planning conditions to limit flow to a suitable rate, often greenfield run-off rates. Even if there were an alternative non-public surface water outfall available (e.g. culverted watercourse or highway drain) in an area with only a public foul sewer, there is no requirement to prevent a new connection into the foul sewer as the developer has an automatic right to connect to a public sewer, but can only connect to a culverted watercourse/highway drain by agreement. Hence WaSCs often find developers taking the easiest option and connecting to the foul sewer, which is why WaSCs favour a mandated hierarchy in statutory standards which is stronger than Part H alone.

Hence the sewerage undertaker often has responsibility for at least part of the train of measures, where the piped drainage is the final destination. Sewerage undertakers only have a responsibility to drain roofs and appurtenant areas and highway run-off by agreement. There is no responsibility to accommodate land drainage. There are also challenges as to what constitutes 'land drainage'. Some undertakers for some sites are able to argue that the SuDS handle significant volumes of land

[26] http://www.therightplace.net/coco/public/

drainage and therefore these undertakers do not have a duty to accept such flows into their assets. One of the benefits of SuDS is that their use encompasses all surface water flow, which could include management of overland run-off from fields but currently there is no right to connect land drainage to a public sewer.

Sewerage undertakers could adopt SuDS if S104 of the Water Industry Act 1991 was modified to allow the adoption of SuDS as well as sewers (see Table 8). Water UK is currently initiating a project to take this work forward, working with interested parties, including government departments, regulators and developers over the next 12-18 months to investigate the changes that would need to be made to current guidance and to company procedures to allow this change of approach to be implemented.

As many SuDS are surface based, they are now increasingly 'entangled' with other urban services and systems. For example, by providing or supporting green and blue spaces, together with ecosystems, SuDS are of direct interest to parks and recreation providers and maintainers of these (Jennings et al, 2016). By supporting human physical and mental health, SuDS should also be of direct interest to health authorities and environmental/human health departments in local authorities (Kirby & Russell, 2015; Watts et al, 2015). These parties formerly had only a remote interest in surface water drainage, but now need to be engaged effectively.

5.3 Adoption

The options and current arrangements for adoption in England are set out in CIRIA (2015a): "*The landowner is the party responsible for ensuring that SuDS component(s) within their land are maintained over the lifetime of the development even if it serves other properties, unless the SuDS component(s) have been adopted*." Even where a third party adopts: "*property freehold is not transferred. The adopter will ensure they have the right to access and maintain the adopted asset. Some SuDS components, particularly surface SuDS components, may be adopted and the freehold of the land on which they lie is also transferred into the ownership of the same (or a different) authority"* (ibid).

Clearly, some SuDS, such as those that provide new park or recreation areas, could become the responsibility of local authority departments who already manage such areas. This is the approach being taken by Sheffield City Council for some of the SuDS included in housing developments, with appropriate additional funds being made available from commuted sums provided by developers. Sheffield is taking a broad approach and some SuDS (e.g. permeable pavements) are being managed by the highway maintenance PFI contractor Amey, whereas others are maintained by a specially set up in-house maintenance organisation entirely funded from commuted sums used to establish a ring-fenced sinking fund and ensure long-term viability.

Guidance on and model agreements for adoption are provided by CIRIA via the Susdrain website and set out in Table 11 (Section 5.5) and an adoption hand-over list is provided in Appendix B.9 in the SuDS Manual.

Overall the extant variety and range of funding models being used in the UK and elsewhere is seen by some as overly complicating the way in which SuDS are being planned and operated, and hence an impediment to their use. However, it is important to facilitate flexibility to enable local needs to be met and agreed as reflected in the solutions addressing local conditions and the appropriate use of the variety of SuDS in the most successful schemes. Hence any policy needs to reflect and encourage this and make provision for the costs, which as shown in sections 3 and 4 are no greater (and often substantially less) than for traditional drainage systems.

5.4 Operation and maintenance

Chapter 32 in the CIRIA SuDS manual (Woods-Ballard et al, 2015) sets out best practice for operation and maintenance, together with the required documentation for a given site. The related principles of landscape management are also laid out. Appendix B.8 of the SuDS Manual provides a maintenance plan and check list for this.

Both conventional and SuDS systems have O&M requirements. Tables 9 and 10 show the maintenance needs for a range of SuDS (once established). However, these do not necessarily include additional maintenance needed to ensure that many of the multiple benefits provided by SuDS continue to be provided.

Table 9:Typical maintenance works and frequencies for a range of SUDS measures

Measure	Annual or sub annual maintenance	Intermittent and/or remediation
Green roofs	6 monthly - remove debris and litter 6 monthly - remove weeds 6 monthly - mow grass (if applicable)	
Simple rainwater harvesting (water butts)	Annual - cleaning inlets, outlets, gutters and tanks	
Advanced rainwater harvesting	3-6 monthly - self-cleaning and coarse filter checks and clean 6-12 monthly - check and clean roof and gutters 6-12 monthly - UV unit operation checks Annual - pump operation checks	
Permeable paving	4 monthly - brushing and vacuuming	Stabilise and mow contributing areas, removal of weeds Remedial work to any depressions or broken blocks Rehabilitation of surface and upper sub-structure where significant clogging occurs Replacement of filter material (20-25 years although recent research suggests this may not be necessary, Sue Illman, pers. comm., Dec 2016)
Filter drain / perforated pipes		Replacement of filter material (10 – 15 years)
Swales	Monthly - litter and debris removal, grass cutting Annual - manage vegetation and remove nuisance plants Annual - checks for poor vegetation growth and re-seed	Repair erosion or damage, re-level uneven surfaces Remove sediment and/or oils (25 years, unless there is an accidental spill or particular site circumstances that generate a large build-up of silt)
Infiltration basin	Monthly - litter and debris removal, grass cutting of landscaped areas Half yearly - grass cutting of meadow grass and around basin Annual - manage vegetation and remove nuisance plants	Re-seed areas of poor vegetation growth Prune and trim trees Remove sediment if reaches 50% full Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows
Soakaways	Remove sediment and debris Clean gutters and filters	

Measure	Annual or sub annual maintenance	Intermittent and/or remediation
	Trim roots that cause blockage	
Infiltration trench	Monthly - litter and debris removal Annual - weed/root management Annual - removal and washing of exposed stones Annual - removal or sediment from pre-treatment devices	Replacement of filter material (20-25 years)
Filter strip	Monthly - litter and debris removal, grass cutting Annual - vegetation management Annual - checks for poor vegetation growth and re-seed	Ensure build-up of silt at road edge isn’t impeding ability to provide over-the-edge drainage onto the filter strip Remove sediment and/or oils
Constructed wetland	Monthly - litter and debris removal, grass cutting of landscaped areas 2-3 times per annum - grass cutting of meadow grass Annual - manage vegetation including cut of submerged and emergent aquatic plants and bank vegetation removal	Remove sediment/clean silt traps Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows Supplement plants if establishment not complete
Detention basin	Monthly - litter and debris removal, grass cutting of landscaped areas 2-3 times per annum - grass cutting of meadow grass Annual - manage vegetation including cut of submerged and emergent aquatic plants and bank vegetation cutting	Remove sediment Repair of erosion or other damage Repair/rehabilitation of inlets, outlets and overflows
Sources: Environment Agency (2015)		

Table 9 provides an insight into the maintenance of SuDS and the consequential competencies required of the maintainer/operator and is derived from original guidance in the first edition of the SuDS Manual (CIRIA, 2007). The 2nd edition, in 2015 of the SuDS Manual (Woods-Ballard et al, 2015) provides operational information (Table 10), including remedial maintenance activities. Within the industry the maintenance requirements of SuDS components are relatively well understood, the main challenge is around how to allocate and fund responsibilities for undertaking maintenance.

Table 10: Outline of typical key SuDS O&M activities

Operation and maintenance activity	SuDS measure												
	Pond	Wetland	Detention basin	Infiltration basin	Soakaway	Infiltration trench	Filter drain	Modular storage	Pervious pavement	Swale/Bioretention /Trees	Filter strip	Green roofs	Proprietary Treatment systems
<u>Regular Maintenance</u>													
Inspection	■	■	■	■	■	■	■	■	■	■	■	■	■
Litter/debris removal	■	■	■	■	□	■	■	□	■	■	■		□
Grass cutting	■	■	■	■	□	■	■	□	□	■	■		
Weed / invasive plant control	□	□	□	□		□	□		□		□	■	
Shrub management	□	□	□	□					□	□	□		

Shoreline vegetation management	■	■	□										
Aquatic vegetation management	■	■	□										
Occasional Maintenance													
Sediment management (*)	■	■	■	■	■	■	■	■	■	■	■		■
Vegetation/plant replacement	□	□	□	□						□	□	■	
Vacuum sweeping and brushing									■				
Remedial Maintenance													
Structure rehab/repair	□	□	□	□	□	□	□	□	□	□	□	□	
Infiltration surface reconditioning				□	□	□	□		□	□	□		
Key: ■ Will be required □ May be required * Sediment should be collected and managed in pre-treatment systems, upstream of the main device													
Source: Woods-Ballard et al (2015)													

5.5 Funding

Funding goes hand-in-hand with responsibilities. With shrinking budgets, especially in local authorities, any new SuDS need to be supported by additional maintenance funds or funds diverted from existing surface water or other management revenues.

Table 11 summarises the range of funded adoption and maintenance models now available. Guidance for England is provided by CIRIA (2015a); currently the same arrangements prevail in Wales, albeit with variations in the requirements such as set out in the Planning Advice Notes. Ministerial Guidance states that when giving development approval, planning authorities should ensure through the use of planning conditions or planning obligations that there are clear arrangements in place for on-going maintenance over the lifetime of the development, which also include adoption.

Table 11: Funding adoption and maintenance options

Funded adoption model	Examples	Advantages	Disadvantages
Model agreement and commuted sum, Section 106 agreements from the Town and Country Planning Act, 1990	Telford & Wrekin Council[27]. Sheffield City Council (use a number of options).	Clear funding stream to maintain SuDS over period defined.	Important to ensure that adequate funding is defined up front. Often the final design is fixed too late in planning approval process to ensure this. Defining the maintenance period, major renovations and replacements is difficult. Commuted sums cannot be ring-fenced in local authorities (unless a separate arms-length body is established).

[27] http://www.telford.gov.uk/info/20170/planning_applications_and_guidance/599/major_development_planning_and_viability

Model agreement and commuted sum, Section 38(6) and Section 278(3) of the Highways Act 1980	Rhondda Cynon Taff (2014) has model agreement as an example. Caerphilly Council, for pilot permeable paved SuDS. Sheffield City Council uses PFI contractor.	As above.	As above, although in this case, highway authority is defined maintainer.
Private management companies funded through a commuted sum or service charge and paying an assurance bond	Greenbelt Group[28], managing recently built SuDS, including in St Canna's Green in Glamorgan.	Risk is borne by the company. Ability to adjust charges over lifetime could be a benefit in that this could ensure solvency of company.	Charges may be adjusted over the lifetime of the SuDS which may be unaffordable for some customers. Where company fails, then SuDS maintenance will cease and alternative arrangement will be needed.
Sinking funds linked to one-off commuted sums	Sheffield City Council[29], used for developers and the parks department, for long-term assurance.	Ensures long term viability and by sharing the income across many schemes, provides guaranteed revenues from investments.	Definition of the commuted sums may be difficult. Discussions required with developers as to the period over which the commuted sums should cover.
Including maintenance responsibilities in property deeds.	Durham County Council[30].	A clear definition of responsibility on the property owner.	May be off-putting to potential property purchaser. Enforcement action may be needed where maintenance is inadequate. On-going education about SuDS will be needed at a cost which is indeterminate.

Determining O&M costs and commuted sums is site and scheme specific, although there are examples of frameworks for this. As commuted sums have been used for infrastructure maintenance for a long time, lessons are available from other domains. For example, ADEPT (2016) provides guidance for estimating commuted sums for the maintenance and reconstruction of bridges: "*A commuted sum is the calculated sum of money necessary to compensate for the transfer of a liability from one to another. The sum should be sufficient to provide for all future costs associated with taking on the liability*." These are routinely used by local authorities in the UK.

There is no consistency in how such sums are estimated. Other examples of guidance for the estimation of commuted sums include Rhondda Cynon Taff (2014), Cambridge City Council (2009) and Telford & Wrekin (2015). Examples of the use of commuted sums include Newcastle City Council[31] and Sheffield City Council[32]. There is also a lack of consistency in the period covered by such sums. These range from 20-25 years (Caerphilly Council) to 100 years (Wakefield Metropolitan

[28] Greenbelt now manage some 200 SuDS, 200 play areas and 10km^2 of green areas across the UK on behalf of some 50,000 households: https://www.greenbelt.co.uk/index.php/news/203-new-residents-autumn-2016

[29] https://www.sheffield.gov.uk/planning-and-city-development.html

[30] http://www.durham.gov.uk/article/7363/Sustainable-drainage-systems

[31] Northern Development Area, Newcastle Upon Tyne: http://www.susdrain.org/case-studies/case_studies/northern_development_area_newcastle_upon_tyne.html

[32] Manor Ponds: http://www.susdrain.org/case-studies/case_studies/manor_ponds_sheffield.html

District Council). Box 2 shows the estimated commuted sums for a SuDS permeable pavement in Caerphilly as an example.

Box 2: Commuted sum example for permeable pavement in St David's Close, Caerphilly Council *(courtesy of Michelle Johnson)*
A development of 11 homes (bungalows), managed by a Housing Association. There is 340m^2 of road surface; each house has a soakaway with an overflow. Highway drainage has been adopted by the Council, but there is a need to ensure that the Housing Association properly maintains the property drainage and vehicle turning area, which has not been adopted.

- 100yr design standard + 30% rainfall uplift: Section 38 bond from WG £61,318. £4900 adoption cost.
- Original commuted sum was set at £17,000 assuming 20 years to replacement and surface cleaning and re-sanding once a year (£830 per year cost).
- Review of figures has found this to be an underestimate: Replacement costs for road with 820mm depth: 80mm block/50mm stone/geotextile then bitumen layer with holes drilled and another geotextile layer below gives an estimate of £122,000 costs for replacing bitumen alone.

The example in Box 2 illustrates the complexities and uncertainties in estimating commuted sums. Much of this relates to replacement costs at end-of-life. The suggested frequency of surface treatment for the permeable pavement of every year may be more intensive than that recommended in guidance (e.g. by Kellagher et al, 2013), although the SuDS Manual (Woods-Ballard et al, 2015) does suggest annual maintenance is required. In the Netherlands, such maintenance is only required when the surface infiltration rate falls below 20.8mm/h (Boogaard, 2015). However, it is unlikely that this type of detailed monitoring will be undertaken in the UK.

There are other approaches being used elsewhere, including 'cap and trade' (Goddard, 2012) which can be used to reduce the amounts of surface water runoff and enhance the performance of the system by reward. Approaches that not only ensure that the SuDS are operating and maintained as designed but actually provide an even better performance over time than envisaged at the outset, should be the aim.

Ultimately SuDS will need to be but part of an integrated catchment approach and managed as such, not as individual and stand-alone entities, other than possibly on individual curtilages (e.g. Southern Water, 2016). This could be achieved by putting O&M into the hands of pan-catchment wide organisations such as the sewerage undertaker or NRW; but this would be for the entire system, rather than single SuDS components. This approach should derive from river basin, flood risk and other large scale strategic planning. The 21st Century Drainage initiative (Water UK, 2016) focuses on 'drainage'; whereas an integrated approach is required to water management as a whole. Elsewhere, broader concepts are now well established, including water sensitive urban design, for which the entire urban design, service provision and quality of environment are all managed together (e.g. Bell, 2015; UK Water Partnership, 2015). SuDS are considered just one, albeit important, part of this, with their main function being to enhance urban life quality and liveability.

Whatever model is used, the ultimate payment for surface water management will come from the user of the service, the property owner, dweller and/or the community. Without a transparent accounting process for how highway drainage is paid for, one that replicates the property drainage process, it is difficult to take as logical and structured approach to auditing and thus placing surface water costs in the appropriate place. If and when the Water Framework Directive is fully implemented in the UK, it will be necessary to understand and assign the full costs of highway drainage to the 'polluter' as part of the process of putting payment in the appropriate place. In other parts of the world the full cost recovery of surface water drainage is also an issue (e.g. Environmental Commissioner of Ontario, 2016) especially in the light of changing future conditions due to climate. Therefore any system needs to be robust and flexible enough to be able to be adjusted in the light of both experience in implementation and also as conditions change, including societal needs and expectations.

To date, not one of the constituent countries in the UK has satisfactorily resolved the challenges faced in the adoption of SuDS. Although the requirements in Scotland appear likely to lead to effective arrangements, this is by no means axiomatic as illustrated by the very low rates of adoption (Ashley et al, 2015). Although a single owner and operator of SuDS across Wales would be attractive, there are many examples where alternatives are working. Individual property owners (e.g. Durham), Housing Associations (Caerphilly), WaSCs (Llanelli) and local authorities (Sheffield) are all engaged in the adoption and maintenance of SuDS. In each case the standards are set locally, albeit drawing on national guidance and each is funded from locally negotiated revenues.

5.6 Implications for a SAB

SABs, were envisaged to be established in Lead Local Flood Authorities as set out in Schedule 3 of the Flood and Water Management Act 2010, however, as this is a part of the Act that has not been commenced, understanding of the SABs' function and way it may be funded is limited. SABs if introduced as envisaged, will be required to adopt and maintain the approved SuDS that serve more than one property. As regards responsibilities for adoption, operation and maintenance these are considered by CIRIA (Susdrain) to remain with the SAB although the delivery may be delegated by the SAB to others. O&M must comply with national standards and in Wales the interim draft standards include details for this. CIRIA explains: "*As the SAB responsibilities are placed with the same local government bodies as the Highway Authority responsibilities, there are clearly opportunities for greater coordination of these roles beyond simple statutory consultation of one by the other*". With the non-commencement of Schedule 3 in England and Wales, no further explanation of the role of the SAB is available. However, certain authorities operate aspects of the way in which they plan for and manage drainage *de facto* as if a SAB was in place, including *inter alia*: Oxfordshire and aspects of drainage by Sheffield City Council.

As regards funding for these duties and as statutory consultees, SABs would need to raise revenues from the developer for the initial approvals and also via commuted sums or the equivalent for the long term O&M responsibilities even if these were delegated elsewhere. Some of this funding could come from diversion of the surface water charges that currently are collected by other statutory bodies that manage surface water to a SAB O&M fund. This would need to be ring-fenced to avoid diversion to other services provided by the local authority in which the SAB is situated. By seeing surface water not only as 'drainage', however, a SAB could seek and utilise partnerships in cooperation with other potential funders by demonstrating to them the many and various added benefits that SuDS provide in various domains such as public health, urban quality of life and climate change mitigation.

6. Conclusions and recommendations

6.1 Conclusions

The main conclusions from the work undertaken and presented here are as follows.

1) The overall capital costs of well designed, good quality landscaped SuDS solutions are always less than those for conventional solutions. In most cases, overall operational and maintenance costs are also lower. Notwithstanding poor or incomplete data, this is a clear and consistent finding.

2) SuDS are not just an alternative to conventional drainage solutions. They can provide significant and multiple benefits, and have particular potential to help Wales meet well-being and wider sustainability goals. Although the arrangements for the way in which water and surface water systems are managed in Wales has evolved in the last decade and there are still many players with diverse responsibilities, all key stakeholders support the role that SuDS can play in achieving these aims.

3) Across the 110,000 new homes planned for Wales by 2021, our analysis suggests that the use of landscaped SuDS on new developments that are compliant with required standards could save Wales nearly £1 billion in capital construction costs and generate benefits of over £20 million per year.

4) Costs and benefits vary according to location, ground conditions, scale of development, the type and range of measure employed and other factors. The biggest advantages for SuDS seem to be associated with the following factors:
    a. SuDS need to be planned at the earliest stage of the planning process and integrated with general landscape design and maintenance;
    b. SuDS on or near the land surface are far more cost-effective than below-ground proprietary systems;
    c. Working in the broadest possible partnership offers the greatest potential to maximise benefits and lever additional funding; and
    d. The significant role of ‘champions’ in obtaining ‘buy-in’, managing relationships using voluntary agreements, and in promoting successful delivery and continuing functioning of SuDS.

5) There is broad and widespread support for commencement of Schedule 3 or a similar process that would make good quality SuDS, which are compliant with national standards, mandatory on new developments. Further, it appears unlikely that such a process would increase costs or hamper or slow down development. However, it would need to be accompanied by a clear but flexible process covering planning, adoption and responsibilities for long-term maintenance, supported by a continuous and sustainable income stream to ensure security of funding. **In short, commencement of Schedule 3 is necessary but not sufficient on its own to facilitate uptake of good quality SuDS on new developments.**

6) Although information and evidence related to SuDS has improved significantly in recent years, some key gaps in knowledge or in readily accessible information remain, including
    a. Monitoring of actual performance, especially longer term (e.g. flows, volume, quality, environmental outcomes)

b. Quantification and monetisation of the costs and benefits of *SuDS compared to conventional systems*, particularly for smaller schemes
c. The need for a comprehensive SuDS Register (size, location, quality, adoption agreements used, costs, performance, benefits, etc.)
d. A clearer understanding of how SuDS can fit within a natural capital framework, such that they can be treated as assets rather than liabilities.

7) Nevertheless, despite a clear vision for the future of Wales and a strong policy framework that seeks to enhance the welfare of future generations, taking responsibility for the long-term adoption and maintenance of SuDS, within an integrated water management framework, remains a risk for any organisation and, in common with the rest of the UK, a major challenge for Wales.

8) To realise the full benefits of SuDS, new models of funding may be required. These should be based on an improved understanding of who benefits, and may include a greater emphasis on the 'beneficiary pays principle', under which households, road users and others that benefit from SuDS, including those outside the immediate local authority area, may need to make larger contributions than at present, or existing revenues redirected to better align with the actual costs and better understood benefits.

9) Regardless of whether or not Schedule 3 is commenced, it is clear that the town planning processes need to be effective and timely and include all parties as consultees. We have found that 'drainage' proposals are often vague at the outset of the approvals process (see Woods-Ballard et al, 2015 for an outline of the process) and (largely due to pressures and complexities of site layout) are not defined by developers until too late in the process. The consequence is that the use of SuDS is often not possible due to the fixing of site details for other reasons – layout of houses, roads etc. SuDS need to be co-designed with the other surface features of a site. In addition, it means that reliable estimates of maintenance costs and commuted sums cannot be determined early in the design and planning process due to the lack of detail about the SuDS. This leaves questions of adoption to the very end of the process and little room for manoeuvre to get the best outcome for this.

There are a number of issues that have arisen during the course of this project which, whilst relevant to the future of SuDS in Wales, are outside the scope of this project. As such, we have not sought to resolve or comment in detail on these issues, but they should be considered by the Welsh Government in developing and taking forward consultation options. The key 'parked' issues relate to:

- How to engage households in supporting and maintaining SuDS (and funding for this where appropriate);
- The resources and skill-sets needed to deliver and maintain SuDS, with learning orchestrated across institutional boundaries;
- The role and contribution of highways, particularly in relation to funding;
- Removing the right to connect to the surface water sewer; and
- Local authority structures, coordination and funding arrangements in relation to town planning and SuDS.

6.2 Recommendations

Following on from the analysis presented and the conclusions set out above, a number of recommendations arise. These are primarily aimed at the WG for consideration and informing possible consultation options around commencement of Schedule 3.

1) In order to realise the benefits of SuDS and for consistency with the goals set out in the Well-being of Future Generations (Wales) Act 2015, the WG should take account of the information and analysis presented here in taking forward SuDS in Wales, including the use of appropriate policy levers and legislation.

2) In developing an approach to the public consultation exercise which will accompany any proposed changes in policy, the WG should consider the following issues.
    a. The need for policy options which provide a clear framework and process for adoption, and for the provision of incentives and sustainability of funding to ensure the long-term operation and maintenance of SuDS. This should consider how the use of incentives could be developed which support the beneficial use and funding of SuDS, consistent with the beneficiary pays principle and encompassing all surface water sources (including highways).
    b. Whether, in order to build the evidence base for SuDS, there is a need to consider developing guidance to support assessments and recording of the expected or actual performance, capital/O&M costs and benefits of SuDS in a consistent and transparent way.
    c. Likewise, whether there is a need to establish and maintain a register of SuDS in Wales.
    d. The possibility of convening (potentially in partnership with a body such as CIRIA) a 'SuDS Summit' to communicate examples of emerging or established good practice, and to provide a forum for identifying and developing partnerships for delivering SuDS.
    e. How SuDS can be consistently treated as assets rather than liabilities (e.g. by adopting a natural capital framework) in order to support delivery of multiple benefits.
    f. The 'parked' issues identified in Section 6.1 above.

3) In parallel to the consultation process, the WG should consider how the town planning process can be reformed to require that 'drainage' and appropriately designed, approved and adopted SuDS are adequately considered and formally accommodated from the outset and at all stages in development proposals. All parties with an interest in SuDS should be made statutory consultees to this process.

4) The SuDS Advisory Group in Wales should establish a sub-group to set out a process map and accompanying guidance that encompasses design, planning, construction, commissioning, adoption, O&M and decommissioning. This should either be defined in terms of a single adopting body (SAB or otherwise), or set out to inform the diverse and various potential adoptees as seen across the UK.

5) Greater priority should be placed on effective regulation and inspection of SuDS. Experience from SuDS use in Scotland has shown that an effective regulation and inspection regime is

required to ensure good practice is enforced and SuDS conform to the guidance set out in e.g. the CIRIA SuDS Manual.

7. References

Adept (2016) Commuted Sums for the Relief of Maintenance and Reconstruction of Bridges - Guidance Notes. Adept National Bridges Group. Rev 1.

Al-Rubaeia, A. M., Engströmc. M., Viklander. M. & G. Blecken (2016) Long-term hydraulic and treatment performance of a 19-year old constructed stormwater wetland—Finally maturated or in need of maintenance? Ecological Engineering 95, 73–82.

Ashley R, Walker L, D'Arcy B.,et al. (2015) UK sustainable drainage systems: past, present and future. Proceedings of the Institution of Civil Engineers – Civil Engineering 168(3): 125–130, http://dx.doi.org/10.1680/cien.15.00011.

Ashley R M., Digman C J., Horton B., et al (under review) Evaluating the longer term financial benefits of sustainable drainage systems. Proceedings of the Institution of Civil Engineers, Water Engineering.

Bell, S. (2015) Renegotiating urban water. Progress in Planning 96, 1–28.

Berwick, N. (2017). Sustainable Drainage Systems: Operation and Maintenance. Chapter 4 in *Sustainable surface water management*. Ed. Charlesworth S., Booth C. A. Wiley ISBN 9781118897706 p45-55.

Bide, P. (2014). Planning Advice for Integrated Water Management. The Cambridge Institute for Sustainability Leadership (CISL) Sink or Swim Water Collaboratory.

BiTC (2016) Water resilient cities: building resilience and saving money through better surface water management: A pilot with Greater Manchester Schools. Report to Defra. Business in the Community.

Blecken, G T., Hunt W F., Al-Rubaei A M., et al (2015): Stormwater control measure (SCM) maintenance considerations to ensure designed functionality, Urban Water Journal, DOI: 10.1080/1573062X.2015.1111913

Boogaard, F. (2015). Stormwater characteristics and effectiveness of sustainable urban drainage systems. PhD Thesis TU Delft, Netherlands.

Brockett, J. (2015) *Project Focus RainScape – an integrated SuDS solution for Llanelli*.Water & Wastewater Treatment. Available from <http://wwtonline.co.uk/features/project-focus-rainscape--dwr-cymru-welsh-water-s-suds-solution#.WBzFN_mLSHt>

Butler, C., Walker-Springett, K., Adger, W. N., Evans, L. & O'Neill, S. (2016). Social and political dynamics of flood risk, recovery and response, The University of Exeter, Exeter.

Cambridge City Council (2009) SUDS - Cambridge Design and Adoption Guide. www.cambridge.gov.uk

Cettner, A., Ashley R., Hedström A., Viklander M. (2014). Sustainable development and urban stormwater practice. Urban Water Journal, Vol.11(3),p.185-197 ISSN: 1744-9006, 1573-062X; DOI: 10.1080/1573062X.2013.768683

Charlesworth, S., Booth C. A. Ed. (2017).Sustainable surface water management. Wiley ISBN 9781118897706.

CIRIA (2013) *Demonstrating the multiple benefits of SuDS – A business case – Literature Review*. Research Project RP993.

CIRIA (2015a) Sustainable Drainage Systems (SuDS) maintenance and adoption options (England).

CIRIA (2015b) *BeST Case Study: Glasgow City Centre Surface Water Management Plan*. Available from <http://www.susdrain.org/files/resources/BeST/best_case_study_glasgow_swmp.pdf>

Coombes, P.J (2000) Figtree Place: A case study in water sensitive urban development. *Urban Water*, 1(4), 335-343.

Daly D., Jodieri R., McCarthy S., et al (2015). Communication and engagement techniques in flood risk management. CIRIA C751. ISBN 978-0-86017-758-9.

Defra (2011a) *Comparative Costings for Conventional Drainage and SuDS: Red Hill C. of E. Primary School, Worcester*. London: DEFRA.

Defra (2011b) *Comparative Costings for Surface Water Sewers and SuDS: Railfreight Terminal, Telford, Shropshire*. London: DEFRA.

Defra/WSP (2013) Final Surface Water Drainage Report, DEFRA WT1505

Defra (2014) Delivering Sustainable Drainage Systems, September 2014.

Duffy, A., D'Arcy, B., Berwick, N., Wade, R., Jose, N. (2013) *Source Control SuDS Strategic Directions Report*.CRWRR006 (CD 2012 7 R3). Aberdeen: CREW.

Duffy, A., Jefferies, C., Waddell, G., Shanks, G., Blackwood, D. and Watkins, A. (2008) A cost comparison of traditional drainage and SuDS in Scotland. *Water Science and Technology*, 57 (9), 1451-1459.

Duffy, A., McKay, G. and McLean, N. (2015) *Surface water management planning in Scotland*. SuDSnet, Coventry. Available from <http://sudsnet.abertay.ac.uk/documents/SUDSnet2015_Duffyetal_MultipleBenefitsfromDiffusePollutionMitigation.pdf>

Dierkes, C., Lucke T., Helmreich B. (2015).General Technical Approvals for Decentralised Sustainable Urban Drainage Systems (SUDS)—The Current Situation in Germany. Sustainability 7, 3031-3051; doi:10.3390/su7033031

Digman, C J, Ashley, R M, Balmforth, D J, Balmforth, D W, Stovin, V R, Glerum, J W (2012). Retrofitting to manage surface water. C713 © CIRIA 2012 RP922 ISBN: 978-0-86017-915-9 CIRIA Classic House 174-180 Old Street, London

Duffy,A., Buchan A., Winter D. (2013) SUDS as usual? A transition to public ownership in Scotland. Water 21. April. 33-38.

DTI (2006) Global Watch Mission Report - Sustainable drainage systems: a mission to the USA. March.

Dwr Cymru Welsh Water (2016) Sustainable Drainage Systems - Evidence gathering exercise. August.

Ellis, J. B., Butler D. (2015). Surface water sewer misconnections in England and Wales: Pollution sources and impacts. Science of the Total Environment 526, 98–109.

Ellis, J. B., Lundy L. (2016). Implementing sustainable drainage systems for urban surface water management within the regulatory framework in England and Wales. Journal of Environmental Management 183, 630-636

Engineering Nature's Way (2016) SuDS: The State of the Nation 2016

Environment Agency (2015) Cost estimation for SUDS - summary of evidence Report –SC080039/R9

Environmental Commissioner of Ontario (2016) Urban Stormwater Fees: How to Pay for What We Need. November.

Everett G. (2017). Public perceptions of sustainable drainage systems. In: Charlesworth S., Booth C A. "Sustainable Surface Water Management" Wiley-Blackwell. Chapter 21. 285-297. ISBN 9781118897706.

Flintshire County Council (2016) Management of Surface Water for New Development: Guidance Note and Pro-forma, Draft February 2016.

Gaoa, Y., Babin N., Turner A J. et al (2016). Understanding urban-suburban adoption and maintenance of rain barrels. Landscape and Urban Planning 153, 99–110

Goddard, H C. (2012). Cap-and-Trade for stormwater management.Ch 10 in: *economic incentives for stormwater control*. Ed. Thurston H W. CRC Press, ISBN 978-1-4398-4560-8. P211-232

Harris, A. (2015) *RainScape GlawLif*. DŵrCymru Welsh Water. Available from <http://thecccw.org.uk/wp-content/uploads/2015/02/RainScape-Andy-Harris-v2.pdf>

Heal, K., Bray, R., Willingale, S.A.J., Briers, F., Napier, C., Jefferies, C., Fogg, P. (2009) Medium-term performance and maintenance of SuDS: a case-study of Hopwood Park Motorway Service Area, UK. *Water Science and Technology*, 59 (12), 2485-2494.

HR Wallingford (2004). Whole Life Costing for Sustainable Drainage. Report SR 627.

Horton, B., Digman, C.J., Ashley, R.M. and Gill, E. (2015) BeST (Benefits of SuDS Tool) Technical Guidance, CIRIA W045c RP993.

Jarden, K. M., Jefferson A J., Grieser J M. (2016). Assessing the effects of catchment-scale urban green infrastructure retrofits on hydrograph characteristics. Hydrol. Process. 30, 1536–1550.

Jennings T E., Jean-Philippea S R., Willcox A., et al (2016). The influence of attitudes and perception of tree benefits on park management priorities. Landscape and Urban Planning 153, 122–128

Kellagher, R. B B., Wilson S., Thomson R J C. (2013).Final Surface Water Drainage Report. DEFRA WT1505. 31/07/2013 - 06/11/2013.

Kirby, V., Russell S. (2015). Cities, green infrastructure and health. A paper for the Foresight Future of Cities project. Landscape Institute, London, July. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/444322/future-cities-green-infrastructure-health.pdf. [Accessed July 2016]

Li, H. (2015). Green Infrastructure for Highway Stormwater Management: Field Investigation for Future Design, Maintenance, and Management Needs. Journal of Infrastructure Systems, ASCE 21 (4) ISSN 1076-0342/05015001(9).

Lucas, R., Earl E R., Babatunde A O., Bockelmann-Evans B N. (2015). Constructed wetlands for stormwater management in the UK: a concise review, Civil Engineering and Environmental Systems, 32:3, 251-268.

O'Brien, C. D. (2015). Sustainable drainage system (SuDS) ponds in Inverness, UK and the favourable conservation status of amphibians. Urban Ecosyst 18:321–331.

Ofwat (2013) Drainage Strategy Framework (For water and sewerage companies to prepare Drainage Strategies): Good practice guidance commissioned by the Environment Agency and Ofwat. May 2013.

Ordinance Survey (2016) 1:25 000 Scale Colour Raster. Available from <http://digimap.edina.ac.uk/datadownload/osdownload> accessed 11/11/2016,

Patmore, C. (2014). Delivering the Vision for SuDS in Oxfordshire. Presentation to CIRIA 'SuDS not duds' event. 11th March. http://www.susdrain.org/resources/presentations.html

Rhondda Cynon Taff (2014). SECTION – D. Commuted Sums Payments For Future Maintenance In Relation To Adoption And Transfer Of Infrastructure Assets. January.

RICS (2016) Placemaking and value RICS information paper, UK. 1st edition, February 2016

Royal Haskoning (2012a) *Lamb Drove Sustainable Drainage Systems (SuDS) Monitoring Project*. Peterborough: Royal Haskoning.

Royal Haskoning (2012b) *Cost and Benefits of Sustainable Drainage Systems*. Peterborough: Royal Haskoning.

Scottish Water (2014) SUDS – Vesting guide. November.

Scottish Water (2015) Sewers for Scotland 3rd ed. http://www.scottishwater.co.uk/business/connections/connecting-your-property/sewers-for-scotland-and-suds

Shirley-Smith C., Butler D. (2008). Water management at BedZED: some lessons. Proceedings of the Institution of Civil Engineers. Engineering Sustainability 161. June 2008 Issue ES2 Pages 113–122 doi: 10.1680/ensu.2008.161.2.113. Paper 700017

Smale, K. (2015) *Technical Excellence: Llanelli Rainscape project*. New Civil Engineer. Available from <https://www.newcivilengineer.com/technical-excellence/technical-excellence-llanelli-rainscape-project/8678229.article>

Southern Water (2016). Integrated water cycle management.

Stephenson A G. (2008). A Holistic hard and soft SUDS system used in the creation of a Sustainable Urban Village Community. Proc. 11th Int. Conf. Urban Drainage. Edinburgh.

SuDS working party (2009) SuDS for roads. WSP Development and Transportation, 4/5 Lochside View, Edinburgh Park, Edinburgh EH12 9DH

Thorne C R., Lawson E C., Ozawa C., et al (2015). Overcoming uncertainty and barriers to adoption of Blue-Green Infrastructure for urban flood risk management. Journal of flood risk management. DOI: 10.1111/jfr3.12218

Transport for London (2016) SuDS IN LONDON: A DESIGN GUIDE (DRAFT V9 18_08_2016)

UK Government (2010) Flood and Water Management Act, London: HMSO. http://www.legislation.gov.uk/ukpga/2010/29/contents

UK Water Partnership (2015). Future Visions for Water and Cities - A Thought Piece.

Vineyard D., Ingwersen W W., Hawkins T R. et al (2015). Comparing Green And Grey Infrastructure Using Life Cycle Cost And Environmental Impact: A Rain Garden Case Study In Cincinnati, OH1. Journal of The American Water Resources Association. Vol. 51, No. 5 American Water Resources Association October 2015

Visitacion, B.J., Booth, D.B. and Steinemann, A.C. (2009) Costs and benefits of storm-water management: case study of the Puget sound region. *Journal of urban planning and development*, 135(4), 150-158.

Water UK (2016) 21st Century Drainage Programme.

Watts N., Adger N W., Agnolucci P., et al. (2015). Health and climate change: policy responses to protect public health. The Lancet. Vol. 386, November 7th. 1861-1913.

Welsh Government (2015a) Water Strategy for Wales: Supporting the sustainable management of our natural resources.

Welsh Government (2015b) The Well-being of Future Generations (Wales) Act 2015

Welsh Government (2016) Recommended non-statutory standards for sustainable drainage (SuDS) in Wales – designing, constructing, operating and maintaining surface water drainage systems

West Country Rivers (undated) LOCAL ACTION TOOLKIT: Ecosystem services in urban water environments. Urban Practitioner's 'Toolbox' of Interventions

Wolf, D.F., Duffy, A.M. and Heal, K.V. (2015) Whole life costs and benefits of sustainable urban drainage systems in Dunfermline, Scotland. *Proceedings of the 2015 International Low Impact Development Conference*. Houston: United States, 19th-21st January 2015.

Woods- Ballard B., et al (2007). The SuDS manual. CIRIA.

Woods-Ballard, B, Wilson, S, Udale-Clarke, H, Illman, S, Scott, T, Ashley, R and Kellagher, R (2015) The SuDS Manual, C753, CIRIA, London, UK. ISBN 978-0-86017-760-9

Yuen, B. *&* Hien, W.N. *(*2005*)* Resident Perceptions and Expectations of Rooftop Gardens in Singapore*.* Landsc. Urban Plann.*,* 73(4)*,* 263–276*.*

Appendices

Appendix 1 List of case studies assessed in review of evidence

Location	Case study name
UK	Hopwood Motorway Service Area
	Killingworth and Longbenton
	Lamb Drove, Cambridge
	South Dalmarnock
	Daniel's Cross, Shropshire
	Roundhay Park
	Dunfermline Eastern Expansion (DEX)
	Hadley, Shropshire
	Railfreight Terminal, Telford
	Red Hill Primary School, Worcester
	Priory Common
	Llangefni Redevelopment
	Riverside Court, Stamford
	Ribblesdale Road, Nottingham
	Stebonheath Primary School, Llanelli
	Queen Mary's Walk, Llanelli
	Greener Grangetown, Cardiff
	Ripple Effect, Coventry
	Rose Revera, Swansea
	Elvetham Heath, Hampshire
	Caw Burn SuDS
	Cromer
	Harrow Way
	Glasgow Green
	Caledonian Road Housing, Islington
	Matchborough First School, Redditch
	Gresham Avenue Flood Alleviation Scheme
International	Puget Sound Stormwater Management
	Alnarpsgården Swedish University of Agricultural Sciences (SLU)
	Arlington, Minnesota
	Figtree Place, Newcastle (NSW)
	Portland Watershed Management Plan, Oregon (Green streets)
	Mimico Creek Watershed
	Sea Street, Seattle

Appendix 2 'Top 10' case studies

1.Lamb Drove, Cambourne

Project Background

A residential development of approximately 35 homes developed and owned by Cambridge Housing Society. The aim was to showcase practical and innovative sustainable water management techniques incorporating SuDS, flood resilience and resistance in new residential developments.

Costs: Construction & Maintenance (PV)

Capital costs of the scheme (per property):
- SuDS = £5,645 (2006)
- Conventional Drainage = £5,960 (2006)

SuDS were £314 per property cheaper which provided a total saving of approximately £11,000 (2006) in comparison with conventional drainage systems in total.
Maintenance costs are £1,340 per year (2011), slightly less than suggested by impact assessments for SuDS for:
- Litter removal
- Vegetation cutting
- Manual sweeping (porous paving system)

In addition, piped drainage system maintenance would cost approximately £1,400/yr based on 35 properties. Therefore, at £1340/yr (2011) the SuDS are slightly cheaper to maintain than the estimated cost for conventional drainage.

Benefits: Monitored performance and valued benefits (PV)

- Improvement in biodiversity, ecology and subsequent quality of life at Lamb Drove compared with typical residential areas.
- The Lamb Drove Site has attenuated surface water flows, significantly reduced peak flows, particularly during heavy rainfall events on 13th and 14th December 2008.
- Improved water quality in comparison to piped drainage systems.
-Water butts collected for reuse applications, such as, watering gardens. The omission of a new storm sewer connection should reduce bills for residents of approximately £30/yr/household (2011) as they avoid annual payments for stormwater disposal charges to the sewerage undertaker.

Summary

Changes from initial proposals had resource implications suggesting it is necessary to include the confirmation from all the key stakeholders and organisations early in the process including the Master Planning stage and start of the Development Plan. However, key benefits relate to installation of water butts and avoidance of stormwater charges £30/yr/household (2011). Capital costs £5,645 (2006), compared with £5,960 (2006) for conventional drainage. At £1340/yr (2011) SuDS maintenance is cheaper than conventional drainage.

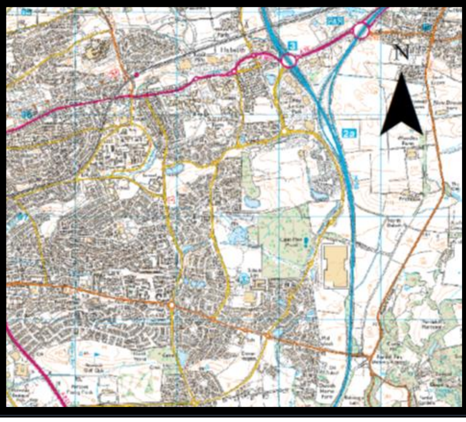
References

1. Royal Haskoning (2012)
2. Royal Haskoning (2012b)

2. Dunfermline Eastern Expansion (DEX)

Project Background

Downstream water quality and flooding issues necessitated a holistic approach to drainage planning and the site has become a European showcase for the application of Sustainable Urban Drainage Systems (SUDS). There are a variety of components across the management trains, including soakaways, filter drains, swales, ponds and wetlands. Multiple stakeholders involved. Two WLC assessments were undertaken.



Costs: Construction (£) and Whole Life (£ PV)

Site	Const.	WERF[1] WLC[2]	SuDS for road WLC
Halbeath Pond	101,193	203,016	167,584
Linburn Pond	174,388	222,853	248,031
The Wetland	65,847	146,289	215,323
Masterton Lea	64,808	123,005	224,456
Pond 6	149,951	216,631	234,955
DM Basin S	9,397	106,824	117,242
DM Basin N	21,986	140,002	110,613
Pinkerton Basin	19,711	79,575	113,889
UI Basin	23,933	199,654	186,969
Roundabout Basin	29,082	109,502	195,805
Highway Swale 1	32,188	108,669	68,752
Highway Swale 2	103,918	180,399	159,027
Highway Swale 3	58,549	135,030	102,329
Highway Swale 4	47,265	123,746	87,955
Wetland swales	192,574	269,055	273,037

[1]Water Environment Research Foundation
[2] Whole Life Costs

Benefits: Ecosystem Services Assessment (£ PV)

Site	Water Quality	Flood	Amenity
Halbeath Pond	101,193	21,945	0
Linburn Pond	174,388	73,950	5,700
The Wetland	65,847	68,367	0
Masterton Lea	64,808	25,223	17,100
Pond 6	149,951	26,970	222,300
DM Basin S	9,397	396	0
DM Basin N	21,986	1,212	0
Pinkerton Basin	19,711	1,050	68,400
UI Basin	23,933	1,355	51,300
Roundabout Basin	29,082	1,752	0
Highway Swale 1	32,188	2,318	0
Highway Swale 2	103,918	7,483	0
Highway Swale 3	58,549	4,216	22,800
Highway Swale 4	47,265	3,403	114,000
Wetland swales	192,574	13,867	85,500

Summary

Total costs = £1,270,511; Total benefits = £1,935,397

References

1. Duffy *et al*. (2008)
2. Wolf *et al*. (2015)

3. Coventry, Retrofitting Green Streets

Project Background

Coventry is heavily urbanised, with issues of flooding from multiple sources, and failing WFD status for the River Sherbourne. This project aimed to investigate the benefits from retrofitting SuDS to create green streets in Coventry. No schemes have been implemented to date, but considerable assessments have been made.

Costs: Construction (£) and 'do nothing' scenario (£/over 40 years)

The total costs of constructing 'green streets' across Coventry: £121,000

City wide sewer flooding compensation costs amount to £3.6-million, £83-million (over 40yrs).

For a 60m^2 roof the surface water runoff would be 36m^3 per year. Using costs for pumping and treating wastewater estimated by STW, and assuming half of Coventry is served by combined sewers, the total value is calculated to be as high as £296,000 per year, or £6.9- million (over 40 yrs).

Reduced energy costs at £32 per tree. The benefit in Stoney Road could be £800 per year or £18,500 (40yrs) (not accounting for likely increases in energy costs). Across Coventry as a whole this gives £2.1 million per year, or more than £48.8-million (40 yrs).

Benefits: across ecosystem services (£/over 40 years)

The total benefits of constructing 'green streets' across Coventry: £1.5billion (over 40 yrs)

Water Quality – Improvement of 10km of Sherbourne, £4.1 million (over 40 yrs)

Drainage Charges - £5.7 million in bill reductions for householders, £131 million (over 40 yrs)

Contingent Property Valuation - Coventry as a whole this would be £1.2-billion

Carbon Sequestration - Up to £4,550 per household or more than £100,000 (over 40 yrs)

Air Quality Improvements - £12 million (over years)

Employment – Associated employment are worth more than £7.4 million (over 40 yrs)

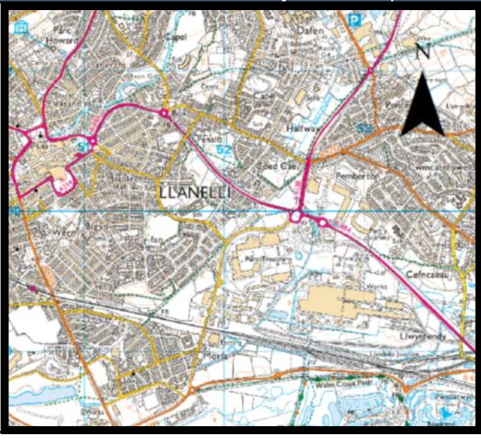
Summary

Total costs = £121,000, Total benefits = £1.5 billion (over 40 yrs)

References

1. CIRIA (2013)

4. Stebonheath Primary School, Llanelli



Project Background

Stebonheath Primary School is situated on a hill top, surrounded by a number of residential streets where surface water flooding has occurred. The school has very little green space, but has a car park to the front and a large playground to the rear with opportunities to retrofit, as part of the wider DwrCymru Welsh Water (DCWW) Strategy. This was subsequently verified by modelling.

Costs: Capital, Whole-Life and cost avoidance associated with traditional drainage

£500,000 (as part of the wider £15 million for the DwrCymru Welsh Water's strategy)

WLC - £3.69 million across the DCWW strategy

These came to a total capital cost of £3.31 million, and an estimated whole life cost of £3.69 million. This represented a 57% whole life cost saving compared with the ruled out traditional solutions.

Benefits: Performance related

There has been monitoring to show a 70% reduction in flow accumulation in the CSO network. The DCWW scheme has had WLC considered across the Queen Mary's Walk, Stebonheath School, and Glevering Street schemes.

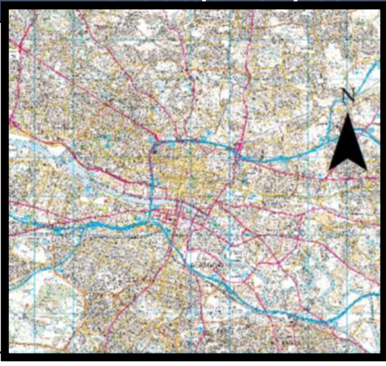
Summary

All of the works were within the boundary of the school on the private drainage system, under private agreement with the local authority. This is a new way of working for DCWW as water and sewerage companies usually rely on using statutory powers to undertake works. Following the completion of the defects period, the system has been handed back to the local authority for long term operation and maintenance from 2015.

References

1. Harris (2015)
2. Brockett (2015)
3. Smale (2015)

5. Glasgow City Centre



Project Background

Glasgow faces many issues with contested space and need for surface water management. Economic appraisal was conducted to consider the role of SuDS across the city. This considered retrofit and new-build SuDS options that can provide multiple benefits over a 60 year appraisal time-frame.

Costs: WLC (PV £ over 60 yrs)

Total costs: £2.83 million

Component	Unit	CAPEX (£)	OPEX (£)	WLC (£)	WLC/yr (£)
Pond/wetland	m^3	55	37	858	14
Basin	m^3	49	27	577	10
Green routes major	m	1092	5	1533	26
Green routes minor	m	1111	6	1978	33
Rainladder	m	408	0.66	1512	25
Green Roof	m^2	51	1	104	2
Geocelullar	m^3	265	18	772	13
Permeable Paving	m^2	100	0.59	174	3
Deep Gutter	m	180	0.15	265	4
Bioretention	m^3	284	0.36	451	8
Rill	m	239	0	239	4
Swale	m	325	4	487	8
Raised threshold	nr	1500	0	1500	25
Waterbutt	2nr	306	39	1316	22
Pond/basin	nr	5009	0	7923	132
Swale	nr	3952	0	6250	104
Petrol interceptor,geocelullar	nr	1030	0	1629	27

Benefits: across ecosystem services (£ over 60 yrs)

The majority of benefits are associated with flood risk reduction. Other potentially important benefits are recreation, water quality and amenity.

Total PV benefits = £68 million

Summary

The estimated benefits of the option are always greater than the costs. The central estimate after confidence is applied gives a benefit cost ratio if 2.3. This is 1.3 under low sensitivity and 3.7 under high sensitivity.

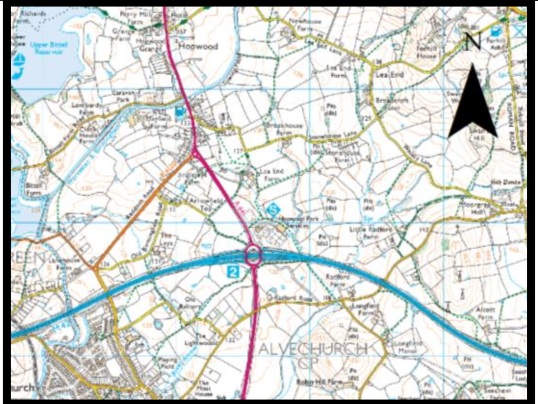
References

1. Duffy (2015)
2. CIRIA (2015b)

6. Hopwood Motorway Service Area SuDS

<u>Project Background</u>

The construction of the Hopwood Motorway Service area (MSA) SuDS receives runoff from the amenity building, car park, coach park, a fuel filling area and HGV park. A variety of SuDS management trains were designed in series to control runoff and diffuse source pollution from the MSA before it reaches the wildlife reserve and Hopwood Stream.



<u>Costs: Construction & Maintenance</u>

- HR Wallingford (2004) has estimated capital costs of £56,000.
- Maintenance costs were estimated at approximately £5,910 annually.
- Costs for occasional maintenance ranged from £250 to £2,000 (2004), dependent on the activity.
- In reality, maintenance costs accounted for £2,500 of the £15,000 landscape budget in 2007 compared to £4,000 for conventional drainage. Sediment was removed in October 2003 at a total cost of £554 for inspection, vegetation and sediment removal, and transfer of dewatered vegetation matter for composting on site.

Currently only some £350 are being spent per annum as the management believe this to be sufficient in the absence of obvious signs of failure.

<u>Benefits: Monitored performance and valued benefit</u>

Performance benefits:

- Runoff rates of 5l/s/ha achieved.
- Water quality improved during passage of the series of SuDS devices.
- Pre-treatment components (e.g. grass filter strip) were successful in removing the majority of contaminants before entering the management train.
- Outlet valve of the spillage basin in the first management train retain a 200l diesel spillage,

Valued benefit:

A conservative value of £0.10 per car per visit was used. As there are 500 car park spaces and it has been assumed 2% (1000 visitors) of the visitors appreciate the SuDS, the benefit has been calculated as £2/day (£720/yr).

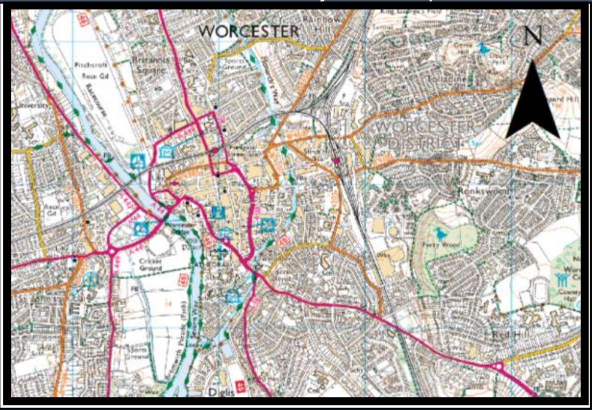
<u>Summary</u>

Estimated capital costs of the SuDS were £56,000. Maintenance costs were cheaper than anticipated and activities have been reviewed since. However, long-term business plans need to be considered before the construction of SuDS to ensure an annual budget is set-aside specifically for maintenance. The annual budget has now reduced to £300.

<u>References</u>

1. Heal *et al*. (2009)
2. HR Wallingford (2004)

7. Red Hill Primary School, Worcester



Project Background

The Red Hill Primary School building and hard surfaces surrounding the area provided limited space for runoff to encourage infiltration and put stress on the new storm water sewer. Therefore, SuDS were implemented to provide storage space for flow attenuation.

Costs: Estimated Construction costs for different runoff rates

Higher costs for 8l/s/ha accounts for the extra storage units that would be integrated with the SuDS components. The SuDS trains implemented achieved 8l/s/ha, although the values in the table below should be considered as estimated costs.

	150l/s/ha	
	Traditional Drainage (£)	**SuDS (£)**
Cost	99,100	46,900
Less Amenity Works on SuDS		-2,400
Preliminaries	9,900	4,900
Contingency	5,000	2,500
Total	**114,000**	**51,900**
	50l/s/ha	
	Traditional Drainage	**SuDS**
Cost	151,000	46,900
Less Amenity Works on SuDS		-2,400
Preliminaries	15,100	4,900
Contingency	7,600	2,500
Total	**173,700**	**51,900**
	8l/s/ha	
	Traditional Drainage	**SuDS**
Cost	237,000	55,100
Less Amenity Works on SuDS		-2,400
Preliminaries	23,700	5,800
Contingency	11,900	2,900
Total	**272,600**	**61,400**

Benefits:

- An avenue of lime trees finish in a small open woodland at the lowest part of the site.
- A spout was designed as an amenity feature instead of using a simple pipe solution.
- SuDS have been incorporated as an educational tool to support environmental studies and other curriculum subjects. However, a 1m high toddler exclusion fence has been put in surrounding the swale maze and wildlife pond.
- Rainwater harvesting scheme stores 20,000 litres of water used for flushing toilets.
- Large overhangs from the roof act as a canopy to protect level thresholds required for disabled access during heavy rain.
- Frogs, dragonfly, nymphs, other aquatic invertebrates and wetland plants can be found in the pond.

Summary

SuDS can be used for educational purposes – bringing water to the surface for use in safe, fun and instructive ways. SuDS are cheaper than traditional drainage, despite the different requirements for runoff rates.

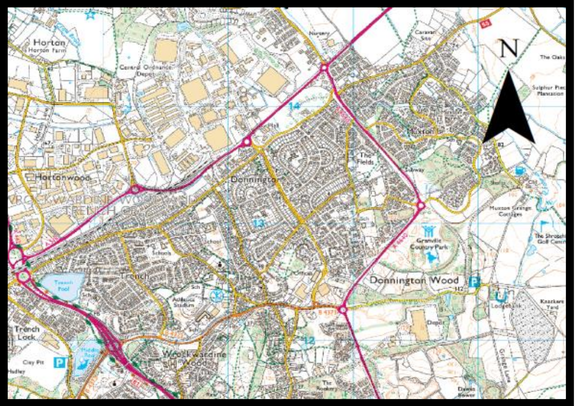
References

1. DEFRA (2011a)

8. Railfreight Terminal, Telford

Project Background

The location is in a modern industrial estate with an opportunity to provide a 'green' supply chain by implementing SuDS and compensating for emissions. This includes a variety of surface water management components to protect an aquifer used for the extraction of potable water.



Costs: Construction & Maintenance

- Total estimated cost for the sewer features were £372,259 and £51,088 for the SuDS. This is a saving of £321,171. The traditional option was originally deemed to be too costly for the scheme to go ahead.
- In terms of maintenance - if the costs to remove surplus material was discounted the saving would still be £253,000.
- Although an effort to reuse surplus material on site was advised, there was still a large quantity to dispose off-site.
- The out-turn costs for the SuDS scheme were in practice substantially reduced as much of the excavation work took place as part of the construction of the general site. This would not have been the case for the sewer works constructed within trenches excavated and backfilled at a slower pace than the general site earthworks.

Benefits:

- SuDS have been accommodated for in areas that would have been used for landscaping and have increased the attractiveness of the Terminal area.
- Enhancing habitats and positive effects on biodiversity.
- Slow conveyance and attenuation of flows have the effect of removing pollutants, reducing diffuse pollution load.
- Maintenance is carried out by Terminal staff or landscape contractors. A piped system would have led to annual visits from specialist contractors.
- Use of SuDS has saved in excess of 100 HGV journeys or in excess of 8,000 vehicles in relation to the construction of piped solutions.

Summary

SuDS were considered to save capital costs and the decision has been vindicated with a saving of £321,171 in comparison with conventional drainage. The significant cost reduction enabled more investment to be placed in features that directly contribute to the functioning of the facility.

References

1. DEFRA (2011b)

9. Figtree Place, Newcastle (Austrailia)

Project Background

Figtree Place was identified as a sensitive area and innovative ways to source stormwater for use were proposed. This was used as a prototype site for water sensitive urban design (WSUD) that includes 27 residential units and an unconfined aquifer for water retention and retrieval.

Costs: Construction & Water Consumption

Basic project costs are as follows:
Development cost (27 units, etc.): $2,700,000
"Water-sensitive" design elements (rain tanks, pumps, recharge basin and plumbing): $89,600
Alternative conventional stormwater system elements ("greenfield" site): $115,500
Hence, the "water-sensitive" elements of the design represent a saving, when compared with conventional practice, of $25,900 or 1% of development cost.
A 30% reduction in internal mains water consumption was experienced during this period. Based on these performances, it is anticipated that long-term internal water saving of approximately 45% will be recorded at Figtree Place.

Benefits: Valued benefits (AUD$)

The expected annual water saving for Figtree Place and the adjacent Bus Station is calculated as follows:
Total water saving (residences): 1190 kL/annum

Irrigation saving: 830 kL/annum

Bus-washing saving: 1,700 kL/annum

Hunter Water Corp. charges: $0.92 kL/annum

Hence, expected overall savings: $3422 per annum

Assuming that the savings are invested for a ten year period using a discount rate of 6% the annual value of the construction savings is $3478. The approximate annual value of the cost saving at Figtree Place (alone) is:
Water savings: $1858

Annual investment saving: $3478

Less annual depreciation and maintenance costs: $1300

Total annual saving: $4036

Summary

If policies are adopted to encourage WSUD and many such projects are completed, then substantial urban infrastructure cost savings to the community are likely to materialise. SuDS used for water reuse could be advantageous, saving on costs per property.

References

1. Coombes (2000)

10. Puget Sound Storm Water Management (USA)

Project background

A case-study to holistically consider BMPs for surface water management regionally, where floods and ecological impacts come at great cost. Data used in this study was to identify and quantify the economic and ecological costs of storm-water-related damage and storm water management programs.

Costs: Construction& 'do nothing' scenario	Benefits: Cost avoidance over 100 year cycle
NPDES (National Pollutant Discharge Elimination Scheme) Phase 1 Jurisdictions in the Puget Sound region spent over $138 million an average of $36/capita/year to meet the 1995 NPDES permit requirements. Capital improvement plan costs ranged from $120,000 to $20 million per year $6 to $127/capita/year in the Puget Sound region with the division of programme area spending varying. Drainage maintenance and flood control costs three jurisdictions $1.5 million to $4.6 million annually $4 to $33 per capita/year. Improving the water quality of a single catchment due to a single contaminant has reported costs as much as $1 million ($1.87/capita). Treatment costs for storm-water discharge by various Puget Sound jurisdictions range from $400,000 to $7 million. Individual restoration projects associated with stormwater discharges have cost individual Puget Sound jurisdictions $570,000 to as much as $100 million.	Primarily considered as a means of cost avoidance over 100 year management cycle (see costs). Other wider benefits recorded qualitatively: Primarily avoided damages, were presumed to exceed expenditures, but most jurisdictions have not systematically evaluated programme effectiveness. The costs of stormwater damages explored in this study, namely, flooding and property damage, degradation of water quality, loss of estuarine and freshwater habitat, and loss of natural resources. Green space was also considered a wider benefit of the Puget Sound holistic approach, incorporating stormwater management and planning of recreational space.

Summary

Total capital costs of construction were $120,000 - $20 million per year, total cost avoidance benefit not systematically evaluated for programme effectiveness. Furthermore, implementing BMPs in the planning stages of development projects, may be the most effective means of mitigating and avoiding stormwater impacts/ unwanted consequences.

References

1. Visitacion *et al*. (2009)

Appendix 3 List of stakeholder interviews conducted

Organisation	Name	Title
Welsh Government	Francois Samuel	Head of Construction
	James Morris	Head of Flood and Coastal Risk Management
	Rob Hay	Head of Local Government Funding & Performance
	Jonni Tomos	Senior Planning Manager - Climate Change Adaptation
	David Thomas	Senior policy manager for flood & coastal risk management
	David Holmes	Senior Development and Standards Manager
	Steve Spode	Head of Ecosystem Management and Implementation
Welsh Local Government Association	Jean-Francois Dulong	Flood and Water Officer
Natural Resources Wales	Martyn Evans	Woodland Senior Advisor (Team Leader)
	Mark Squire	Knowledge, Strategy & Planning Advisor
Caerphilly local authority	Michelle Johnson	Senior Engineer
Home Builders Federation	Steve Weilebski	Chair, HBF Technical Committee
RSPB	Carly Jones	Water Project (Policy) Officer
	Simon Wightman	Senior Land Use Policy Officer
Wildfowl and Wetlands Trust	Hannah Freeman	Government Affairs Officer
	Andy Graham	Head of Community Working Wetlands
CC Water	Deryck Hall	Head of Policy and Research
	Steve Grebby	Policy Manager
	Bob Gilchrist	Local Consumer Advocate (Wales)
Severn Trent Water	Paul Hurcombe	Strategic Planning Analyst - Growth & Resilience
Flintshire Copunty Council	Ruairi Barry	Project Engineer (Flood and Coastal Risk Management)
Dwr Cymru Welsh Water	Michelle Russ	Regulatory Policy Adviser
	Julian Hill	Regulation &. Legislation Manager
	Tony Harrington	Director of Environment
	Peter Perry	Chief Operating Officer
Wrexham County Borough Council	Neil Taunt	Senior Flood Management Officer
City and County of Swansea	Dan McAulay	Senior Drainage Engineer
City of Cardiff Council	David Brain	Team Leader (Flood and Water Management)
Rhondda Cynon Taff County Borough Council	Andrew Stone	Strategic Projects Manager
RICS	Tony Mulhall	Associate Director Land Professional Group
	Alan Carter	Head of Project Data
Portsmouth University	Prof Mark Gaterell	Professor of Sustainable Construction
	Roshni Jose	Research Associate
Illman Young	Sue Illman	Former President, Landscape Institute