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Cost-benefit of SUDS retrofit in urban areas

Science Report – SC060024

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Steve Killeen

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Head of Science

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1. Floods put spotlight on UK's drainage systems

The large scale flooding in many parts of the country during the summer of 2007 blighted the lives of the many people affected and caused an estimated £3 billion worth of damage to property. The report from the Independent Review Body on the floods in Hull identified the drainage system as being overwhelmed by the magnitude of rainfall.

OFWAT estimates that about half the average annual flooding incidents (between 5,000 and 7,000) are a result of the capacity of the drainage system being exceeded. Rainfall events such as those experienced during June and July 2007 are exceptional one in 150 events and beyond the one in 30 rainfall events that drainage planning design currently stipulates. The report into the Hull flooding also expressed concern that drainage systems would come under increasing pressure as a result of climate change, which would likely make these types of rainfall events more common. This pressure on the current capacity of urban drainage systems to cope with future storm events would likely be compounded by the additional amount of surface water run-off from large-scale housing development.

The **Association of British Insurers** (ABI) has said it wants the Government to spend more on flood defences and rethink plans to build new homes on potential flood plains.

Currently, insurers give flood cover to houses, even those at risk, as long as the Government commits to investing sufficient sums on a sustained basis to provide flood defences in at-risk areas.

In July 2007, Environment Secretary Hilary Benn announced that spending on flood risk management and defences would rise from £600 million to £800 million in 2010-11. But the ABI said there is a need for an additional £150 million for maintenance.

A letter from the ABI to Mr Benn noted that in some places watercourses and drains are blocked due to inadequate maintenance, leading to some flooding taking place in areas not identified as being at risk.

ABI Director-General Stephen Hadrill said: "The scale and impact of the floods has been massive. The cost to the industry of over 60,000 claims is approaching £3 billion and more claims continue to come in."

Issues of storm water management are not limited to flooding, but concerns water quality. Water pollution occurs during flood events from Combined Sewerage Overflows (CSOs) discharges and from significant quantities of pollutants that are washed from paved surfaces into surface water drains and watercourses. These pollutants mainly come from a wide range of urban activities, such as transport, on street activities such as car washing, car parks and from industrial estates. The key pollutants involved are sediments, oils, fuels and toxic metals.

Increased housing and climate change can only make problems worse

Flooding and the risk of flooding has always been an important fact of life in England and Wales, with around 10 per cent of homes at risk and 400,000 of these homes at very high risk of flooding. Government plans to increase the number of new houses by three million before 2020[1] have the potential to place a significant additional burden on existing drainage systems. In many cases, the additional pluvial flood risk is generated by an increase in the volume of storm water run-off from the creation of more impervious surface areas in the watershed. The ICF and RPA report, *"The potential costs of climate change adaptation for the water industry"*[2], prepared for the Environment Agency, estimates costs to the water industry of increasing the capacity of drainage and storm water management systems using traditional drainage systems to cope with climate change as being about £1 billion per year.

2. Rationale for considering SUDS retrofitting

The SUDS (SUstainable Drainage Systems) approach to managing surface water is increasingly important in drainage planning. This approach uses a range of techniques including swales, permeable paving and green roofs to mimic the natural drainage of a site. They increase infiltration of water where it lands and reduce the speed of run-off. The use of SUDS in new developments is an important component of the flood risk planning process of PPS25. But in practice the approach has faced barriers such as the issue of who is to take responsibility for ownership and maintenance. SUDS adoption is an important issue, since with some types of SUDS ownership and responsibility options will influence the cost-benefit results. SUDS adoption is currently being considered in a Defra consultation.

SUDS in new housing developments alone will not make a significant contribution to reducing flood risk and improving water quality. New developments only account for a small percentage of housing stock per year (around one per cent). Hence, there is a need for a combined strategy for installing SUDS in new developments and retrofitting them to existing ones. This study examines this potential for retrofitting SUDS at a national level, along with an initial analysis of costs and benefits.

SUDS can be retrofitted under a number of conditions, for example at the "end of life" of existing paved areas. Other conditions include:

- at the time of building refurbishment;
- during drainage improvement for large areas such as trading estates or where there are unsatisfactory CSOs;
- through incentives to property owners to "disconnect" roof or driveway run-off from the public drainage system.

This study takes as a baseline the implementation of traditional drainage techniques (hard drainage systems into sewage systems or separate surface drainage systems) and compares the costs and benefits of replacing traditional systems with SUDS. Where relevant, these are applied at the normal end-of-life of the current traditional systems or hard surfaces.

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[1] Statement by Minister of State for Housing to House of Commons on 23 July 2007

[2] http://www.environment-agency.gov.uk/economics

Data on the surface areas available for undertaking SUDS retrofitting comes from Generalised Land Use database from Communities and Local Government.[3]

Table 1.1: Description and implementation scenario for SUDS retrofit

Technique	Description	Implementation scenario	Coverage potential for retrofit
Permeable paving	Instead of using impervious bituminous or concrete (conventional surfaces), permeable paving blocks are used.	When conventional surfaces require resurfacing, approximately every 20-40 years, it is possible to replace with permeable surfaces. Benefits will come from reduced drainage charges and from reduced CAPEX and OPEX costs.	It is estimated that it is possible to retrofit around 50 per cent of OFF ROAD hard standing surfaces with porous paving. This is a conservative judgement based on an expert view. Further research might indicate that this percentage could be increased.
Rainwater harvesting	Disconnection of premises from the drainage system to provide an “in-house” collection and storage system for rainwater that can be used for non-potable water use.	Large premises could disconnect from drainage infrastructure and install a rainwater harvesting system. This would most likely be done during building refurbishment programmes. Benefits would arise in reduced drainage charges and water bills.	Around 75 per cent of industrial and commercial premises could adopt rainwater harvesting systems, and 50 per cent of public buildings, such as schools and hospitals, could do the same.
Water butts	Water butts store rainwater from roof drainage and are particularly applicable for household properties with gardens. Their attenuation benefits are limited when they are full.	This is a relatively easy and cheap option for all households (not individual apartments). Water butts are however likely to be full when attenuation for flooding is required and some further storage needed. Benefits for households will be reflected in lower water bills.	There is the potential for 90 per cent of semi-detached and detached properties to install water butts, and for around 45 per cent of terraced housing.
Swales, infiltration ditches, filter drains	These drainage systems provide good attenuation for surface water run-off, particularly from highways.	Generally these SUDS techniques have greater benefits for new roads and hard surfaces – greenfield or brownfield – but can also be introduced during road upgrading projects. Benefits are most likely to be realised in their local context.	These SUDS techniques are more limited in a retrofit context, particularly in an urban situation. Roads in rural areas have a greater potential for retrofitting, around 20 per cent, whilst in urban areas this might be as low as four per cent.

[3] http://www.communities.gov.uk/publications/planningandbuilding/generalisedlanduse

The option of retrofitting "green roofs" was also looked at. The available information on roof areas was used to assess the benefits of rainwater harvesting and water butts, but green roof retrofitting has other requirements, particularly on the load-bearing capability of buildings and damp proofing requirements. It was not possible to estimate the potential for retrofitting without more information on the load-bearing capacity of current building stock. Hence, this option was not included in the final analysis.

3. Identifying costs and benefits of SUDS retrofitting

The picture below provides an overview of the wider benefits of SUDS and gives reasons why they might not arise in particular local circumstances, for instance where there is significant infiltration for an old drainage and sewerage system.

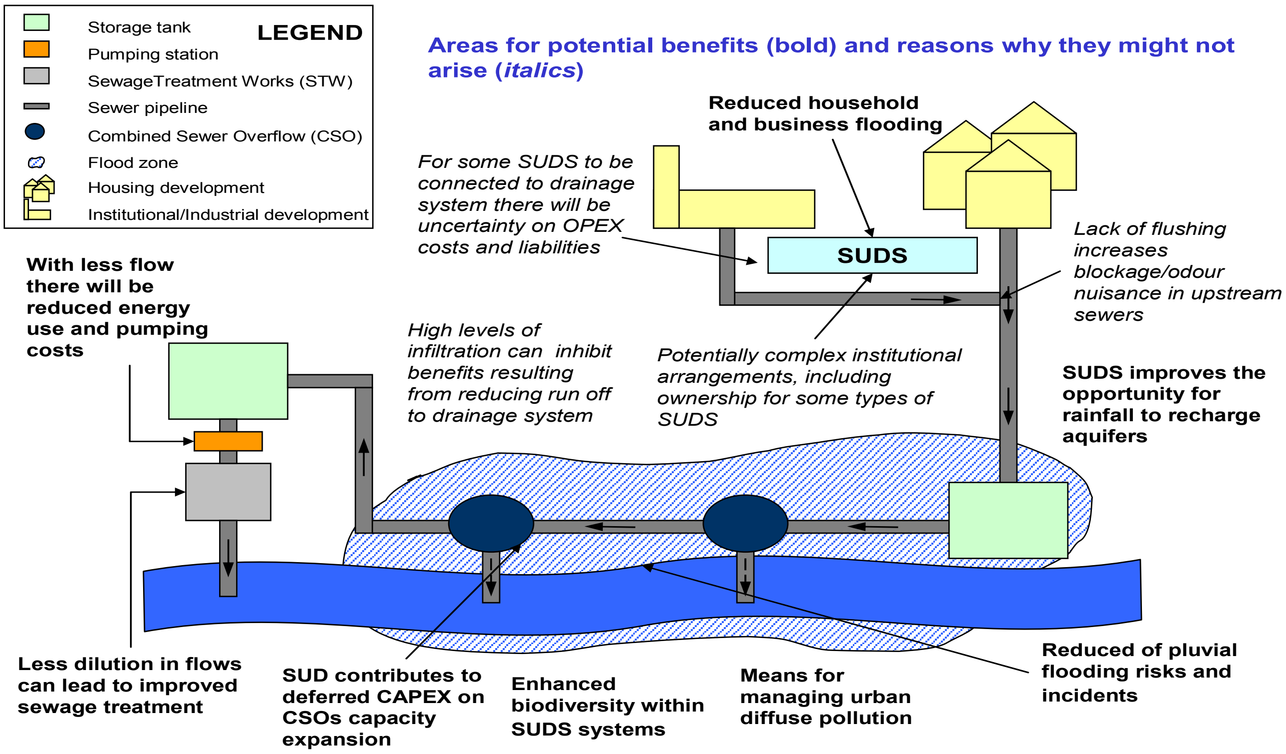

Figure 1.1 Benefits of SUDS

The nature and extent of benefits will depend on local conditions. For example, the extent of infiltration to the local sewer and drainage system may inhibit the realisation of these benefits, because in this situation any diversion or attenuation of surface water run-off from the drainage system will make an insignificant impact.

Benefits likely to be derived from retrofitting SUDS in many local contexts include:

1. Extensive use of SUDS will lessen the amount of urban run-off into the drainage and sewer system and hence lessen the ***run-off load*** at combined sewer overflows and sewage treatment works which, in many urban centres, are already near full capacity. This may help defer investment in expanding their capacities. In addition, by reducing run-off load, SUDS and an appropriate retrofitting strategy will

contribute to the ***reduction of pluvial flooding risks and incidents.***

2. SUDS provide a means of managing and treating urban diffuse pollution at or near the source (managing the ***pollution content***) such as industrial or construction sites and petrol forecourts. They will help reduce downstream pollution risks caused by CSO surcharging. Artificial drainage ditches and swales will intercept run-off and remove pollutants before returning it to rivers.

3. Some SUDS, such as water butts and rainwater harvesting, provide an alternative source for non-potable water within domestic and commercial settings. These will help to meet ***water efficiency targets***.

4. SUDS provide a route for ***additional recharge of aquifers*** in areas under water supply stress, and this benefit will be especially applicable in the South East of England, thus helping to make savings on new water resource investment.

5. Reducing or limiting volume of flow to the sewage treatment works wil help ***reduce energy costs.*** Reduced pumping from storage facilities and less diluted sewage may result in ***more efficient treatment*** of wastewater. This would also help reduce the need to ***provide additional capacity.*** A number of sewage works are already at the limit of their capacity; this is especially the case in the South East which is the region designated to receive significant new housing development.

6. SUDS can also provide benefits through an ***enhancement of biodiversity*** because many SUDS types, such as swales, filter ditches and infiltration ponds mimic the natural environment, retaining water that will attract wildlife, creating stable habitats and providing corridors along which wildlife can move.

7. Some SUDS techniques can help to ***reduce the urban heat island effect***. For example, adding 10 per cent green cover keeps maximum surface temperatures in high density residential areas and town centres at or below the 1961-1990 baseline up until the 2080s (Newcastle University, 2007).

Where local conditions allow these benefits to be realised, it is possible to make an economic case for the retrofitting of SUDS. For example, cost comparisons between conventional drainage systems and SUDS made by Abertay (Dundee) University for the Dunfermline Eastern Expansion[4] showed that in this area, the capital costs of SUDS were half that of conventional drainage. The annual average maintenance costs were 20-25 per cent lower for SUDS, and the whole-life maintenance costs of SUDS within the catchment were half that of the conventional alternative.

The economic assessment undertaken by this study included the use of available cost data[5] on the different SUDS options mentioned in Table 1.1 compared to traditional approaches. These included capital costs, any transition costs related to the retrofitting of SUDS and operations/maintenance costs for the different solutions.

Although a number of important benefits were identified, it was not possible to monetise all possible benefits likely to be realised in many local drainage catchments. Monetised benefits included reduced water bills; indirect capital and operations savings that might result for deferring expenditure on the current drainage system (such as upgrading CSOs); and reductions in the cost of pluvial flooding incidents.

Benefits that could not be estimated included:

[4] *A cost comparison of traditional drainage and SUDS*, Urban Water Technology Centre, University of Abertay, 2005.
[5] See Appendix 2 – Description of the Economic Model

- reductions in diffuse pollution;
- energy savings;
- additional recharging to aquifers;
- deferred investments in sewage treatment capacity;
- enhancements in biodiversity;
- amenity value.

Barriers to benefit realisation such as infiltration levels and the potential for sewage blockage and odour nuisance could not be assessed. Further research would be required to quantify these aspects.

4. Initial assessment of costs and benefits

Of the SUDS techniques reviewed within the economic model and using the implementation scenarios described in Table 1.1, the following results emerged.

- Widespread use of permeable paving provides net financial benefits for property owners as well as overall net economic benefits. Permeable paving costs less on a lifecycle basis than traditional surfaces, with reduced maintenance costs outweighing increased capital costs. While extra excavations are required to lay permeable paving, replacing worn out paving blocks is less costly than the digging required to renew worn out tarmac. For those areas where water companies only charge for surface drainage on hard surfaces, there will be further financial savings of no charges for permeable surfaces. A nationwide application of permeable paving covering approximately 50 per cent of current non-road hard surface areas retrofitted at their “end of life” would provide discounted economic benefits of nearly £1.7 billion. The majority of these benefits would accrue to the site owners and operators.

- Water butts also provide economic benefits, as they repay their cost via savings in the cost of water. For those with water meters, this would lead to increased net benefits. For a national cost outlay of just over £325 million, the widespread use of water butts could deliver national savings of nearly £1 billion to households. However, these benefits would only be realised if the butts were regularly used through the summer months, when maximum water savings could be achieved.

- Other types of SUDS, such as swales and filter drains, tend to show a benefit-cost ratio of less than one, implying that these schemes cost more and provide fewer benefits. Benefits are not clear when presented in a uniform national context, but are likely to appear at a local level where conditions permit their realisation.

5. Rationale for intervention in promoting SUDS

The results show that there is a prima facie case for the widespread use of permeable paving and water butts. However, the results raise the following questions: given that there are direct financial benefits for owners of water butts and for applying permeable paving instead of conventional approaches, why are they not currently in more widespread use? What is the rationale for policy intervention? Where are the market failures? For instance, most providers of permeable paving products are very upbeat about their market and forecast significant growth. However, the actual use of these products remains low compared to conventional methods and this is especially true of the retrofitted market.

This study did not look in depth at the reasons for this lack of market penetration of permeable paving, but experts from the industry, such as from the SUDS Forum, suggest the following explanations:

- Decisions on resurfacing parking are not considered of sufficient importance for organisations, hence this is not given much thought by those responsible for procurement (this includes Government premises). Also, procurement may not be taken nationally and may be taken at a relatively low level in the organisation, with little consideration of options beyond the conventional.
- Awareness of the existence of permeable paving and suppliers is likely to be low due to its lack of market penetration, creating a Catch-22 situation.
- Property owners and managers may perceive greater risks with an unfamiliar (though not unproven) technology. Furthermore, upfront increased capital costs might outweigh overall savings due to lower lifetime costs.
- Consultants often mistakenly discount permeable paving where infiltration is poor, failing to recognise that such systems have significant benefits even where infiltration can not be used..
- In some instances, the competitiveness of suppliers of permeable paving may be disadvantaged through lack of knowledge and understanding of those advising property owners – these include design consultants, architects and planners.
- Most retrofit is not done on a site-wide basis but on parts of the site; there may thus be a preference to retrofit in a manner consistent with other parts of the site.

Further research is required to establish the above explanations as likely causes, but they suggest a primary facie case for intervention to promote retrofitting of SUDS.

Conversely, one barrier that does not generally exist for retrofitting permeable paving is uncertainty over ownership and responsibility. For instance, a car park is owned and the owner would be responsible for maintenance of the paving.

6. Towards a 'twin track' approach to drainage

Retrofitting SUDS could be seen as an analogous agenda to retrofitting water-efficient devices to existing housing. Both relate to demand management, the latter for water supply and the former for drainage services. Government policy could aim to develop a 'twin track' approach to drainage services, akin to the twin track approach to water supply of resource development and water-demand management, as follows:

- The first 'track' would address urban flooding and CSO problems due to lack of drainage system capacity with a combination of traditional and SUDS solutions. This would extend the thinking of PPS25 to embrace SUDS retrofitting and would involve Government providing guidance and encouragement to consider different SUDS technologies as part of flood risk management and pollution control at the local level.

- The second 'track' would set the conditions for an overall reduction in pressures that might increase flooding and pollution risk – a preventative approach. An important part of this would be better management and coordination under the current Department for Environment, Food and Rural Affairs (Defra) consultation on *Making Space for Water*, but also setting the use of permeable paving as 'the rule' and first preference for new surfaces and surface replacement or refurbishment. Specifically, policy should concentrate on measures to use more permeable paving.

Currently there is no second 'track', meaning that the process of fixing drainage problems is unlikely to 'catch-up with itself'. As soon as problems are fixed, others will develop as pressures increase from more housing, property owner preference for more private parking space[6] and the forecast impacts of climate change. Furthermore, without the second 'track' approach, managing the future drainage infrastructure will potentially be much more expensive than controlling the pressures at source and managing demand for drainage services.

7. Policy recommendations to promote retrofitting

Many of the decisions on SUDS retrofits are the responsibility of property owners. This includes private domestic and commercial properties, and public properties such as schools, leisure centres, hospitals and the associated hard-surfaced areas and roads. For instance, the responsibility to retrofit permeable paving resides in organisations that sit outside the formal regulatory process of water management; these include local authorities in a variety of roles as highway authorities, as planning authorities and as property managers in their own right, but also property developers and property owners and managers. A consequence of this is that incentives for change will need to be directed at changing the behaviour of property owners.

[6] London Assembly, 2005, *Crazy paving: The environmental importance of London's front gardens* states that 12 square miles of London's front gardens have been paved for carparking.

One of the recommendations of Sir Michael Pitts Review[7] following flooding in the summer of 2007 includes the interim conclusion (IC9) "….that householder and business owners should no longer be able to lay impermeable surfaces as of right". This conclusion is now out for consultation with the rest of the review and the additional 72 interim conclusions and a further 15 urgent recommendations.

Potential measures include the following:

1. **Building regulations or planning guidance** should be amended so that local authorities can require properties to have a neutral impact in terms of surface water run-off when constructing extensions or parking bays.

2. Government **planning policy** should clearly promote the retrofitting of SUDS to encourage adaptation to climate change – particularly in areas which currently or are likely to suffer from surface water flooding.

3. Government, government agencies and public organisations should take the lead in using permeable paving in <u>their own</u> building and property upgrading and refurbishments as a part of their **green procurement** policy.

4. Government should promote the use of permeable paving to large businesses with substantial hard surfaces (such as the property rental and retailing sectors) as a key part of their **corporate social responsibility** agenda, in effect ensuring they are not responsible for flooding their neighbours.

In addition to policy initiatives on permeable paving, this report suggests the following actions to promote wider consideration of SUDS as potential retrofit options:

Sewerage company actions:

5. Sewerage companies should consider the potential for SUDS retrofitting to help meet their duties to drain catchment areas, provide drainage services, prevent sewage flooding and reduce CSOs. SUDS retrofitting should be incorporated into their **Business Plans for PR09**.

6. Sewerage companies should provide property owners with more **information** about options for disconnecting surface water drainage. This information should explain the potential benefits of adopting SUDS techniques. Government should provide guidance to OFWAT to require such of water companies as part of their duty to provide drainage services.

OFWAT actions:

7. As part of Ofwat's **duty to promote sustainable development and cost-effective** services, it should challenge sewage companies to demonstrate that they have made a clear strategic assessment of their delivery of drainage services, possibly including analysis of the replacement and refurbishment of hard surfaces in their drainage areas with permeable surfaces.

8. OFWAT should insist that sewerage companies **charge commercial properties for surface water drainage**[8] on the basis of area drained, as other

[7] Sir Michael Pitts independent review, *Learning the lessons from the 2007 floods*, published 18 December 2007

[8] To date three companies have introduced this method (Severn Trent in 1990, Yorkshire in 2001 and Northumbrian in 2005) and one other, United Utilities, is planning to do so in 2008.

non-area based charging systems clearly discriminate against companies with lower-than-average drained property areas. This charging basis will provide incentives for property owners to replace hard surfaces with permeable ones. Government should provide guidance to this effect in its Social and Environmental Guidance to OFWAT for the Pricing Review 2009.

Government actions:

9. Government should consider introducing **instruments to incentivise local authorities (LAs).** These could provide LAs with an incentive to ensure that their planning and refurbishment requirements for both new and existing developments would help reduce surface water run-off.

10. Government and local authorities need to lead by example, preparing a **SUDS retrofit action plan** for their premises, consistent with the Government's own climate change 'commitment'. Each local authority, NHS Trust, MOD establishment and local education authority should be working towards a SUDS retrofit for their sites.

11. Government should **work with professional services associations**, perhaps though professional accreditation schemes, to reinforce best practice in SUDS implementation, including retrofitting.

8. Recommendations for further research

Two main areas require further research:

1 Areas that would be suitable for retrofitting permeable paving.

2 A better understanding of the costs and benefits of other SUDS.

This research would need to be conducted with case studies covering different drainage area conditions and circumstances, where these would properly reflect the local cost-benefit situations.

References & Bibliography

1. Upton Sustainable Drainage System. Pell Frishmann /English Partnerships Presentation.

2. Wavin Stormwater Management System. Commercial Catalogue.

3. Scottish Water SUDS Retrofit Research Project, Atkins, August 2004.

4. Draft Planning Agreement under Interim Code of Practice for SUDS.

5. Soakaway Design. BRE Digest, September 1991.

6. Sewers for Scotland 2nd Edn.

7. Infiltration Drainage – Appraisal of Costs. Ove Arup, J. D. Roberts, December 1995.

8. Setting the Scene in Scotland. SUDS Scottish Working Party (SUDSWP).

9. SUDS Advice Note on Brownfield Sites. SEPA/SUDSWP.

10. Guidance for Developers and Regulators. North East Scotland Flooding Advisory Group.

11. Habitat Enhancement Initiative – Ponds, Pools and Lochans. SEPA.

12. Scottish Building Regulations, (extracts section 3.6).

13. CIRIA Note on SUDS. CIRIA Website, February 2005.

14. WTB Geotechnics Commercial Catalogue.

15. Formpave Commercial Catalogue.

16. Aggregate Industries Commercial Catalogue on SUDS.

17. EPG Commercial Catalogue.

18. Interpave Commercial Catalogue.

19. Flood and Coastal Defence R&D Programme – Preliminary Rainfall Run-Off Management for Developments. Defra/Environment Agency, February 2004.

20. Code for Sustainable Homes - A Step Change in Building Practice. DCLG, December 2006.

21. DCLG – Planning Policy Statement 25 – Development and Flood Risk. December 2006.

22. SUDS Design Manual for England and Wales, CIRIA.

23. Making Space for Water. Defra et al, March 2005.

24. Interim Code of Practice for SUDS. Defra/ODPM/ National SUDS Working Group, July 2004.

25. 3rd National Conference on Sustainable Drainage – June 2005. Various Papers.

26. Water Related Infrastructure for Sustainable Communities – Technological Options and Scenarios for Infrastructure Systems. Environment Agency (draft).

27. Environment Agency Website, SUDS Pages.

28. CIRIA Website, SUDS Pages.

29. The Retrofit SUDS Research Group Website Pages.

30. SUDSnet. Website Pages.

31. UK SUDS Database. Website Pages.

32. How to Harvest Rainwater. Steff Wright, UK Rainwater Harvesting Association 2008.

33. Retrofitting SUDS - Dunfermline Case Study. M. Greene, J. Brannan, Hyder Consulting, June 2004.

34. Bourne Stream Partnership Website Pages.

35. Downspout Disconnection Program. Portland Oregon Bureau of Environmental Services, Website Pages.

36. Scottish Water Retrofit. B. Barbarito.

37. Mimico Creek Watershed Stormwater Retrofit Plan - Case Study.

38. Restoration challenges for urban rivers. BJ D'Arcy, T Rosenqvist, G Mitchell, R Kellagher, and S Billett; IWA Diffuse Pollution Conference August 2005.

39. Glasgow Strategic Drainage Plan Stage 1 – Overview and Case Study. O. Akornor, D. W. Page, Hyder Consulting 2004.

40. Best Management Practices for Stormwater Run-off with Alternative Methods in a Large Urban Catchment in Berlin, Germany. H Sieker and M Klein; Water Science and Technology, Vol 38 No 10.

41. Caw Burn Case Study. K.Heal, M.Scholz, N. Willby, B. Homer.

42. SUDS in Scotland, Cardowan Case Study. Hyder Consulting Presentation, A. Moseley, March 2006.

43. British Water Guidance to Proprietary SUDS.

44. Site Handbook for the Construction of SUDS. B. Woods Ballard, R. Kellagher, P. Martin, C. Jefferies, R. Bray, P. Shaffer, CIRIA 2007.

45. SUDS – a Guide for Developers. Environment Agency Booklet 2003.

46. Retrofit SUDS. V Stovin Presentation, May 2004.

47. Feasibility Study for the Retrofitting of Green Roofs. MSc Thesis , B. Munby, May 2005.

48. SUDS in Scotland, A. Moseley Presentation, Hyder Consulting, March 2006.

49. Making Space for Water Consultation Exercise, Urban Issues Workshop, Full Write-Up Pack. Defra.

50. Unique Scottish SUDS Research. Article, Atkins Website Pages.

51. SUDS Manual. CIRIA 2007.

52. UKWIR Report – Performance and Whole Life Costs of Best Management Practices and SUDS.

53. Rooftops to Rivers. USA Natural Resources Defence Council Paper, C. Kloss, C. Calarusse, June 2006.

54. Integrated Urban Water Pollution Control in the UK. B. Crabtree, WRc plc, February 2004.

55. Whole Life Costs and Living Roofs, The Springboard Centre, Bridgewater. Solution Organisation, January 2005.

56. Hidden Infrastructure, Pressures on Environmental Infrastructure, Environment Agency 2007

Appendix One: Technical options of SUDS[9]

SUDS is not a descriptor for a niche group of techniques, but is a concept that embraces a number of different types of surface water management solutions.

SUDS can be described as an approach to managing rainfall that as far as practically possible replicates natural drainage. The approach aims to prevent pollution, control flooding, recharge groundwater and enhance the environment. SUDS techniques include filter strips and swales, filter drains and permeable surfaces, infiltration devices, basins and ponds, 'green' roofs, and water butts and rainwater harvesting.

Because they mimic natural catchment processes, these technologies are viewed by many as a more sustainable approach to managing urban storm run-off than conventional underground pipe and storage-based solutions. In reality, a sustainable approach will involve the use of many such techniques, even conventional ones, and what is important is that **all** techniques are given equal value for their potential contribution to sustainable drainage and surface water management.

However, because a number of these techniques can not be easily installed within the current institutional and legislative context, the familiar underground pipe solutions to urban drainage persist in new developments and in the re-development of existing urban surfaces (retrofitting).

The term **retrofit** is employed when a SUDS approach is used to replace and/or augment an existing drainage system in a developed catchment. Examples of retrofit SUDS might be the re-paving of large surfaces such as car parks with permeable surfaces, the installation of green roofs, the diversion of roof drainage from a combined sewer system into a garden soak-away, or the conveyance of road run-off via roadside swales into a pond sited in an area of open space. Such measures are alternative ways of alleviating downstream water quantity and quality problems, potentially providing more effective and sustainable solutions overall.

Retrofitting of SUDS could prove an important policy in dealing with "urban creep". Current planning legislation allows property owners to pave over their property's front and rear gardens as "permitted development". In many cities and towns where there is parking pressure and with the dramatic increase in the number of cars per household, there has been a huge increase in hard-standing parking areas within properties. The London Borough of Ealing reported over 1,000 applications a year for pavement cross-overs to allow for vehicle access across pavements.

Retrofitted SUDS may prove useful in any situation where inadequate stormwater management leads to poor performance of the urban drainage system. This includes problems associated with excessive Combined Sewer Overflow (CSO) discharges, separate storm sewer outfalls and flooding of urban watercourses. Retrofitting also has a potentially important role to play in tackling sewer flooding risk; expanding the capacity of sewers and drainage systems to take on more 'load' deals with just one side of the supply-demand balance. Parallels with water supply-demand management are worth making, in terms of improving efficiency and investing in new resources.

Although to date most SUDS installations in the UK have been within new developments (where national policy guidance has been concentrated), the full benefits

[9] All diagrams used in this section have been downloaded from the website of the Environment Agency

are only likely to be achieved through widespread use of different techniques and this must necessarily include a significant degree of retrofitting.

The picture below provides an overview of the wider benefits of SUDS and gives reasons why they might not arise in particular local circumstances, for instance where there is significant infiltration for an old drainage and sewerage system

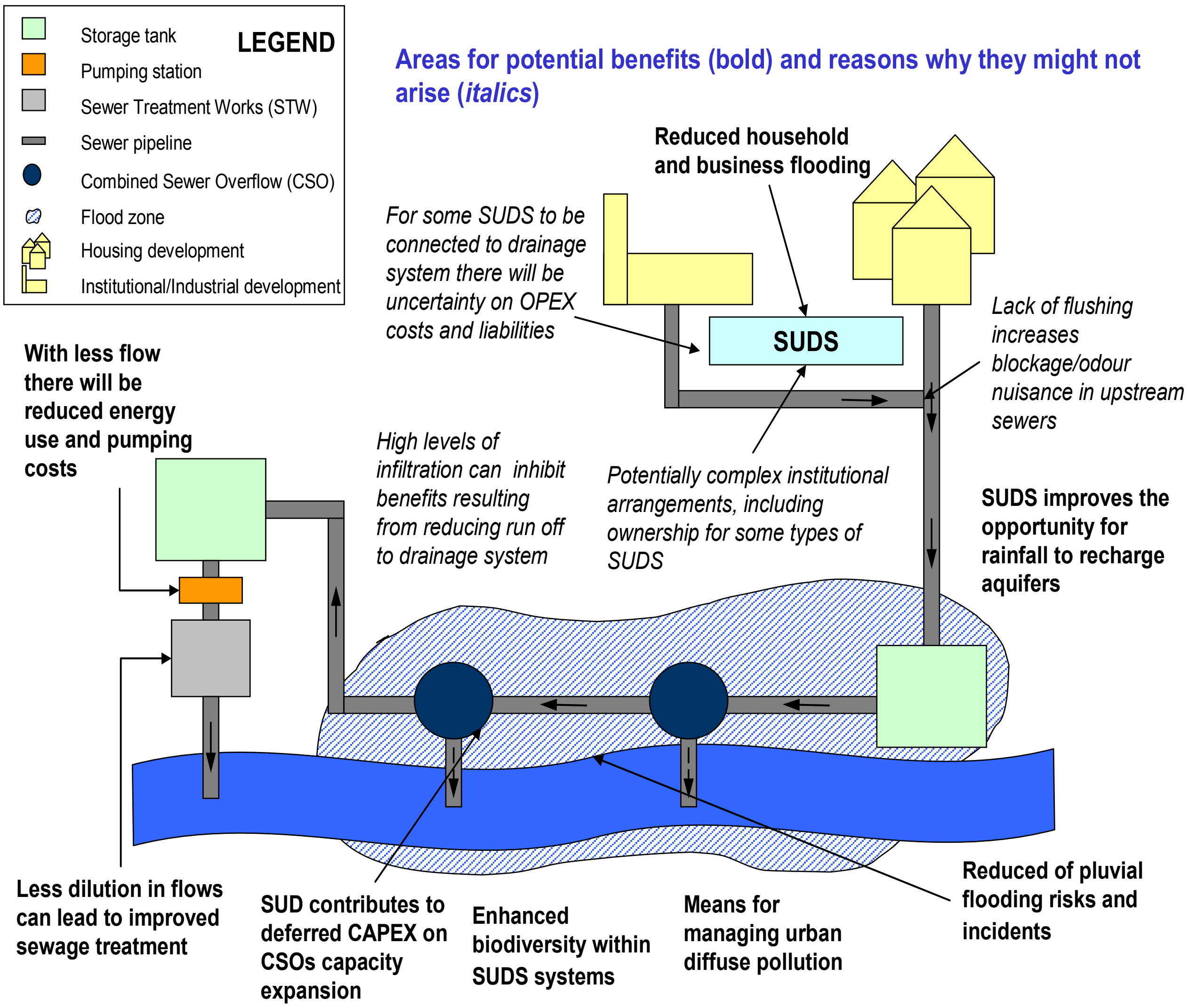

Figure A1.1 Benefits of SUDS

Not all SUDS techniques can be used for urban retrofit. The large areas required for ponds and wide roadside strips required for swales are not always available in domestic housing estates. Smaller and more individual systems, such as water butts and other forms of down-pipe disconnection may be better for such crowded environments. Commercial and industrial properties, and large municipal buildings such as schools and hospitals, offer other possibilities. With large roof areas and extensive hard-standing, green roofs and permeable paving systems are frequently possible. In some circumstances, swales and ponds will also be viable.

Despite some technical difficulties, retrofit has been undertaken in several countries, and England and Wales may be falling behind in good drainage practice.

SUDS most likely to be applicable for retrofit, and some examples of international activities, are outlined below.

Permeable paving is the most commonly used SUDS technique and has very well established markets in Europe. With permeable paving, specially formulated permeable asphalt or load-bearing paviors with designed-in outsized joints are laid over a bed and a graded, single-size granular sub-base. Using crushed rock, the capacity of the reservoir is about 30 per cent of the volume. Typical sub-base depths range from 150 to 250 mm, depending upon loadings, the designed rainfall events and the type of sub-soil.

Permeable paving can be used as part of both retention and detention systems.

Advantages might include:

- use of a buried infiltration medium, so no extra land take is needed;
- load-bearing surface, so traffic and water management functions can be combined;
- works as an effective filter medium for many forms of pollutant.

Tokyo, Japan

Permeable pavement connecting to infiltration pits and trenches have been combined with a high take up of private soakaways to dispose of storm water in Tokyo. Over the 10-year period to 1995, 484,000 m^2 of permeable paving, 33,300 infiltration pits, 285 km of infiltration trenches and 19,200 soakaways were installed across a 1,400 ha area of the city.

Some of the porous concrete blocks are now made from incinerated sewage sludge or slag of melted sewage sludge. The infiltration trenches are used in locations as diverse as housing complexes, streets, schools and public gardens.

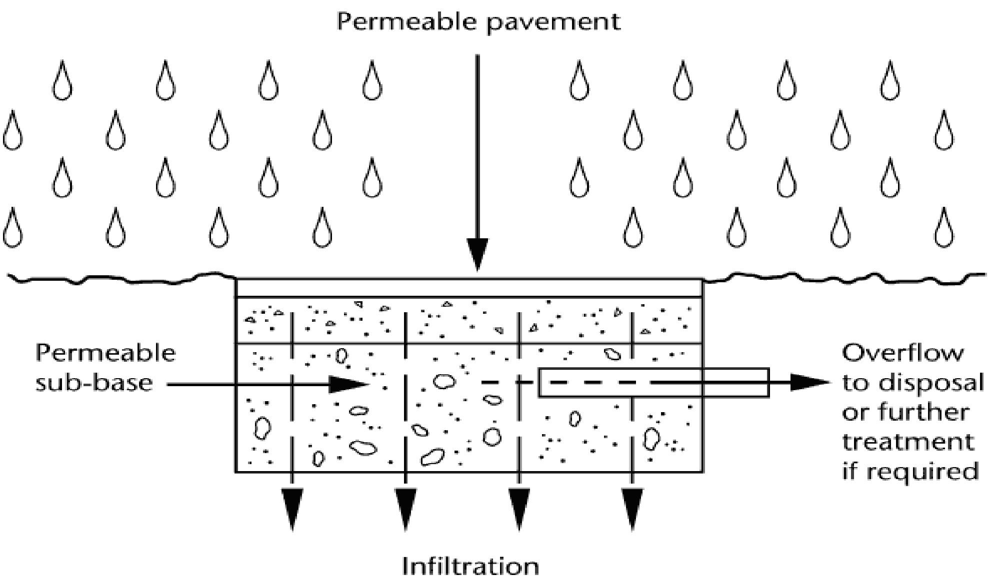

Figure A1.2: Permeable pavement

Permeable paving can be used in combination with infiltration into the ground. Where infiltration is restricted by factors such as groundwater levels, sub-soil structure, location of abstraction wells or the risk of contamination, permeable paving can be combined with an impermeable membrane to store and regulate surface water flows off site.

Soakaways and infiltration trenches are used to disperse surface water run-off. Both are below-ground features filled with crushed rock, relying upon the long-term permeability of surrounding soil for effective operation. Their location may constrain development on the site by increasing soil moisture content or by reducing the bearing capacity of the soil. The performance of soakaways degrades over time as they become clogged with silt and access for inspection and maintenance is required.

Mimico Creek Watershed, Toronto, Canada

The Mimico Creek drains an area of 40 square kilometres in the former city of Etobicoke. The area had previously shown a willingness to participate in storm water pollution abatement research and was considered a typical urban environment.

The goals of this project were to:

- rehabilitate and enhance the existing hydrologic cycle;
- rehabilitate and improve the quality of run-off;
- integrate the storm water strategy with municipal capital works and maintenance programmes;
- minimise the cost of storm water management in urbanised areas.

Several different types of SUDS were proposed to achieve these targets, including downspout disconnection, oil-grit separators, exfiltration systems (soakaways) and ponds. These new methods were added to existing swales and ditches to produce a comprehensive storm water management system.

A GIS system was used to identify the different areas where the different drainage methods would be most appropriate and two overall strategies were produced. For the first of these, it was estimated that the maximum run-off volume reduction and solids loading reduction would be 14 per cent at a cost of $7.8 million over 25 years; for the second, the reduction was 18 per cent at a cost of $10 million over 25 years. These figures rose to 17 and 33 per cent if the existing swales and ditches were included as part of the SUDS solution.

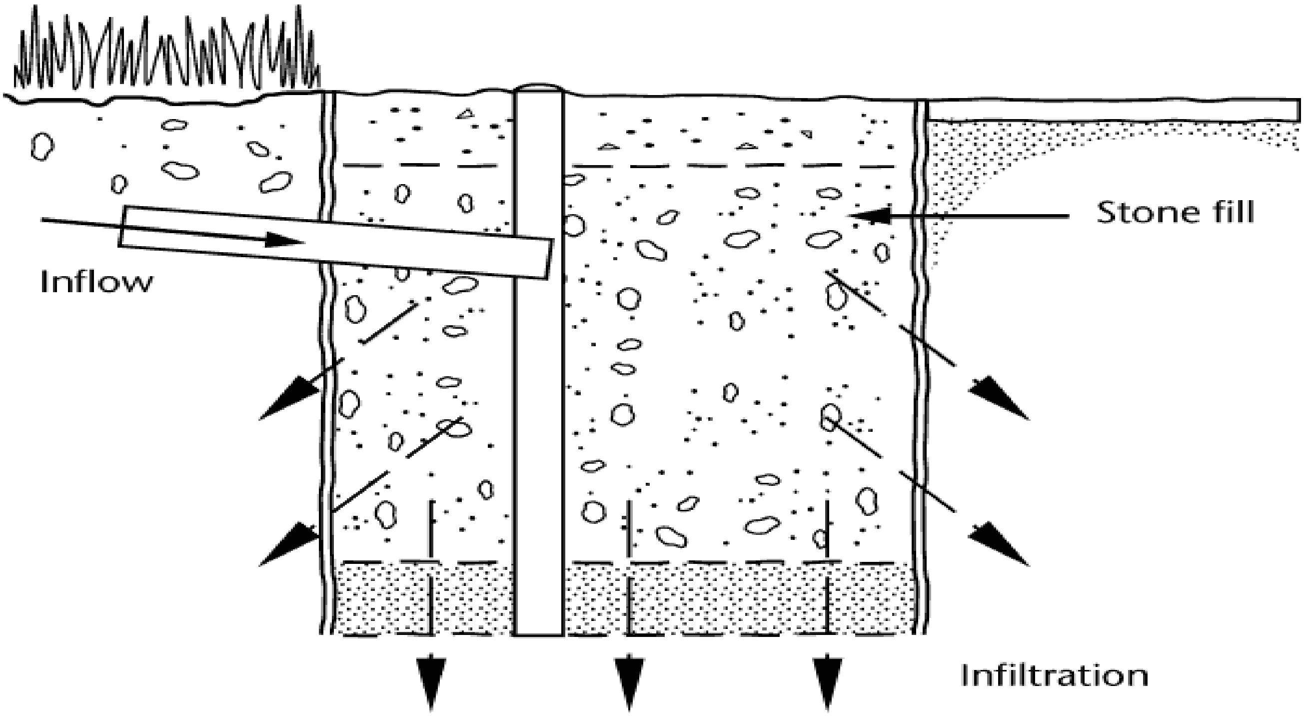

Figure A1.3: Soakaways and infiltration trenches

Swales and infiltration basins are vegetated surface features that drain, filter and disperse surface water. A swale is a vegetated channel that directs water to a dispersal or storage system. Swales are shallow and wide and are dry during normal conditions. During storms they provide temporary storage. Infiltration basins are similar in construction, but are designed as the terminal point of a SUDS system. Swales can provide economical and easy-to-maintain drainage for highways, car parks and other areas of extensive paving.

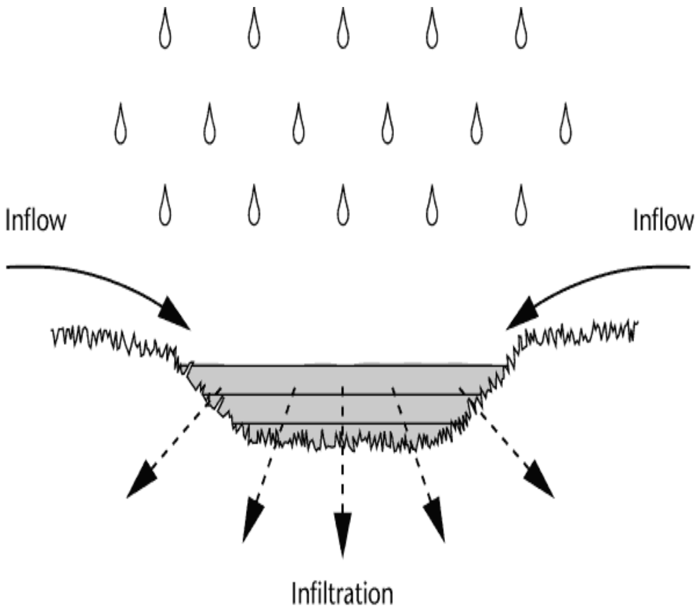

Figure A1.4 Swale

On-site attenuation and storage is used where it is not possible to disperse surface water through infiltration, and where the peak flow rate from a site needs to be restricted. Typical sites that might benefit from this approach are heavily contaminated urban sites, where infiltration might leach pollutants, or sites where existing drainage infrastructure imposes limits on peak flow rates.

There are three components to the system:

- A collector network - typically swales, pipes or permeable paving.
- A flow control device - a valve that limits flow from the system to the capacity of the downstream infrastructure. Vortex flow control devices are a common, non-mechanical technology used to switch flows in below-ground drainage systems at a defined output level.
- A storage medium – typical alternatives include "geocellular systems" or large diameter concrete pipes. Because of the low load bearing of geocellular systems compared with, say, spun concrete pipes, use of these systems may have an impact on the subsequent use of parts of the site used as a reservoir.

Augustenborg, Malmo, Sweden

Augustaenburg is a highly populated inner city suburb in Malmo, southern Sweden. The original storm water drainage system in the area consisted of a combined sewer network with pipe diameters ranging from 225 mm to 750 mm. CSO spills and basement and garage flooding incidents were a problem under this system during heavy storms.

In order to reduce these flooding incidents, it was proposed that storm water be disconnected from the combined system and drained using an open system consisting of green roofs, swales, channels, ponds and small wetlands. The installation of these systems was targeted at areas of public and private apartment blocks and offices which were in need of renovation and it was estimated that the new system could manage peak storm flows up to a 10-year storm.

These systems are typically used in combination to provide a solution that addresses the surface water loads, constraints of the site and opportunities to create landscape features using swales.

Green roofs are vegetative layers over an impermeable roof membrane that attenuate the run-off and allow some evaporation of water. The vegetation can range from low grass to large shrubs. The larger the plants the greater the depth of growth medium required and the greater the imposed load. The slope of the roof should be designed to a fall of 1 in 40, though greater falls can be used if the depth of the growth medium substrate is increased. They are more cost-effective for larger roofs.

Retrofitting is most feasible for existing flat roofs with some residual load-bearing capacity. The type of vegetation used can be tailored to the load-bearing capacity of the roof. However for the purposes of this analysis, green roofs were not included. Although information on the roof areas available was obtained and used to assess the benefits of rainwater harvesting and water butts, green roof retrofitting has other requirements, particularly on the load-bearing capability of buildings and damp proofing requirements. It was not possible to estimate the potential for retrofitting without more information on load-bearing capacity of the current building stock. Hence this option was not included in the final analysis.

Rainwater harvesting and water butts, which are the most traditional form of rainwater harvesting, provide water for garden irrigation. Typically, the water butt has a high level overflow to maximise the storage of water for garden irrigation. However, in this configuration the water butt no longer provides attenuation when it is full. A design was therefore adapted to provide a mid-level throttled outlet in addition to the high level overflow, to create a more effective attenuation device. Such systems could be relatively easily retrofitted into most domestic properties with gardens.

FLOWS Project, Cambourne Village, Cambridge, UK

This is a new development site where SUDS were incorporated into an existing design to replace the conventional drainage system. The site has a density of 35 dwellings per hectare and the storm water system was required to alleviate flooding for a 100-year storm.

A variety of SUDS techniques were used including water butts, a green roof, porous paving, swales, detention basins and a retention pond. Additional 'sacrificial storage' areas were set up to provide temporary storage in green areas for flooding caused by particularly heavy rainfall.

More formal rainwater harvesting systems store water for reuse in the building – usually for toilet flushing. This has the additional benefit of reducing demand for potable water. To achieve maximum reuse, the tanks are larger and ideally should be stored underground to moderate temperatures and minimise growth of pathogens. A filtration system and secondary pipework must also be installed in the house to allow reuse. The water can also be used for garden irrigation.

Meanwood, Leeds, UK

Leeds City Council has undertaken a desk study for Yorkshire Water into the retrofitting of SUDS in Meanwood. Meanwood is a 56 ha catchment comprised mainly of twentieth century housing and retail premises and connected to a combined sewer system. During storm events of a one-year return and greater, the combined system floods. The catchment has significant amounts of grassed areas suitable for the retrofitting of swales and 46 per cent of the roof area and 31 per cent of the paved area are suitable for infiltration-based SUDS. The remaining areas would be drained by storage-based SUDS. The hydraulic performance of the proposed system has been modelled and it is anticipated that for a 10-year storm the SUDS would reduce the flood volume by 68 per cent. A reduced level of conventional sewer rehabilitation would also be required to fully alleviate the flooding.

Costs for a range of conventional and hybrid solutions have been analysed and the most expensive hybrid solution is still 12 per cent cheaper than conventional solutions, with the least expensive hybrid being 23 per cent cheaper.

Appendix Two: Developing the cost-benefit model

Introduction the cost-benefit model

Tables in this section provide the following information about the model and the information and criteria used in the development of the cost-benefit analysis.

Table A2.2 describes the model assumptions with regard to conversion periods, the retrofit areas, unit costs and unit benefits estimates.

Table A2.3 gives the estimated potential area for the different SUDS schemes considered in the model.

Table A2,4 lists the estimated benefits of the SUDS schemes considered and describes the assumptions made in their estimation.

The results of the model show the following costs and monetised benefits.

Table A2.1: Total financial summary of cost-benefit analysis of SUDS

Total financial summary				
	Benefits (£'000)	**Costs (£'000)**	**Benefits minus costs (£'000)**	**Benefit to cost ratio**
Permeable paving	515,217	-896,603	1,411,820	Very positive
Rainwater harvesting	8,647,965	13,702,282	-5,054,317	Neutral
Water butt	733,075	325,824	407,251	Very positive
Swale	60,392	610,134	-549,742	Negative
Infiltration trench	105,687	8,739,055	-8,633,368	Very negative
Filter drain	60,392	7,212,069	-7,151,676	Very negative

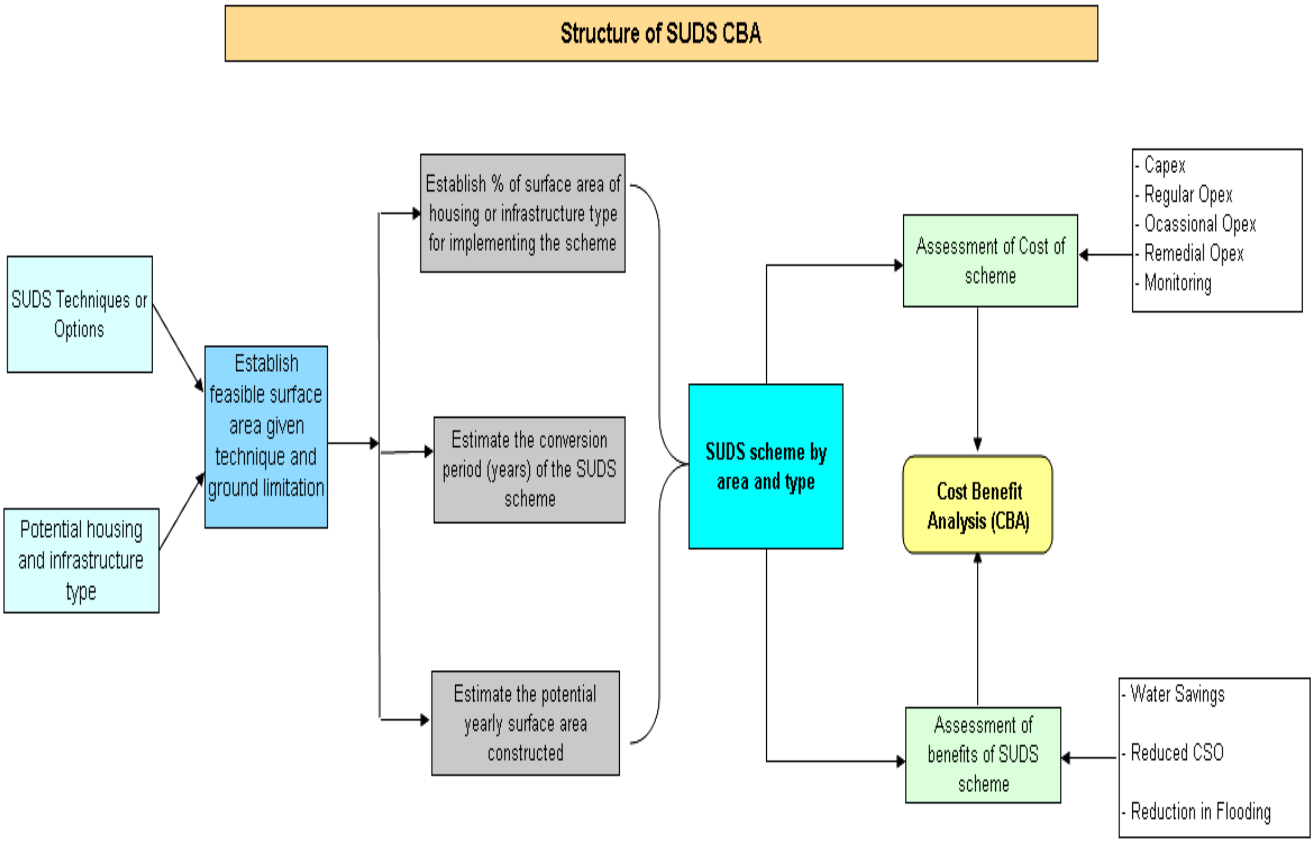

Figure A2.1: Cost-benefit analysis of SUDS scheme – Model assumptions

Table A2.2: Model assumptions: conversion period, retrofit area, unit costs and unit benefits estimates of SUDS schemes

SUDS type	Model estimates and assumptions	Explanatory notes/references
Rainwater harvesting		
Conversion period of scheme	15 years	This would be most economically phased with replacement of plumbing fittings, which is typically carried out on a 12-year cycle.
Retrofit area:	5% of terraced housing 10% of detached housing 75% of industrial and commercial 50% of schools and leisure centres	
Unit cost estimates:	Capex £45/m^2 for detached/semi-detached homes £45/m^2 for terraced houses £9/m^2 for schools £3/m^2 for leisure centres £9/m^2 for other non-domestic buildings	Capital costs were found using various case studies ranging across the different building types. Operating costs were

	Regular Opex £0.6/m^2 for detached/semi-detached houses and terraced houses £0.15/m^2 for the other retrofit areas Occasional Opex 0.4/m^2 for detached/semi-detached houses and terraced houses 0.1/m^2 for the other retrofit areas	supplied by Hydro International.
Benefit estimates	*Water savings per m^2 of impermeable area:* Detached/semi-detached – 66 m^3 Terraced houses – 66 m^3 Schools – 0.5 m^3 Leisure centres – 0.5 m^3 Other non-domestic buildings – 0.5 m^3 *Run-off reduction (m^2 impermeable area):* 0.65 m^3 for all the retrofit areas	
Water butts		
Conversion period of scheme	15 years	The relatively minor nature of the changes should allow benefits to be achieved over a relatively short period of time.
Retrofit area:	45% of terraced housing roof area 90% of semi-detached and detached	
Unit cost estimates:	Capex £0.75/m^2 for terraced housing £0.50 /m^2 for detached/semi-detached housing	Price per water butt was estimated using typical manufacturers costs. This price was then divided by average size of each house type to derive cost per m^2.
Benefit estimates	*Water savings per m^2 of impermeable area:* Detached/semi-detached houses and terraced housing – 6 m^3 *Run-off reduction (m^2 impermeable area):* Detached/semi-detached houses and terraced housing – 0.25 m^3	
Permeable paving		
Conversion period of scheme	40 years	Traditionally paved surfaces have a 40-year life before major maintenance is required.
Retrofit area:	50% of car parking hard-standing areas	This estimate is based on judgement of the market development in permeable paving, the

		pace of implementation in which it will be applied by private sector institutions and its prioritisation in flood risk areas.
Unit cost estimates:	Capex £54/m^2 Regular Opex £0.4/m^2	Capex and regular opex were taken from CIRIA's *SUDS manual*. Other operational costs were taken from Scott Wilson's *Whole life cost analysis for various pavement and drainage options*. Cost relating to the removal and disposal of old hard-standing areas were taken from CESMM3 Price Database 1999/2000.
Benefit estimates	*Run-off reduction (m^2 impermeable area):* 0.8 m^3 for car parking hard-standing surfaces	
Swales, filter drains, infiltration trenches		
Conversion period of scheme	15 years	Swales can be retrofitted without full reconstruction of the carriageway. The period of construction can therefore be correspondingly shorter.
Retrofit area:	*Swales*: 20% of rural roads 4% of urban roads *Filter drains:* 20% of rural roads 4% of urban roads *Infiltration ditches:* 35% of rural roads 7% urban roads	
Unit cost estimates:	*Swales (rural and urban roads)* Capex – £12.50/m^2 Regular Opex – £0.1/m^2 Occasional Opex – £0.15/m^2 Remedial Opex – £2.0/m^2 Monitoring – £0.05/m^2 *Filter drains (rural and urban roads)* Capex – £120/m^2 Regular Opex – £0.60/m^2 Occasional Opex – £3.0/m^2 Monitoring – £0.20/m^2	Costs for all of these were taken from CIRIA's *SUDS manual*. Capex and regular opex were taken from the main literature, with the other opex costs coming from the example given of Hopwood park sustainable drainage scheme.

	Infiltration trenches (rural and urban roads) Capex – £60/m^2 Regular Opex – 0.6/m^2 Occasional Opex – 3.0/m^2 Monitoring – 2.0/m^2	
Benefit estimates	*Run-off reduction (m^2 impermeable area):* Estimated as 0.8 m^3 for all retrofit areas for swales, infiltration trenches and filter drains	

Table A2.3: Estimates of potential areas for SUDS scheme

Housing or infrastructure type	Potential total area for SUDS retrofit ('000 m^2)	Assumptions
Domestic properties:	Detached/semi-detached – 753,000 Terraced – 234,800 Low-rise flat – 151,965	The average sizes of domestic properties were estimated with reference to typical houses on estate agents websites. The numbers of each type were taken from the national house condition survey.
Other non-domestic buildings	Non-domestic buildings – 842,835	The total area of other non-domestic buildings was found for England using the generalised land use database. The area for Wales was then found by multiplying the area for England by the ratio of Wales' population compared to that of England. The areas of schools, leisure centres and hospitals were then subtracted from this area.
School	School – 47,000	The number of schools was taken from the Department for Education and Skills' *Schools in England*. The average size per school was found using the recommended floor size as described in *Schools for the future: Exemplar designs*. The different sizes for primary and secondary schools were then weighted by the numbers of each type of school and finally this size was halved to acknowledge that the majority of schools have at least two floors.
Leisure centre	Leisure centre – 8,400	The number and size of leisure centres were found using an estimated size (checked against

		local leisure centres to Swindon), and multiplied across population centres of 15,000 and above.
Hospital	Hospital – 12,250	The number of hospitals was found by counting the number of hospitals listed on the NHS websites for England and Wales. The average size was estimated using expert judgement – it was decided that on average, the size of hospitals would lie between schools and leisure centres.
Hard-standing area	Hard-standing area – 1,938,830	The total size of hard-standing area was available for England in the generalised land use database. The area for Wales was then found by multiplying the area for England by the ratio of Wales' population compared to that of England.
Roads	Urban roads – 123,160 Rural roads – 207,980	The lengths of both urban and rural roads were found using Tables 7.8 and 7.9 of TSGB 2006: Road Lengths. It was assumed that motorways should be classified as rural roads.

Table A2.4: Estimating the benefits of SUDS scheme – Modelling and assumptions

Benefit	Explanatory notes/reference	Assumptions
Run-off reduction **Monetary savings on flood reduction**	The installation of SUDS would have a direct impact on flows in sewers, either by direct disconnection of rainwater from the sewer systems or by reducing the volume and rate of run-off of the rainwater that still enters the sewer system.	The modelling assumes that a uniform 10% reduction in the connected area to the sewer system over the entire country would achieve a 90% reduction[10] in the numbers of incidents of flooding due to hydraulic overload of the sewer system For each SUDS scheme, the annual *run-off reduction* is estimated as a product of unit benefit of run-off reduction per m^2 of impermeable area and cumulative total potential area constructed over the conversion life of the scheme. The total run-off reduction (m^2) of a scheme is the sum of the annual run-off reductions over the life of the scheme. Percentage (%) run-off reduction of a SUDS scheme is estimated as the total run-off reduction (m^2) *divided by* the total area of housing and infrastructure type. Total % reduction in flooding incidents is estimated to be 90% if the reduction in connected area is more than 10% and linearly up to 90% below that level. Number of flood reduction is then estimated as the product of total % flood reduction and 2062, which is the annual number of internal sewer flooding incidents due to hydraulic overload (from OFWAT June Returns). The reduction in the number of flooding incidents is converted into monetary savings, at a rate of £39,000 per incident and discounted using a discount rate of 5.5% over a period of 20 years.
Water savings	Full implementation of rainwater harvesting and water butts will lead to a reduction in demand from	For each SUDS scheme, the annual *water savings* is estimated as a product of unit benefit of water

[10] It is assumed that reductions up to 10 per cent affect the reduction in flooding in a linear fashion. For example, a one per cent reduction in the area connected to the sewer system will reduce flooding incidents by nine per cent. It is also assumed that it would not be possible to reduce the number of incidents by greater than 90 per cent; thus, reductions in connected area greater than 10 per cent will not reduce the number of flooding incidents by greater than 90 per cent.

	domestic households for water from the supply network, leading to a reduction in demand for potable water.	savings (m^3) per m^2 of impermeable area and cumulative potential area constructed over the conversion life of the scheme. The total water savings of a scheme is the sum of the annual water savings over the life of the scheme.
Discounted water bill savings	Reduction in demand for water will lead to a reduction in water bills for customers.	Total water bill savings of a scheme is estimated as the product of total water savings and cost per m^3 of water saved (this was estimated as £2.01/m^3 for properties on meters)
CSO reduction monetary savings	SUDS can improve the river water quality in two ways, by reducing pollutants discharged to surface water sewers and by reducing discharges from Combined Sewer Overflows (CSOs).	It is assumed that a 10% reduction in run-off in catchments with CSOs will reduce the number of unsatisfactory CSOs in that catchment by 90%. Furthermore, this will increase to a maximum of a 98% reduction for a 25% reduction in run-off. Between 0% and 10% and 10% and 25% values are determined by linear interpolation. There are currently estimated to be 1,000 unsatisfactory CSOs (Ofwat June Returns). The cost saving for each unsatisfactory CSO is estimated at £51,000 per CSO and discounted using a discount rate of 5.5% over a period of 20 years.

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