



# VALUING THE BENEFITS OF STORM DISCHARGE IMPROVEMENTS FOR USE IN COST-BENEFIT ANALYSIS

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# WATER UK

## VALUING THE BENEFITS OF STORM DISCHARGE IMPROVEMENTS FOR USE IN COST-BENEFIT ANALYSIS

### Executive Summary

#### Introduction

The vision of the 21st Century Drainage Programme is to enable the UK water industry, in partnership with the UK's governments and regulators, to make plans now that will ensure the sustainability of our drainage infrastructure in the future.

The Programme recognises that storm overflows are an important part of our drainage system, providing protection to properties from flooding by alleviating surcharging of combined sewer systems that occurs in wet weather. However, they have the potential to impact on the receiving waters they discharge to, and can be sources of pollution if they are not designed and managed effectively.

To help manage the environmental, reputational and other risks from storm discharges, the Environment Agency and the water industry have collaborated to produce the Storm Overflow Assessment Framework (SOAF). This is intended to address overflows that are considered to operate at too high a frequency and cause a detrimental impact to the receiving water.

Stage 3 of the SOAF requires an economic assessment of the benefits of addressing high spilling overflows that cause an environmental impact, or any overflow in a drainage catchment greater than the Urban Wastewater Treatment Directive (UWWTD) threshold of 2,000 pe (population equivalent).

This report is accompanied by a Practitioners' Guide, which is designed to support application of the framework that has been developed. The Guide includes a methodology and step-by-step framework (with a recommended approach in each step) that enables the direct and indirect benefits of improvements to storm overflows to be assessed and valued in a robust, consistent and transparent way. The Report and Guide have been written for asset managers, investment planners and others involved in identifying and assessing improvements to storm discharges.

#### Objectives

The objectives of the project were to:

- i. Identify the social, economic and environmental benefits of improving high spilling storm overflows;
- ii. Review international practices for valuing benefits associated with storm discharge improvements within a cost-benefit analysis (CBA) framework;
- iii. Develop a methodology to enable the marginal benefits of improvements to be valued; and
- iv. Provide a CBA framework so future investment decisions can be made.

The key outputs of the project are:

- A benefit valuation methodology that can feed into the SOAF as part of the broader 21<sup>st</sup> Century Drainage Programme of work; and
- A framework to support decisions on whether or not improvements to high spilling storm overflow are required, the level of improvements needed and how improvements should be prioritised.

## Approach

The key elements of the approach adopted in developing this project are as follows.

- Development of key principles related to benefits assessment in the context of storm overflows.
- Identification of the range of direct and indirect benefits that may arise as a result of improvements to high spilling storm overflows, within a coherent framework.
- Review of the relevant literature in relation to the benefits of storm overflow improvements.
- Development of a framework that facilitates the robust, consistent and transparent assessment of the benefits associated with storm overflow improvements.
- Application of the framework to a number of case study sites, to test and illustrate the framework.
- Reporting and dissemination.

The project has benefitted from the input and advice of an active steering group throughout.

## Conclusions

The key conclusions from this project are as follows.

- The assessment process and framework developed here is only applicable to a subset of storm overflows. It only applies to those high spilling overflows that, based on application of stages 1 and 2 of the SOAF, cause an environmental impact, or to any high spilling overflow in a drainage catchment with a greater than Urban Wastewater Treatment Directive (UWWTD) threshold of 2,000 pe.
- The framework supporting the assessment process is based on a number of key principles and a clear methodology that enable the whole range of direct and indirect benefits of storm overflow improvements to be valued in a robust, consistent and transparent way.
- For the subset of cases to which the assessment process and framework is applicable, a simple and straightforward screening stage enables users to quickly develop a view on whether benefits are likely to be (a) significant, and (b) greater than costs.
- For those cases that get through the screening stage, the framework enables the benefits of storm overflow improvements to be explored and assessed in detail. This level of detail is likely to be necessary to support a case for investment that is robust and transparent.
- Application of the framework to a number of case studies suggests that the benefits of improvements can be significant, especially for options that involve upstream or

distributed-type measures like SuDS. From the case studies assessed, options of this type are also most likely to be more cost-beneficial.

- vi. Familiarity with the Practitioners' Guide and benefits appraisal process is necessary to generate robust and transparent evaluations. Experience from the case study testers suggests that they gained greater confidence in applying the guidance as more case studies were completed.

## Recommendations

The main recommendations that arise from this project are as follows.

- i. Application of the framework should draw on the experience and expertise of a multidisciplinary team. Users of the framework should draw on this team and take the time necessary to familiarise themselves with the scheme to be assessed and with the assessment process, if the economic case to be built is to be robust.
- ii. To support this, the industry should consider a dissemination and training programme to ensure the assessment process is understood, applied appropriately and used to generate robust results.
- iii. To create significant benefits, distributed multi-functional options upstream and downstream of overflows are likely to be necessary. It is important to consider that these may need to be delivered over several investment planning periods, as the opportunities present themselves and work is undertaken in collaboration with other stakeholders.
- iv. The framework should be reviewed within a few years, so lessons can be learnt from its application. The assessment process embedded in the framework may also need to evolve over time, to reflect better information and evidence (e.g. around indirect benefits like health and around less tangible benefits like skills).
- v. The industry should consider a benefits evaluation programme to improve the number and quality of values available for monetisation as a direct result of 'drainage' interventions.

## Benefits

The key benefits of the project will be a consistent and agreed approach to identifying what level of investment is appropriate for improvements to high spilling storm overflows, the types of benefits that materialise based on types of interventions and local context and a framework to help determine where and when this investment should best occur.

This will ultimately lead to more efficient use of resources and better outcomes for the water industry, the environment and society as a whole.

**For further information, please contact Water UK, 3rd Floor, 36 Broadway, London, SW1H 0BH quoting the report reference number**

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## Glossary

<b>Aesthetic impacts</b>	Changes to the visual appearance of a waterbody or area, either due to sewage litter, debris or options that include landscaping/greening.
<b>Benefit-cost ratio</b>	An indicator of the overall value for money of an option, project or proposal, used in cost-benefit analysis. A BCR is the ratio of the discounted present value benefits of a project or proposal, expressed in monetary terms, relative to its discounted present value costs, also expressed in monetary terms.
<b>Benefits of SuDS Tool</b>	Tool developed by CIRIA (Construction Industry Research and Information Association), which provides a structured approach to identifying and valuing a wide range of benefits associated with SuDS (sustainable drainage systems).
<b>Cost-benefit analysis</b>	A systematic approach to estimating the strengths and weaknesses of alternatives. It is used to determine whether a project or proposal represents a worthwhile (efficient) investment, and to select between different projects or proposals. In the context of this project, CBA incorporates wider (e.g. environmental and social) costs and benefits.
<b>Combined sewer overflow</b>	A structure on a combined or partially separate sewerage system that allows the discharge of flow in excess of that which the sewer is designed to carry, usually to a receiving surface water body.
<b>Event Duration Monitoring</b>	Monitoring of CSOs to determine the number of times and how long a CSO operates during a year.
<b>Green infrastructure</b>	An approach to managing wet weather impacts that is designed to be resilient and provide a range of financial, environmental and social benefits. It involves holding back water to reduce run-off and treating stormwater at its source.
<b>Multi-Coloured Manual</b>	A handbook and tool to support assessment of the impacts of flooding and coastal erosion.
<b>Net Present Value</b>	An indicator of the value for money of an option project or proposal, calculated by subtracting the discounted present value costs of a project or proposal, expressed in monetary terms, from its discounted present value costs, also expressed in monetary terms.
<b>Option</b>	A combination of measures/physical interventions that, taken together, are designed to achieve a specific improvement or outcome in relation to stormwater discharges.

<b>Revealed preference</b>	A method of eliciting values for preferences in relation to non-market goods or services, through analysis of purchasing habits and choices made by individuals. Revealed preference techniques deduce people's willingness to pay from observed evidence of how they behave in the face of real choices.
<b>Stated preference</b>	Techniques which rely on asking people hypothetical questions, rather like a market research interview. The aim is to see how people respond to a range of choices, and thus to establish the extent of collective <i>willingness to pay</i> for a particular benefit (or their <i>willingness to accept</i> payment in exchange for bearing a particular loss).
<b>Storm Overflow Assessment Framework</b>	An assessment framework, developed as part of the water industry's 21 <sup>st</sup> Century Drainage Programme, which is intended to address the problems caused by discharges from storm overflows considered to operate at too high a frequency.
<b>Sustainable Drainage</b>	An approach designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharges. Encompasses a range of measures including green roofs, permeable surfaces, ponds, wetlands and shallow ditches called swales.
<b>TOTEX</b>	The combination of capital expenditure (capex) and operational expenditure (opex) into a single measure of overall expenditure. Originally proposed to remove any potential bias towards capex in the water industry.
<b>Travel cost method</b>	A revealed preference method of economic valuation used in CBA to calculate the value of a good or service where market prices are not available (e.g. national parks, beaches, ecosystems). It is based on the premise that willingness to pay to visit a site can be estimated based on the time and travel cost expenses that visitors incur.
<b>Willingness to Pay</b>	The maximum amount an individual is willing to forego to procure a good or avoid something undesirable. Estimated WTP values for water, wastewater and environmental service improvements are generally derived from water company customer surveys and used to inform investment planning.

## Acronyms

<b>BCR</b>	Benefit-cost ratio
<b>BeST</b>	Benefits of SuDS Tool
<b>BTKNEEC</b>	Best Technical Knowledge Not Entailing Excessive Cost
<b>CBA</b>	Cost-benefit analysis
<b>CSO</b>	Combined Sewer Overflow
<b>EA</b>	Environment Agency
<b>GI</b>	Green Infrastructure
<b>MCM</b>	Multi-Coloured Manual
<b>NIEA</b>	Northern Ireland Environment Agency
<b>NPV</b>	Net present value
<b>NRW</b>	Natural Resources Wales
<b>PSG</b>	Project Steering Group
<b>SEPA</b>	Scottish Environmental Protection Agency
<b>SOAF</b>	Storm Overflow Assessment Framework
<b>SuDS</b>	Sustainable Urban Drainage
<b>UWWTD</b>	Urban Wastewater Treatment Directive
<b>WaSC</b>	Water and Sewerage Company
<b>WTP</b>	Willingness to Pay

# 1 Introduction

## 1.1 Background

Storm overflows are an important part of our drainage system. They are designed to provide protection to properties from flooding by alleviating surcharging of combined sewerage systems that occurs in wet weather, and to avoid overloading of downstream wastewater treatment plants.

They are widespread throughout the UK, particularly in older parts of the network, and are subject to permit conditions (consents) issued by the EA (Environment Agency), NRW (Natural Resources Wales), SEPA (Scottish Environmental Protection Agency) or the NIEA (Northern Ireland Environment Agency).

They are recognised as having the potential to impact on the receiving waters they discharge to, and can be sources of pollution if they are not controlled and managed effectively.

Significant investment by the water industry over recent decades has improved the performance of many storm overflows. There is currently a programme to monitor the vast majority of storm discharges by 2020 and there is a need to be able to assess where improvements are required considering any societal impact of the current arrangements.

As well as potential cost savings and an improved drainage system, additional investment has the potential to deliver a range of economic, social and environmental benefits.

To help manage the environmental, reputational and other risks from storm discharges, the Environment Agency and the water industry have collaborated to produce the Storm Overflow Assessment Framework (SOAF). This is intended to address the problems caused by discharges from storm overflows considered to operate at too high a frequency.

This report is the main output of a joint EA/Water UK project to develop a framework for the economic assessment of storm overflows. This is Stage 3 of the SOAF, i.e. for high spilling overflows that cause an environmental impact, or any overflow in a drainage catchment greater than the Urban Wastewater Treatment Directive (UWWTD) threshold of 2,000 pe (population equivalent), the SOAF requires water and sewerage companies (WaSCs) to:

*“Assess options (costs & benefits) (including BTKNEEC analysis) with reference to the wider drainage strategy where applicable”.*

This report is accompanied by a Practitioners’ Guide, to support application of the framework that has been developed. Together, these resources will inform future policy and legislation in this area, and form a key component of the water industry’s 21<sup>st</sup> Century Drainage Programme, providing a strategic and long-term approaches to planning drainage management.

## 1.2 Project objectives

The objectives of the project were to:

- v. Identify the social, economic and environmental benefits of improving high spilling storm overflows;
- vi. Review international practices for valuing benefits associated with storm discharge improvements within a cost-benefit analysis (CBA) framework;
- vii. Develop a methodology to enable the marginal benefits of improvements to be valued; and
- viii. Provide a CBA framework so future investment decisions can be made.

The key outputs of the project are:

- A benefit valuation methodology that can feed into the SOAF as part of the broader 21<sup>st</sup> Century Drainage Programme of work; and
- A framework to support decisions on whether or not improvements to high spilling storm overflow are required and how improvements should be prioritised.

## 1.3 Structure of report

Following this introduction, Section 2 of this report provides an overview of the methodology developed to deliver the project objectives. Section 3 sets out the principles of benefits assessment and Section 4 discusses the range of potential financial, social and environmental benefits of storm discharge improvements. An understanding of these principles and benefits underpins the benefits assessment framework, which is described in Section 5.

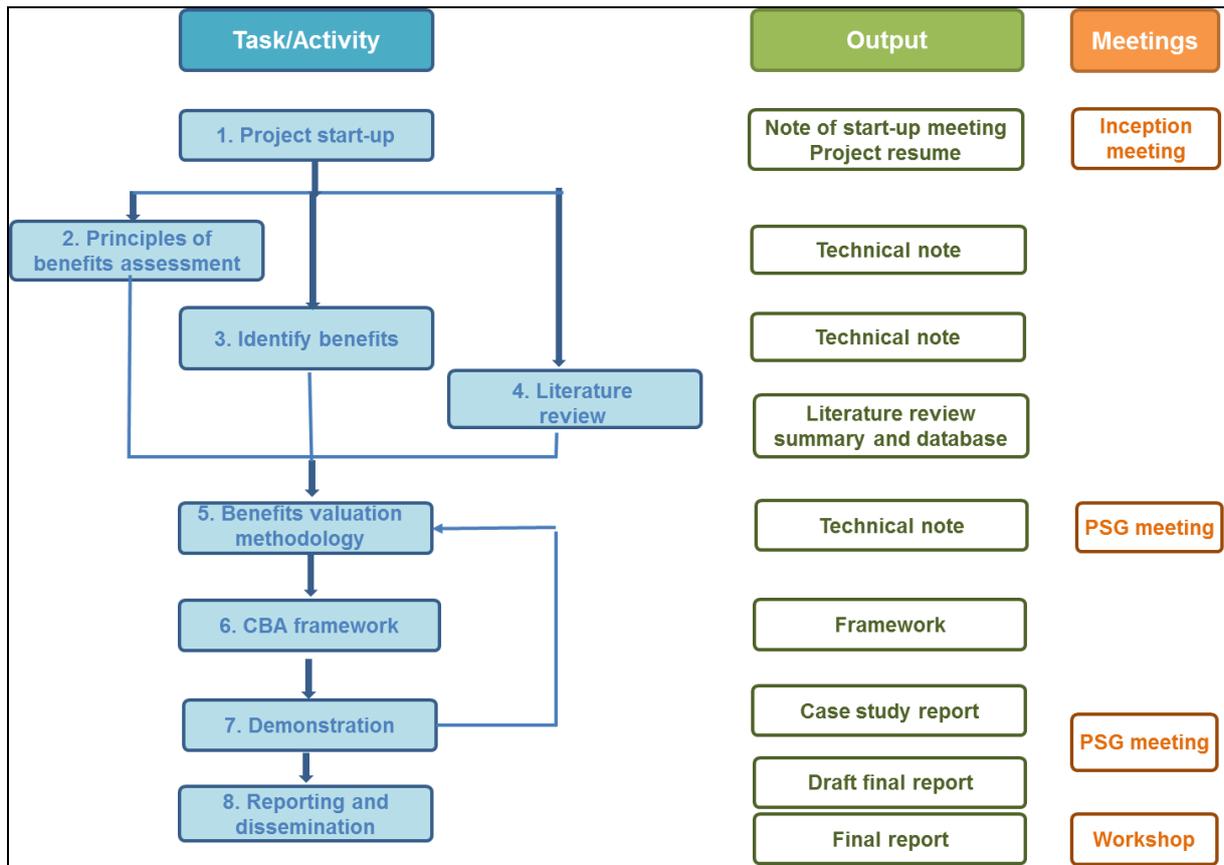
A key part of the project has been to demonstrate and test the framework using case studies, and the process, results and lessons from this exercise are considered in Section 6. Section 7 sets out the key conclusions from the project and Section 8 proposes some recommendations. Finally, Section 9 lists the references cited in this report.

Appendices are included at the end of this report. A Practitioners' Guide is available separately and is designed to support application of the framework described in Section 5.

## 2 Methodology

The project team developed a methodology to support implementation of the project and delivery of the objectives. This is shown in Figure 1.

**Figure 2 Overview of methodology**



The key elements of each stage of the methodology are set out and discussed in subsequent sections of this report.

### 3 Principles of benefits assessment

Improvements to storm overflows have the potential to deliver a range of economic, social and environmental benefits. In the UK, guidance relating to the identification, assessment and valuation of these benefits comes from a number of sources, as outlined below.

#### HM Treasury, The Green Book (2011)

This states (p21) that *“the purpose of valuing benefits is to consider whether an option’s benefits are worth its costs, and to allow alternative options to be systematically compared in terms of their net benefits or net costs. The general rule is that benefits should be valued unless it is clearly not practicable to do so.”*

Further (p57), *“Social Cost Benefit Analysis seeks to assess the net value of a policy or project to society as a whole. The valuation of non-market impacts is a challenging but essential element of this, and should be attempted wherever feasible. The full value of goods such as health, educational success, family and community stability, and environmental assets cannot simply be inferred from market prices, but we should not neglect such important social impacts in policy making.”*

#### Defra, An Introductory Guide to Valuing Ecosystem Services (2011)

This focuses on the valuation of ecosystem services and states (p10) that *“the underlying case for the valuation of ecosystem services is that it will contribute towards better decision-making by ensuring that policy appraisals fully take into account the costs and benefits to the natural environment and by highlighting much more clearly the implications for human wellbeing while providing policy development with new insights.”*

#### eftec, Environmental and social costs: Developing guidance on environmental valuation for water environment planning (2015b)

This proposes a number of ‘good practice’ principles when appraising environmental and social impacts, which have been taken forward (Environment Agency, 2016) and which have been used to inform the next section.

#### UKWIR (2010) Review of Cost-Benefit Analysis and Benefit Valuation

This makes recommendations on the future (post-PR09) application of cost-benefit analysis (CBA) and benefits valuation for water companies and their regulators. It includes lessons from the PR09 experience and considers the future role for CBA in business planning in the water industry.

The principles that guide the assessment of benefits should be consistent with best practice as outlined above and specific to the needs of the project. In conjunction with the PSG (Project Steering Group), the project team developed a number of principles to inform a literature review to identify values associated with key benefits (see Appendix 1) and to guide the development of a benefits assessment framework. These are shown in Table 1, which also explains the need for (purpose of) the principle and how it is embedded into the framework.

**Table 1 Principles of benefits assessment**

<b>Principle</b>	<b>Purpose</b>	<b>How embedded into framework</b>
Consider all benefits and dis-benefits of options	Ensure completeness and consider both private and wider societal benefits (both current and future), both <i>direct</i> and <i>indirect</i> benefits, and both tangible and intangible benefits to all potential beneficiaries	Ensure framework is coherent and consistently applied by basing consideration of benefits on ecosystem service and natural capital approaches
Minimise risk of double counting	Ensure benefits are counted only once and not considered again when they would have been accrued elsewhere (e.g. another policy) or incurred regardless of the intervention (additionality)	Include matrix of benefits against options to illustrate areas of potential overlap, and highlight risk of double counting, and ways to mitigate/minimise risk, throughout framework
Consider scale	Recognise that benefits will be related to size of investment and some benefits are only likely to be important above a certain scale	Explicit consideration of scale, potential thresholds and tipping points in framework, with focus on most significant impacts
Proportionate approach	Focus effort and resource on those benefits likely to be most pertinent to final decision	Include screening stage and adopt stepped approach in framework
Link interventions to benefits	Ensure attribution of benefits is as robust and realistic as possible (e.g. greater impacts for overflows that spill frequently, spill to more sensitive receiving waters, or are in high amenity areas/areas with low dilution)	Develop matrix linking range of typical interventions to outcomes and potential benefits associated with these outcomes, and describe process by which benefits come about in framework
Monetise benefits where possible	Enables benefits to be consistently assessed, clearly communicated and explicitly included in decision making	Focus literature review and framework on quantified and monetised impacts, with guidance on non-monetised impacts
Consider variability	Recognise that value of benefits will vary across space and time – this is to be expected and is due to location, condition, type of intervention and resultant change, scarcity, availability of substitutes, etc	Identify factors impacting on benefit values, and develop ranges of values where possible
Consistency and certainty	Maximise credibility and reliability through consistent approach to assessment of benefits and costs, which explicitly considers uncertainty	Embed consistency into framework, and provide reporting template
Best available information and evidence	Maximise robustness by utilising information and values from studies that are particularly relevant or add significant value to the evidence base	Ensure literature review is based, as far as possible, on local/UK studies within last 10 years
Transparency	Provide clear explanation and audit trail of complete appraisal process	Ensure approach, information used and assumptions are clear and explicit throughout

## 4 Benefits of storm discharge improvements

The range of potential impacts (either positive, i.e. benefits, or negative, i.e. dis-benefits) of storm discharge improvements on human welfare is based on expert knowledge and previous work in this area, including CIRIA (2015) and UKWIR (2013 & 2014). To ensure that these impacts are considered and assessed comprehensively, the approach adopted is based on an ecosystem services framework (MEA, 2005; Defra, 2011).

The full range of ecosystem services considered is shown in Table 2.

**Table 2 Potential impacts of storm discharge improvements**

<b>Ecosystem service impacted by storm discharges</b>	<b>Impacts on human welfare</b>
<b>Provisioning services</b>	
Food & fibre	<ul style="list-style-type: none"> <li>• New/improved opportunities for commercial fishing</li> <li>• Impacts on food production (e.g. via improved soils, pollination)</li> </ul>
<b>Regulating services</b>	
Air quality	<ul style="list-style-type: none"> <li>• Physical/mental health benefits from air quality improvements (e.g. avoided/reduced health care costs)</li> </ul>
Climate regulation	<ul style="list-style-type: none"> <li>• Cost savings from reduced summer or increased winter building temperatures</li> <li>• Physical/mental health benefits from improved climate</li> <li>• Reduction/sequestration of GHG emissions</li> </ul>
Water regulation	<ul style="list-style-type: none"> <li>• Increased water available for use</li> <li>• Change in river flows</li> </ul>
Water quality	<ul style="list-style-type: none"> <li>• Additional/avoided treatment (e.g. aeration) or pumping</li> <li>• Avoided fines/penalties, regulatory rewards</li> <li>• Enhanced reputation (e.g. companies, regulators)</li> <li>• WFD-related improvements</li> <li>• Avoided fish kills</li> <li>• Reduced micropollutants</li> </ul>
Natural hazards	<ul style="list-style-type: none"> <li>• Avoided flood damage to property/land, infrastructure, etc</li> <li>• Disruption, inconvenience, anxiety caused by flooding</li> </ul>
<b>Cultural services</b>	
Aesthetic values	<ul style="list-style-type: none"> <li>• Increased property/land values</li> <li>• Litter, odour and noise</li> <li>• Community cohesion</li> <li>• Improvements to landscape</li> </ul>
Recreation	<ul style="list-style-type: none"> <li>• Increased revenues from recreational activities</li> <li>• Enhanced enjoyment of and/or participation in recreation</li> </ul>
Education	<ul style="list-style-type: none"> <li>• Enhanced learning opportunities</li> </ul>

Ecosystem service impacted by storm discharges	Impacts on human welfare
Health	<ul style="list-style-type: none"> <li>• Avoided costs of sickness/illness to employers, schools and others</li> <li>• Enhanced physical &amp; mental wellbeing (e.g. avoided/reduced health care costs)</li> </ul>
Supporting services	
Biodiversity	<ul style="list-style-type: none"> <li>• Habitats and ecology</li> </ul>

In addition to the impacts above, other (non-ecosystem service related) impacts may need to be considered and incorporated. These include

- Additional drainage network capacity (headroom)
- Reduced/avoided planning delays
- Local economic growth, development and regeneration, increased tourism
- Employment and productivity
- Value added skills
- Leveraging - engaging new partners for collaboration and/or co-funding
- Dis-benefits from construction and operational activity (e.g. traffic delays associated with works)

## 4.1 Summary of literature review

The literature review is focused on the impacts presented above, and on the identification of monetary values associated with these impacts. A summary is provided here, with more detail provided in Appendix 1. This incorporates quantitative and monetary evidence taken forward into the framework, including relevant details of the study such as:

- General information about the study (e.g. author, title, year undertaken);
- Context (e.g. country/location, interventions, spatial scale and whether interventions are planned, ongoing or implemented);
- Benefits (e.g. benefit types/categories considered, description and quantification of benefits);
- Valuation (e.g. approach used, monetary values provided); and
- Usefulness (applicability to this project, and additional comments).

### 4.1.1 Approach

The aim of the review was to identify and interrogate key evidence relevant to the socio-economic and environmental benefits that are associated with improving storm overflows.

The project team reviewed a wide variety of literature regarding existing national and international practices for valuing the benefits associated with storm discharge improvements, for use in CBA or other forms of economic appraisal.

Around 150 pieces of evidence are included in the database, drawn from several dozen studies across many countries. The review focussed on studies relating to the valuation of improvements to storm overflow discharges, as opposed to studies valuing relevant benefits in another context, although some of these were included where deemed relevant.

The key sources of information explored in undertaking the review were:

- Methods and tools for assessing the benefits of wastewater infrastructure investments, e.g. BeST (CIRIA, 2016), TEEB (The Economics of Ecosystems and Biodiversity);
- Economic valuation databases, e.g. Environmental Valuation Resource Inventory (EVRI), Environmental Valuation Look-Up Tool;
- Water company valuation studies (Accent, 2014);
- Water industry research projects, e.g. UKWIR (2017), UKWIR (2015), work for the Thames Tideway; and
- Academic and scientific studies, utilising commonly used databases and search engines, e.g. SCOPUS and Web of Science, as well as relevant review of the grey literature, e.g. Sinnett et al (2017).

#### 4.1.2 Review of studies

A complete analysis of all studies reviewed is included in Appendix 1. These have been organised into three themes:

- UK water industry and other research;
- Studies covering the wider benefits of green infrastructure (GI); and
- Benefits valuation in different countries.

Table 3 summarises the key types of study reviewed in each area.

**Table 3 Summary of studies reviewed**

Theme	Studies reviewed
UK water industry and other research	<ul style="list-style-type: none"> <li>• UKWIR reports</li> <li>• Water company willingness to pay (WTP) work</li> <li>• Water UK projects</li> <li>• Collaborative/club projects</li> <li>• EA NWEBS (National Water Environment Benefits Survey) work</li> </ul>
Studies on wider benefits of GI	<ul style="list-style-type: none"> <li>• Broader, ecosystem service-based benefits of GI and sustainable drainage systems (SuDS), e.g. health, air quality, climate change</li> <li>• Life-cycle type approaches</li> </ul>

Benefits valuation in different countries	<ul style="list-style-type: none"> <li>• US (CSO/storm drainage studies and tools)</li> <li>• Netherlands (e.g. The Economics of Ecosystems and Biodiversity)</li> <li>• Denmark (e.g. Open Urban Drainage Systems)</li> <li>• Australia (e.g. Water Sensitive Urban Design)</li> </ul>
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### UK water industry and other research

Detailed evidence from UK water industry research on the valuation of the benefits from storm overflow improvements is set out in Appendix 1.

UKWIR reports provide a useful framework for undertaking and applying benefits valuation in general (UKWIR, 2010) and in considering and valuing the benefits from storm overflow improvements in particular (UKWIR, 2014).

In relation to specific valuation evidence, much of the existing research and evidence from the UK water industry comes from WTP studies. This is often complemented or supplemented by work from other sources (e.g. BeST) and organisations (e.g. Environment Agency).

There are a number of existing guidance documents, tools and manuals that support the valuation of storm overflow improvements. These can be incorporated into, and/or signposted from, a framework for valuation of benefits.

With improved understanding of concepts such as ecosystem services (ES) and natural capital, and the advent of analytical tools such as BeST, it is now possible to identify a wider range of benefits for drainage or surface water schemes than in the past. Understanding of who are the beneficiaries of the wide range of benefits from SuDS makes it possible to attribute appropriate costs, responsibilities and risks appropriately. This also reveals where there were previously hidden benefits and implicit beneficiaries from schemes. This information now provides the evidence to engage with beneficiaries to ensure they provide the required funding where they are obtaining such benefits.

Better evidence is now available to help to engage with communities with a potential interest in managing stormwater. This will be crucial for future effectiveness (e.g. Montalto et al, 2013). Much more financial and economic data can be generated to show that there are a diverse range of direct economic benefits – many of which have not been quantifiable before, and for which beneficiaries appear willing to pay to secure.

### The wider benefits of green infrastructure

Much of the literature around the valuation of benefits related to storm overflow improvements focuses on the role of green infrastructure (GI) and its potential for delivering multiple benefits. Detailed evidence on the wider benefits of GI is set out in Appendix 1.

This information provides compelling evidence that, from an overall economic benefit perspective, GI and SuDS used in appropriate combination with limited grey (piped drainage) infrastructure, will provide the greatest value in all but a minority of situations (e.g. Thurston, 2012; Woods-Ballard et al, 2015).

Understanding of and approaches as to how to utilise SuDS as part of multi-functional urban systems and also to deliver multifunctional use of space has advanced as more and more infrastructure related domains take an interest (e.g. Silva & Costa, 2016). Associated with this is the drive to develop methods and evidence to set out very clear business cases for the use of GI in urban areas that are likely to be profitable (e.g. Mekala et al, 2015; Berkeley Law, 2015).

Notwithstanding the roll-out and use of tools for valuing SuDS (e.g. BeST), there has been limited progress over recent years in understanding the financial and other benefits that GI and SuDS can provide.

Considering stormwater management as an integral part of land use planning (e.g. Hansen & Pauliet, 2014) offers the greatest potential for delivering multiple benefits. Traditional, buried drainage which is ‘out-of-sight-out-of-mind’ could be designed and operated in semi-isolation from other societal needs and functions provided it continued to deliver the required service. Many studies now show that this traditional drainage delivers a limited number of single focused benefits – flood risk reduction, public health protection and, if properly managed, minimal environmental impacts. Society now expects more from the services provided and it is clear that ‘drainage’ is one of many needs and expectations, but surface water is still largely seen as a ‘problem’ to be managed rather than an opportunity to be maximised.

Case study examples, such as that in Philadelphia (see Appendix 1) where almost \$3bn of added benefits are provided by managing CSOs using SuDS as part of a GI strategy that delivers multiple functions, provide compelling reasons to move away from a drainage mindset to one in which surface water is seen as providing opportunities to enhance urban areas.

Whilst there is evidence of significant benefits from GI in terms of water quality and reduced flood risk, there is increasing evidence that other benefits, particularly related to enhanced amenity and improved health, could be even greater.

The review also considered approaches used to value benefits in monetary terms. Valuation based on avoided cost and revealed preference techniques (e.g. travel cost method) is often used to value many of the wider benefits of GI. The application of stated preference techniques (e.g. WTP-based studies) is less common, although it is sometimes used for less ‘tangible’ benefits (e.g. biodiversity) where other approaches are not available or appropriate. It is also used in particular contexts with some relevance to the benefits of storm overflow improvements, e.g. in the Environment Agency’s NWEBS work (EA, 2016a; Metcalfe et al, 2012) and by water companies in customer research.

### Benefits valuation in different countries

Detailed evidence on the valuation of the benefits from different countries is set out in Appendix 1.

While much of the evidence related to the benefits of GI comes from applications in the USA (e.g. Roseen et al, 2011; Hair et al, 2014; Sinnett et al, 2017), there is also a growing body of evidence from around the world that combinations of blue and green SuDS and grey piped drainage produce the greatest benefits to society as a whole (Sinnett et al, 2017).

However, there are difficulties in ensuring that these many benefits are actually provided by any given scheme. While many impediments relate to the policy and regulatory frameworks (e.g. Lundy and Ellis, 2016), there are other difficulties related to the ease or otherwise of retrofitting into congested urban environments, land take, policy maker, institutional, community and individual acceptability and the complexity of managing and maintaining SuDS as assets over their lifetime.

Valuation outside the UK is, especially in the US, often based on non-monetary techniques, predominantly using multi-criteria approaches. However, there are exceptions to this. For example, a tool by the Centre for Neighbourhood Technology (CNT, 2010) is widely used to assess benefits, and variants of the SUSTAIN tool (US EPA, 2011) are used for cost optimisation purposes.

Lack of data sharing or collection is impeding confidence in benefit valuation, not only in the UK. This applies to both the physical performance data, especially longer term, and also the financial costs and benefits of SuDS. Most notable progress regarding the economic aspects has been in the recognition, quantification and monetisation of the mental and physical health benefits brought from the use of GI (not specifically SuDS) and the bringing together of indoor and outdoor space valuations (e.g. WHO, 2017; Bowen and Parry, 2015; Taylor and Pineo, 2015).

#### **4.1.3 Summary of relevance to benefit categories**

Table 4 relates the findings of the literature review to the ecosystem service and other benefit categories considered important in storm overflow improvements (Table 2).

**Table 4 Summary of review findings related to stormwater improvement benefits**

<b>Ecosystem service</b>	<b>Impacts on human welfare</b>	<b>Literature review findings</b>	<b>Potential for valuation</b>
<b>Provisioning services</b>			
Food & fibre	New/improved opportunities for commercial fishing	Considered in EVL Tool, with valuation of commercial fish/food based on Defra (2015b)	Good
	Impacts on food production (e.g. via improved soils, pollination)		
<b>Regulating services</b>			
Air quality	Physical/mental health benefits from air quality improvements (e.g. avoided/reduced health care costs)	Considered in BeST (CIRIA, 2016) and EVL Tool, based on Air Quality Damage Cost Guidance (Defra, 2011)	Good
Climate regulation	Cost savings from reduced summer or increased winter building temperatures	Partially considered in previous work (see Stratus Consulting, 2009; Van Peijpe, 2016; CIRIA, 2016), but limited evidence from UK.	Medium
	Physical/mental health benefits from improved climate	Very limited evidence to date	Poor
	Reduction/ sequestration of GHG emissions	Comprehensive evidence, largely linked to Valuation of energy use and greenhouse gas emissions for appraisal (DECC, 2014) in UK	Good
Water regulation	Increased water available for use	Very limited evidence to date (main exception is CH2M, 2015) and requires additional cost information from water companies to support valuation.	Poor
	Change in river flows	Partly covered in (some) water company WTP studies	Medium
Water quality	Additional/avoided treatment (e.g. aeration) or pumping	Partially considered in previous work (e.g. CIRIA, 2016) and other studies (e.g. Van Peijpe, 2016, CH2M, 2015), but requires additional cost information from water companies to support valuation.	Medium
	Enhanced reputation (e.g. companies, regulators)	No evidence found	Poor
	WFD-related improvements	Good evidence from Environment Agency NWEBS and water company WTP work	Good
	Avoided fish kills	Water company WTP work includes pollution incidents, which is likely to	Good

<b>Ecosystem service</b>	<b>Impacts on human welfare</b>	<b>Literature review findings</b>	<b>Potential for valuation</b>
		encompass values related to fish kills. Thames Tideway study also covers fish kills.	
	Reduced micropollutants	Water company WTP work includes pollution incidents, which is likely to encompass values related to micro-pollutants.	Good
Natural hazards	Avoided flood damage to property/land, infrastructure, etc	Considered in BeST (CIRIA, 2016) and other UK-based studies, generally linked to detailed values from water company WTP studies or Multi-Coloured Manual.	Good
	Disruption, inconvenience, anxiety caused by flooding	Partly covered by BeST (CIRIA, 2016) and Multi-Coloured Manual.	Medium
<b>Cultural services</b>			
Aesthetic values	Increased property/land values	Good evidence from around the world, including BeST (CIRIA, 2016) and many of the studies included in the review	Good
	Litter, odour & noise	Litter and odour at least partly considered in water company WTP studies and NWEBS, as well as Thames Tideway and other studies. Environmental noise impacts considered in EVL Tool and based on values from Defra (2014).	Good
	Community cohesion	Limited evidence (e.g. from Zwolle, Van Peijpe, 2016)	Medium
	Improvements to landscape	No specific evidence, but likely to be covered by property/land values	Medium
Recreation	Increased revenues from recreational activities	Some evidence from EVL Tool (e.g. Sen et al, 2014). May also be partly captured by categories included in water company WTP studies (e.g. pollution incidents) and NWEBS.	Medium
	Enhanced enjoyment of and/or participation in recreation	As above	Medium
Education	Enhanced learning opportunities	Some, very limited valuation evidence in BeST (CIRIA, 2016)	Medium
Health	Avoided costs of sickness/illness to employers, schools and others	Some patchy evidence identified in review, e.g. CIRIA (2016), UKWIR (2014), NRDC (2013), Bowen & Parry (2015), WHO (2017)	Medium

<b>Ecosystem service</b>	<b>Impacts on human welfare</b>	<b>Literature review findings</b>	<b>Potential for valuation</b>
	Enhanced physical and mental wellbeing (e.g. avoided/reduced health care costs)	As above, plus some evidence (e.g. in BeST, CIRIA, 2016), and health risk included in Thames Tideway study	Medium
<b>Supporting services</b>			
Biodiversity	Habitats and ecology	Considered in BeST (CIRIA, 2016), with additional evidence in EVL Tool. Also partly captured by categories included in water company WTP studies (e.g. pollution incidents) and NWEBS	Good
<b>Other</b>			
Headroom	Additional drainage network capacity	Very limited evidence to date and requires additional cost information from water companies to support valuation.	Poor
Planning	Reduced/avoided planning delays	No evidence found	Poor
Growth	Local economic growth, development and regeneration, increased tourism	Limited evidence only, e.g. NDRC (2013), Stratus Consulting (2009)	Poor
Jobs	Employment and productivity	No evidence found	Poor
Skills	Value added skills	No evidence found	Poor
Leveraging	Engaging new partners for collaboration and/or co-funding	No evidence found	Poor
Construction	Dis-benefits from construction (e.g. traffic disruption)	Good evidence from UKWIR (2011)	Good

#### **4.1.4 Conclusions from literature review**

A number of conclusions emerge from the literature review presented here:

- There is significant evidence from many contexts and locations that storm overflow improvements can deliver a wide variety of significant benefits, offering a flexible approach with greater potential for adaptation and resilience to future changes.
- There is also significant evidence related to the value of many of the direct benefits expected to arise from storm overflow improvements. This primarily includes those benefits where market-based information is available or where specific valuation research (e.g. WTP surveys, NWEBS) has been undertaken.

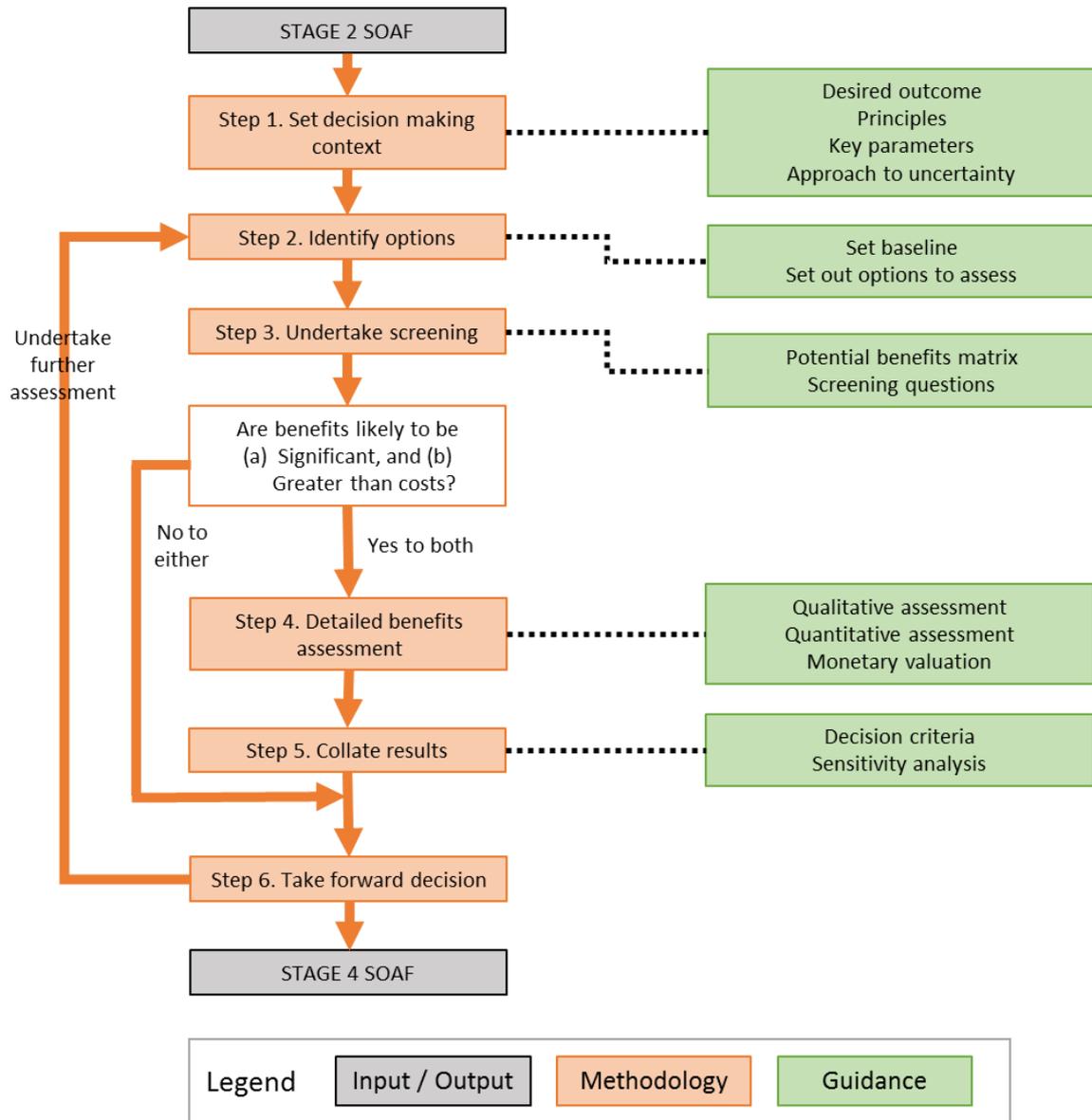
- In addition, a number of existing guidance documents, frameworks and tools support the assessment of benefits and can be used to inform a valuation framework.
- There is some, often mixed or limited, information related to the value of some of the indirect benefits. This primarily includes non-market benefits where some valuation research has been undertaken, e.g. health. The evidence that is available suggests that, particularly where interventions that can be broadly defined as green infrastructure are employed, some of these benefits can be very important. However, more evidence from assessments is needed in this area, and methods and techniques need to be developed and employed to ensure these are properly considered and greater certainty attached to the values.
- The opportunity to realise many of these wider, multiple benefits is maximised where surface water is seen as providing opportunities to enhance urban areas. However, there are often technical, institutional and other barriers that can hinder the prospect of these benefits being realised. Not least of these is the fact that water and sewerage companies have little or no control over wider land use management.
- A narrow approach to valuation, focusing on ‘traditional’ benefits linked for example to water quality and flood risk only, could significantly underestimate the wider potential benefits from storm overflow improvements. Benefits related to amenity and improved health could be particularly significant if a material change in these benefits can be achieved.
- There is poor or no evidence related to the value of some other benefits. This primarily encompasses those less tangible benefits (e.g. reputation, skills) where little research has been undertaken and where it is more difficult to attribute benefits to interventions. It is therefore difficult to quantify and value these benefits reliably, and any framework for valuation should therefore allow for the inclusion of non-monetised benefits.
- The actual benefits delivered by any given project or intervention will depend on a number of factors, including the nature and scale of the intervention, location, proximity to watercourses and beneficiary populations, and the availability of substitute sites. It is therefore difficult to generalise about the type of scale of benefits that may arise from different projects – a case-by-case assessment will generally need to be undertaken, within a consistent framework.

In summary, there is sufficient evidence from the UK and elsewhere to enable the development of a framework within which all potentially significant benefits and some of the more minor benefits from storm overflow improvements can be reliably valued.

## 5 Overview of the benefits assessment framework

The framework for assessing the benefits of storm discharge improvements is shown in Figure 2 and is designed to support an approach based on cost-benefit analysis (CBA). The aim of the framework is to ensure consistency in and robustness of assessments whilst allowing flexibility and ensuring the level of effort is proportionate to the decision to be made. Each step of the framework is discussed in more detail below. A separate Practitioners' Guide is available to support completion of assessments.

**Figure 2 Overall framework**



The key 'input' to the framework is the output from Stage 2 of the SOAF. This confirms that there is clear driver/justification for intervention, i.e. the overflow has been identified as causing an environmental impact, or that it is high spilling and above the 2,000 pe drainage catchment threshold.

A number of quantified or semi-quantified outputs from Stage 2 are expected, including:

- Number of spills;
- Details of aesthetic impact including amenity (e.g. litter) and public complaints (score and classification from no impact to severe); and *either*
- Details of invertebrate (biological) impact (score and classification from no impact to severe); *or*
- Water quality impact (based on dilution or modelled impact).

Stage 2 should also provide information about the watercourse itself and the surrounding environment close to the overflow.

The approach adopted in the framework is sufficiently flexible to be applicable to both an individual overflow and a group of overflows (as part of a catchment-wide programme). It is consistent with government guidance (HM Treasury, 2011), principles set out by the Environment Agency (EA, 2016a), water industry approaches (UKWIR, 2010) and natural capital concepts (Natural Capital Coalition, undated).

To facilitate consistent recording of outputs and reporting, an Appraisal Summary Table (AST) is provided (Table 5). A completed example AST is included in Appendix 3.

**Table 5 Appraisal Summary Table**

<b>Scheme details: site, location, etc</b>						
<b>Baseline:</b>						
<b>Option name:</b>						
<b>Summary of screening:</b>						
<b>Detailed assessment</b>						
<b>Benefit category</b>	<b>Qualitative description</b>	<b>Quantitative assessment (1)</b>	<b>Value taken (2)</b>	<b>Monetary valuation (1x2)</b>	<b>Sensitivity</b>	<b>Assumptions</b>
<b>Results:</b>						

## 5.1 Set Decision Making Context

The purpose of this step is to ensure the decision to be made is clear, agreed and recorded. It should be applied to all overflows that are assessed using Stage 3 of the SOAF.

This stage should explicitly articulate the desired outcome of the intervention. This should be the optimal level of investment, i.e. that which provides best value for money for customers and society, but could also consider cases where CBA may be 'constrained', including:

- How benefits can be maximised, either relative to costs, or subject to a fixed budget or level of affordability;
- Whether a minimum reduction in spills needs to be achieved;
- Whether a minimum water quality, environmental or other standard needs to be met; and
- Ensuring no detriment to other drivers.

This step should also set out and define any key parameters relating to the assessment. These include the timeframe for the assessment (note that the 21<sup>st</sup> century drainage programme of work is about taking a longer term approach, beyond the next few years), discount rate, geographical scope of benefits, and the beneficiary groups to be considered.

Finally, this stage should set out the proposed approach to uncertainty. As a minimum, each assessment should utilise ranges for key metrics/values, and adopt sensitivity analysis around the results. More advanced approaches, including those based on scenario planning, are permitted and discussed.

## 5.2 Identify Options

The purpose of this step is to ensure that the options to be assessed (including the baseline) are clear, agreed and recorded. It should be applied to all overflows that are assessed using Stage 3 of the SOAF.

It provides the basis for ensuring that all storm overflow interventions are assessed against a common baseline.

### Step 2a – Record baseline information

The baseline ('business as usual' or 'do nothing' option) should be articulated and recorded. This includes the location of the overflow, drivers for intervention, reasons for failure (RFF), current spill frequency, water quality (generally based on measured EDM (event duration monitoring) data), WFD status and hydraulic capacity. This may also include water quality modelling completed as part of stage 2 of the SOAF, or as necessary to assess the benefit of that an option has on the receiving water and the length of watercourse.

External (e.g. climate change, growth) and endogenous (e.g. volume available for dilution) changes over time should also be considered, since projections of water quality (based on modelling) or other parameters may suggest deterioration if no action is taken.

### Step 2b – Set out the options

Once the baseline has been established, the options for assessment should be set out. It is up to the water company to identify potential options for the assessment. However, in order to provide an indication of the likely scale and breadth of different costs and benefits, we recommend that a minimum of 2 options are considered, which should be varied in nature.

Each option should include a description of the type, scale and other characteristics of the option and its component measures (which may differ in scale or timing). All options must be specified consistently in terms of their ability to achieve the desired outcome, e.g. an option to just reduce spills and tackle water quality through additional storage will have different impacts, costs and benefits to an option which also seeks to tackle flood risk (if a wider problem exists). Options should be assessed *relative to* the baseline.

### Step 2c – Evaluate the options

Options should be evaluated to understand their performance against the required need and the agreed decision making context. This will provide an indication of the likely hydraulic, water quality and other benefits that the options will create.

## **5.3 Undertake Screening**

The purpose of this step is (a) to ensure the assessment is focused on those options most likely to be cost-beneficial, and (b) to ensure assessed options focus on benefits of greatest significance. It should be applied to all options identified in Step 2.

The purpose of the screening process is to remove infeasible options or identify a clearly favourable option (one which dominates all the others) based on the potential scale of net benefits (the difference between benefits and costs). This will help to ensure that the assessment is undertaken in a proportionate way and focused on those impacts of greatest likely significance.

The screening process comprises a series of questions. These provide a means of determining whether or not a detailed assessment is needed and appropriate. Guidance is provided in the Practitioner's Guide accompanying this report to enable users to answer each of these questions.

- a. What is the maximum length of improved watercourse?
- b. What is the maximum value of direct benefits per year?
- c. What is the maximum value of direct benefits over the assessment period?
- d. Are benefits significant?
- e. Are other benefits important?
- f. What is the approximate cost of each option?
- g. Are benefits potentially greater than costs?

Based on responses to these questions, the assessment should record whether benefits are likely to be (a) significant, and (b) greater than costs. To provide an initial indication of whether benefits are likely to be significant, this is defined as PV benefits greater than £100,000 for any given option. To allow for uncertainty in the assessment, options with a benefit cost ratio greater than 0.5 under any sensitivity analysis scenario should be taken forward. If the answer to either (a) or (b) is no, then a detailed assessment of benefits for that option is unlikely to be required. However, where the answer to both (a) and (b) is yes, then a detailed assessment should be undertaken.

## 5.4 Detailed Benefit Assessment

The purpose of this step is to develop a detailed, robust and auditable assessment of the direct and indirect benefits of those options which have been carried forward from the screening process. It should be applied to all options that are carried forward from the Step 3 screening process.

The first step is to identify the benefits to assess. The Practitioners' Guide facilitates a more detailed investigation and assessment of the direct and indirect benefits in each relevant benefit category, with a step-by-step summary of how to undertake an evaluation.

Guidance relating to each specific benefit category is provided in Appendix 3 of the Practitioner's Guide. For each benefit in each category, Appendix 3 includes a table, which provides:

- i. Information to support either a *basic* or *advanced* assessment for that benefit. A basic assessment requires a lower amount of effort and information than an advanced assessment.
- ii. A description of the impact
- iii. Guidance on how to quantify the benefit, using either the basic or advanced approach
- iv. Guidance on possible ways to value the benefit in monetary terms (including examples of monetary values that may be appropriate to apply), using either the basic or advanced approach
- v. Guidance on the output expected from the assessment of each benefit

## 5.5 Collate Results

The purpose of this step is to bring together and present the results of each option. It should be applied to all options that are carried forward from the Step 3 screening process and subject to a detailed assessment in Step 4.

There are a number of key steps to consider when collating the results of the assessment.

### Step 5a – Aggregate benefits

The first step is to aggregate the estimates of benefits, particularly over the time period of assessment. This is only necessary for options that have been subject to a detailed benefits assessment (Step 4), as benefits of options at the screening stage are automatically aggregated in Step 3.

#### Step 5b – Incorporate costs of options

Estimates of costs are exogenous to this assessment process but may include both financial costs (e.g. capital equipment, operating expenditure and opportunity cost of providing land for storm overflow improvements) and other financial, social and environmental costs which are not explicitly considered within the framework described in this report (e.g. embodied carbon in materials).

#### Step 5c – Establish decision criteria

The decision rules used in economic appraisal are based on the concept of economic efficiency. A proposed action is deemed cost beneficial, providing an efficient allocation of resources (and therefore justified) if the discounted benefits of the action are greater than the discounted costs over a set period of time, typically 40 years. Each WaSC will have its own approach to determining efficiency based on the balance of costs and benefits. The Guide recommends that, for every option, you should calculate both NPV and BCR, the most commonly used decision criteria in economic analysis.

#### Step 5d – Consider non-monetary information

It is likely that some of the benefits are not amenable to valuation. However, these could be important and non-valued effects should remain part of the decision making process. There may also be other potential benefits that are not currently captured by the framework. Finally, there may also be benefits of wider initiatives of which storm overflow improvements form a part but are not the principal component. This may include programmes to develop sustainable transport corridors or to green urban areas. In these cases, it may be possible and appropriate to allocate a certain proportion or percentage of the benefits of the whole programme to the storm overflow component or reduce the costs through partnership funding.

The Guide recommends that assessments should include a qualitative ranking score (low, 1 to significant, 5) for key non-monetised benefits. Where this score is 4 (high benefit) or 5 (significant benefit), the Guide recommends that these should be explicitly brought into the assessment, and provides suggestions on techniques for doing so.

#### Step 5e – Uncertainty and sensitivity analysis

Information used to inform CBA is inherently uncertain as it is to do with future events. To ensure proportionality of effort, the Guide recommends that a relatively simple and pragmatic approach to managing uncertainty, based on the use of ranges and sensitivity analysis, should be applied.

Sensitivity analysis can include changes to key parameters in the assessment, including:

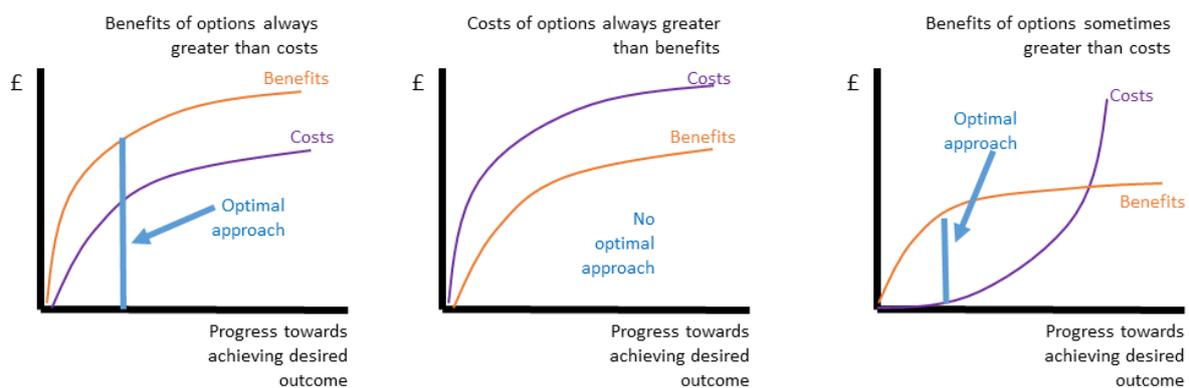
- the discount rate
- the assessment period (when benefits start and end)
- quantified estimates of impacts
- monetary values
- cost estimates

## 5.6 Take Forward Decision

The purpose of this step is to (a) refine and improve options to enhance their cost-benefit justification, and (b) to ensure the most economically efficient options are taken forward. It should be applied to all overflows that are assessed using Stage 3 of the SOAF.

The economic case for some options is likely to be clear-cut, e.g. where the BCR of option A is always positive and always greater than options B and C. At other times, the case for an option may not be obvious, e.g. where the BCR of option A is sometimes  $<1$  and/or sometimes  $<$  option B and C. In all cases, the optimal approach (the best or most efficient option) is that for which the difference between benefits and costs is greatest. This is shown in Figure 3.<sup>1</sup>

**Figure 3 The Economic Case for Options**



The framework includes a feedback loop at this stage, back to 'Identify options'. This is because the outputs of the benefits assessment should inform the options considered. It may be possible for example to increase benefits or leverage additional benefits/funding by bringing in additional detail or information, by tweaking options, or by considering radically different options. It may be necessary and appropriate to go through the benefits assessment cycle twice or more to refine and bring in greater detail and improved information.

<sup>1</sup> Note that, depending on the decision criteria used, different options could be preferred/selected. For example, if option 1 has benefits of 100 and costs of 10, the NPV is 90 and the BCR is 10. If option 2 has benefits of 500 and costs of 100, the NPV is 400 and the BCR is 5. If NPV was used as the decision criteria, option 2 would be selected, but if BCR was used, then option 1 would be chosen. Therefore, to ensure both absolute and relative costs and benefits are considered, both NPV and BCR should be calculated.

## 6 Case studies

### 6.1 Overview of process to developing case studies

The purpose of developing case studies was to both illustrate and test the framework (rather than to develop and evaluate options per se). The project team developed a proforma for collecting information related to case study candidate sites. This included a number of criteria designed to cover a wider range of discharge contexts, locations and possible options. It included consideration of individual overflows, and situations where more than one overflow may discharge to a reach or share a common outfall. The proforma is shown in Table 6.

**Table 6 Case study proforma**

Criteria	Response
Case study name	
Location	
Rural or urban	
Individual or group of overflows	
'Annex A Decision Framework' Assessment completed to Stage 2?	
Option/solution types developed* (Yes (please add types) / No)	
Options assessed (Y/N)	
Details of any existing benefit evaluation undertaken	

\* note this might include grey options (e.g. offline tank), upstream surface water management to reduce inflows, or natural treatment on discharge

In addition, general overflow information was obtained for each site. This included the overflow name, number of spills, amenity class and details of any other environmental assessment completed.

Based on this, a long list of 16 potential case studies were put forward by water and sewerage companies (WaSCs). From these, 10 were selected for application, reflecting a range of locations and contexts. Complete information was not available for all of these sites, so the project team developed relevant information where necessary, based on expert judgement and recording any assumptions made. This included potential options, plausible costs and the likely type and scale of impacts and subsequent benefits.

Application of the framework to the 10 case studies was completed by a number of different people within the project team. Four of the 10 case studies were assessed twice (i.e. by 2 different people). The purpose of this approach was both to provide a 'stress test' of the framework from a range of perspectives (and disciplines), and to ensure that the framework could be applied by those with different types of experience and different levels of existing knowledge and familiarity with the process. Feedback from the process was recorded.

## **6.2 Summary of case study results**

A summary of the results from the application of the framework to the 10 case studies is shown in Table 7. Detailed tables relating to each of these are included in Appendix 2.

Whilst real locations were used with recorded EDM data, options were developed using engineering judgement. No modelling took place. The aim was to test the application of the guidance and approach advocated to determine lessons that could improve the guidance. Note that the options are given as examples to help demonstrate how this changes the benefit assessment. They also contain high level estimates of costs. The Practitioners' Guide recommends a minimum of two options for comparison, and this would therefore change values presented in Table 7.

**Table 7 Summary of case study results**

Case study	Step 1: Decision making context	Step 2: Options	Step 3: Screening	Step 4: Detailed assessment	Step 5: Results	Step 6: Decision
A	The CSO is 1km southwest of a town centre. The water body is currently failing WFD requirements. The aim is to reduce spills from 118 currently to 67, in turn improving WFD status from 'moderate' to 'good'. It spills into a sizeable river and various other CSOs upstream could influence the outcome.	Due to its location, the identified option is a large tank in the grass field near it, with an estimated cost of £6m.	The maximum length of improved watercourse approx 5km, giving £27,200/km/yr. PV benefits = £2.4 million with PV costs expected to be £6 million. Therefore benefits are expected to be significant, but less than costs. BCR is 0.4, below 0.5 threshold.	The option is expected to have an impact on aesthetics, macroinvertebrates and water quality, other benefits are not expected to be important. Therefore, a detailed assessment is not required.	N/A	Do not implement option
B	This case has seen 79 spills over the last 10 years into transitional water that is heavily modified. Whilst there is no plans for SuDS retrofitting, a storage tank is a strong option to reduce spills to 30 over 10 years. The only benefits will be that to the river.	The tank, 12.5m diameter shaft tank with pumped return, will reduce spills to the river, with a screened overflow. The suggested cost is around £3m.	The maximum length of improved water body is 2.5km and change from 'moderate' to 'good'. With a maximum value of 24,900/km/yr. PV benefits = £1.11 million with PV costs circa £3m, therefore BCR <1 and NPV negative.	There will be expected impacts on: aesthetics, macroinvertebrates and water quality. However pumping costs will increase. A detailed assessment is not required.	N/A	Do not implement option
C	The waterbody currently doesn't meet the water quality objectives for WFD, the SuDS retrofit will aim to fix this, whilst reducing flows to the terminal station along with an arbitrary reduction in pumped flows and flows to work.	Planters on 300 properties and street side SuDS, such as roadside swales, tree pits and rain gardens would cost around £1.25mn. In addition to this, there is the possibility to disconnect 35% of Storm Water sewers draining to foul or combined sewers.	2km of water body will improve from 'moderate' to 'good', giving a maximum value = £24,900/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £0.89 million with PV costs circa £1.5m, therefore CBA <1 and NPV -ve. However, significant other benefits due to SuDS and major savings for WaSC due to large reductions in pumping costs as well as treatment efficiencies. Therefore, detailed assessment required.	There is expected to be significant impacts to: aesthetics, macroinvertebrates, water quality, natural hazards, aesthetic values, recreation, health, carbon sequestration and biodiversity. It is thought there will be savings for the WaSC from the reductions in pumping costs as well as some treatment efficiencies.	BCR = 2.7 and NPV = £2.5m	Implement option

Case study	Step 1: Decision making context	Step 2: Options	Step 3: Screening	Step 4: Detailed assessment	Step 5: Results	Step 6: Decision
D	The CSO spills 45 times a year, discharging into a watercourse with 'poor' overall WFD classification. It is assumed the changes will achieve a 50% spill reduction.	The option includes small scale SuDS retrofit to reduce discharge to CSO, affecting roughly 60 houses with the introduction of rain gardens. The scheme is expected to cost £400k, increasing the water quality from 'poor' to 'moderate'.	The improvement will impact around 2km of water body, at an expected benefit of £15,500/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £552,000 whilst PV costs = circa £400,000, therefore CBA = 1.4 and NPV +ve.	Water quality, Aesthetic value, recreation, health, carbon sequestration and biodiversity will all see improvements, whilst there are expected to be major savings for the WaSC due to reduction in pumping costs as well as treatment efficiencies.	BCR = 1.8 and NPV = £0.32m	Implement option
E	The CSO discharges close to the town centre, near a heavily used riverside walk. The aim of this scheme is reduce the CSO spills to the water body, meeting WFD requirements (currently moderate), and to identify if the proposed scheme is cost beneficial, albeit it may be difficult to quantify as several other CSOs spill to the same body. The CSO currently spills 59 times a year, however there is limited space for waste water storage hence a combination of green and grey SuDS will be used.	It is assumed that 500 properties will be retrofitted with storm water planters (half of which will enhance the current gardens), with an estimated 5 street scape SuDS. The cost for this is estimated at £2mn.	A 2km stretch of water body will be improved, with an associated cost of £19,300/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £687,000. PV costs = circa £1.93m. The BCR is 0.36, and below the 0.5 threshold. However, other benefits (e.g. health) could be significant, so detailed assessment required.	There is considerable uncertainty about potential benefits for flood defence (not included) and impacts on fish (included), however no fish kills are noted. There is also potential scope for reputational benefits (both for implementing organisations and private hotels) Therefore, a detailed assessment of the fish impact is needed. Additional benefits include: Water quality health, carbon sequestration and amenity improvements.	BCR = 0.52 and NPV = -£0.92m	Do not implement option
F	The spills are originating from a small rural treatment works, subject to an ongoing investigation under NEP. Subject to the results of this, a scheme may be required to reduce spills from the current level of 79 in 2016.	Options include reed bed treatment of the spills.	The maximum length of improved watercourse (assuming low base flows) is expected to be 2km. The watercourse is already assessed as good status. The relevant value for the Water Company (good to high) is £0 per km. Therefore,	N/A	N/A	Do not implement option

Case study	Step 1: Decision making context	Step 2: Options	Step 3: Screening	Step 4: Detailed assessment	Step 5: Results	Step 6: Decision
			minimal benefits are expected and a detailed assessment is not required, as limited other benefits from improvement.			
G	The catchment is urban, predominantly comprising of residential properties and bathing areas (beaches). It is substantially combined and protected by a storm interceptor tunnel. Investment is required to achieve a spill frequency of 20/yr.	The preferred option is a combination of grey and green and reduces discharges from the storm interceptor by optimising the operation of existing assets, providing reduced storage near key pumping stations and reducing the amount of surface water that enters the sewer network using surface water separation (including reed bed and disconnection of highways, commercial and residential areas) and SuDS (bioretention swales, planters and rain gardens). Outfall pipe size is 1,200mm.	5km of water body is expected to be improved from 'moderate' to 'good' at a cost of £21,000/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits = £1.87 million and PV costs = circa £10 million. BCR is 0.19, below 0.5 threshold. However, other benefits are expected to be important and a detailed assessment is required.	Based on the modelling work and preliminary assessment undertaken, a number of benefit categories are expected to be important: Water regulation (pumping), Water quality (WFD status, water treatment), Natural hazards (flood damage), Aesthetic values (property value), Recreation (enjoyment), Education (learning), Biodiversity (habitats).	Total PV benefits are £4.03 million, giving a NPV of -£5.97 and BCR of 0.4.	Do not implement option
H	The area has been identified for action to meet WFD requirements, improving the environmental quality impacted by the 86 spills a year. The spills are close to a pumping station, serving a treatment works and with the increased flows during winter, the SPS is overwhelmed. The village has a population below 1000, with a	The option would be an online screen and reed bed treatment, costing approximately £500,000. However the ecological change would be neutral, with no great amenity benefits with the exception of litter and odour for 10 nearby cottages.	The length of watercourse to be improved is 2km, however retained at a 'moderate' and with an expected benefit of £31,900/km/yr. impact on aesthetics only expected, therefore take 1/6 of NWEBS value. PV benefits = £227,000 based on aesthetics alone with PV	In addition to WFD water benefits other benefits relating to health and amenity (house values) for those with neighbouring properties could be considered but high risk of double counting aesthetics (litter and odour) and house values or house view amenity.	N/A	Do not implement option

Case study	Step 1: Decision making context	Step 2: Options	Step 3: Screening	Step 4: Detailed assessment	Step 5: Results	Step 6: Decision
	surrounding area designated as an 'Area of Great Landscape Value'.		costs = circa £500k. The BCR is 0.45, and below the 0.5 threshold. Other benefits not expected to be important and a detailed assessment is not required.	The ecological value is expected to be neutral.		
I	This is a 'high spilling' overflows, with options, where cost beneficial, applied to meet the requirements of the Urban Waste Water Treatment Regulations (UWWTR), with the aim to achieve a spill frequency of 20 spills per annum.	Additional storage at a cost of £2m will be employed. Estimated water course improved = 2km (downstream reach to STW). There may be additional amenity / biodiversity benefits. NOTE issue is macro-invertebrate - severe impact only from SOAF assessment - this is due to decline from High to Good macro-invertebrate status (change in WFD class). Aesthetic impact is Low. Overall water body status is moderate, Ecological element is moderate due to fish status, physio-chemical is moderate (phosphate is poor), Supporting elements (Surface Water is moderate).	The maximum length of improved watercourse is assumed to be 2.0km with a benefit of £31,900/km/yr however there is no change expected to the overall improvement. Although assumed macro-invertebrates will be restored from Good to High, the overall status of the water body is driven by other elements. For the purposes of this exercise it may be beneficial to assume Moderate to Good overall status change associated with the implementation of this option. The option is expected to have an impact on macroinvertebrates alone (i.e. take 3/6 of NWEBS value). Therefore, PV benefits = £681k and PV costs = £2,000k. BCR is 0.34, below the 0.5 threshold.	Other benefits limited to amenity along this reach as well as on biodiversity due to presence of downstream nature reserve. Given estimated PV benefits and BCR ratio, with limited likely benefits elsewhere, a detailed assessment is not required.	N/A	Do not implement option
J	The pumping system appears to be the head of the system so a SuDS retrofit would be employed here to reduce flows to this. There is currently low	Two options can be used: combining reed bed treatment and small SuDS property level retrofit of rain gardens for	The maximum length of improved watercourse is assumed to be 2km. For the water body, the maximum value is £31,900/km/yr.	There will be expected impacts on: aesthetics, macroinvertebrates and water quality in addition to savings for	BCR = 3.4 and NPV = £0.6m	Implement option

Case study	Step 1: Decision making context	Step 2: Options	Step 3: Screening	Step 4: Detailed assessment	Step 5: Results	Step 6: Decision
	<p>base flow in brook, with WFD said to be 'moderate'. This will be improved to 'good' for both categories however there are minimal other benefits due to the rural setting.</p>	<p>disconnection to roughly 50 properties. The cost of the option is around £250K, through disconnection and rainwater barrels for harvesting will take out baseloads and reduce pumping in dry/wet weather for further savings.</p>	<p>The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits are estimated around £1.14 million with PV costs circa £0.25m, therefore BCR around 4.5 and NPV around £0.9m. There are expected to be other benefits due to the retrofit of SuDS throughout the community. There will also be savings for the WaSC as there will be reductions in pumping costs as well as treatment efficiencies.</p>	<p>the WaSC with large reductions in pumping costs and an increased treatment efficiency.</p>		

### 6.3 Lessons from case studies

Application of the framework to the 10 case study sites highlighted a number of key learning points.

First, improvements to storm overflows are, in most cases, likely to be associated with a limited range of benefits. Table 8 shows the benefit categories assessed for each case study. Impacts on water quality were considered in every case where a detailed assessment was undertaken. Other important benefit categories are climate regulation, water regulation, aesthetics values, health and biodiversity. An economic case for intervention will be difficult unless there are significant benefits in at least one of these categories.

**Table 8 Benefit categories assessed in case studies**

Case Study	Benefits																
	Provisioning ES	Regulating ES					Cultural ES				Supporting ES	Other					
	Food & fibre	Air quality	Climate regulation	Water regulation	Water quality	Natural hazards	Aesthetic values	Recreation	Education	Health	Biodiversity	Headroom	Planning	Growth	Jobs	Skills	Leveraging
A																	
B				Y	Y												
C			Y	Y	Y	Y	Y	Y		Y	Y						
D			Y		Y		Y	Y		Y							
E			Y		Y		Y			Y							
F																	
G				Y	Y	Y	Y	Y	Y		Y						
H			Y		Y		Y			Y							
I					Y						Y						
J			Y	Y	Y		Y	Y	Y	Y	Y						
		Detailed assessment not undertaken															

Second, distributed or multi-functional options tend to deliver the greatest range of benefits. Conversely, options focused solely on the overflow or discharge are likely to lead to a limited set of benefits, such that an economic case for such options will be harder to make.

Third, assessments undertaken by different people gave different answers. This is not surprising, given that many aspects of the assessment process are subjective, especially for the 10 case studies which were based on limited available information and for which assumptions therefore needed to be made. Typically, those with a level of familiarity of the scheme, or with some experience of evaluation tended to identify and evaluate more benefits.

Importantly, this included estimating the quantities related to other benefits, which can significantly skew these results, whereas when undertaken with all the information, these quantities will be determined with greater accuracy (e.g. any flood risk benefit).

The key differences between the assessments undertaken for the four duplicated case studies are shown in Table 9. This shows the number of benefits evaluated were different, as well as the estimated quantities which led to different levels of benefits estimated.

**Table 9 Key differences in duplicated case studies**

Case study	Assessor	Screening BCR	Detailed BCR	Benefit categories assessed
C	1	0.4	2.7	Water Quality (WFD status, pumping, water treatment), Natural hazards, Aesthetic values (property value), Recreation, Health, Carbon sequestration, Biodiversity (habitats)
	2	0.7	0.7	Water Quality (WFD status, water treatment), Aesthetic values (property value) and Biodiversity (habitats)
D	1	0.7	0.6	Amenity, Recreation, Health and Leverage, Air Quality
	2	1.3	1.8	Water Quality, Aesthetic values, Recreation, Health, Carbon sequestration, Biodiversity
G	1	0.17	0.4	Water regulation (pumping), Water quality (WFD status, water treatment), Natural hazards (flood damage), Aesthetic values (property value), Recreation (enjoyment), Education (learning), Biodiversity (Habitats)
	2	-	1.9	Recreation, Amenity, Biodiversity, Education, Enabling development, Flood risk
J	1	0.6	0.6	Water quality, Natural hazards, Aesthetic values, Recreation, Biodiversity
	2	5	3.4	Water quality, pumping, Aesthetic value, Recreation, Education, Health, Carbon Sequestration, Biodiversity

This finding indicates that more robust assessments will be undertaken through collaboration, supported by a multidisciplinary team and drawing on the experience and expertise of those who are most familiar with the background to, and context of, the scheme. In addition, the size of the benefits (quantities) will be determined with greater accuracy (than in the case study testing). Some prior knowledge is required to effectively establish the appropriate baseline and the case for change. This also helps to provide an understanding of the impacts that are likely to arise from a given option.

Fourth, the results of the assessment are sensitive to the context of the overflow and decisions taken. In particular, where a waterbody is assumed to be already meeting the WFD requirements, or where modelling suggests there is no identifiable water quality impact, then there are low or no quantifiable benefits from the framework, unless other benefits (e.g. amenity, health) are considered to be potentially significant.

Finally, the results of the assessment are also sensitive to the assumptions made, particularly around the length of waterbody improved, the option type and cost, the benefit categories considered and any sensitivity analysis or confidence intervals applied.

## 7 Conclusions

The key conclusions from this project are as follows.

- i. The assessment process and framework developed here is only applicable to a subset of storm overflows. It only applies to those high spilling overflows that, based on application of stages 1 and 2 of the SOAF, cause an environmental impact, or to any high spilling overflow in a drainage catchment greater than the Urban Wastewater Treatment Directive (UWWTD) threshold of 2,000 pe.
- ii. The framework supporting the assessment process is based on a number of key principles and a clear methodology that enable the whole range of direct and indirect benefits of storm overflow improvements to be valued in a robust, consistent and transparent way.
- iii. For the subset of cases to which the assessment process and framework is applicable, a simple and straightforward screening stage enables users to quickly develop a view on whether benefits are likely to be (a) significant, and (b) greater than costs.
- iv. For those cases that get through the screening stage, the framework enables the benefits of storm overflow improvements to be explored and assessed in detail. This level of detail is likely to be necessary to support a case for investment that is robust and transparent.
- v. Application of the framework to a number of case studies suggests that the benefits of improvements can be significant, especially for options that involve upstream or distributed-type measures like SuDS. From the case studies assessed, options of this type are also most likely to be more cost-beneficial.
- vi. Familiarity with the Practitioners' Guide and benefits appraisal process is necessary to generate robust and transparent evaluations. Experience from the case study testers suggests that they gained greater confidence in applying the guidance as more case studies were completed.

## 8 Recommendations

The main recommendations that arise from this project are as follows.

- i. Application of the framework should draw on the experience and expertise of a multidisciplinary team. Users of the framework should draw on this team and take the time necessary to familiarise themselves with the scheme to be assessed and with the assessment process, if the economic case to be built is to be robust.
- ii. To support this, the industry should consider a dissemination and training programme to ensure the assessment process is understood, applied appropriately and used to generate robust results.
- iii. To create significant benefits, distributed multi-functional options, upstream and downstream of overflows, are likely to be necessary. It is important to consider that these may need to be delivered over several investment planning periods, as the opportunities present themselves and work is undertaken in collaboration with other stakeholders.
- iv. The framework should be reviewed within a few years, so lessons can be learnt from its application. The assessment process embedded in the framework may also need to evolve over time, to reflect better information and evidence (e.g. around indirect benefits like health and around less tangible benefits like skills).
- v. The industry should consider a benefits evaluation programme to improve the number and quality of values available for monetisation as a direct result of 'drainage' interventions.

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## **Appendix 1: Literature review and key values**

### **UK water industry and other research**

#### Standards and regulation of CSOs

UKWIR (2010) makes recommendations on the future application of cost-benefit analysis (CBA) and benefits valuation for water companies and their regulators. The report documents an independent review by a multi-disciplinary team of consultants and academic experts of the use and application of CBA and benefits valuation in investment planning and decision making at the 2009 Periodic Review (PR09).

An analytical review and quantitative analysis of Business Plans was undertaken together with a consultation and engagement process with all water sector stakeholders. The findings from the research help address four key questions. 1) What happened at PR09? 2) What can be learnt from the PR09 experience? 3) What is the future role for CBA in business planning in the water industry? 4) How can the future role for CBA be developed?

In addition to a synthesis of the findings and recommendations, the study also produced a Practitioners Guide for asset planning managers and others in water companies to assist them in the delivery of benefit valuation and CBA for future price setting exercises

The position regarding UK storm discharge improvements and the means to identify the best options for these is founded in the major programme of work that led to the UPM (Urban Pollution Management) manual.

This advocates an integrated approach, one in which all components of the wastewater system are considered together, with optimal management of the various surface (storm) water, foul (wastewater), sewer overflow and treated effluent streams. However, since the advent of UPM (now in 3<sup>rd</sup> Edition, FWR, 2012)<sup>2</sup> there have been significant developments in understanding the way in which surface water can and should be managed.

Currently the Urban Waste Water Treatment Regulations (UWWTR) require sewer networks for drainage catchments with a population equivalent of 2,000 or more to be designed, constructed and maintained according to best technical knowledge not entailing excessive costs (BTKNEEC).

The Storm Overflow Assessment Framework will help to address the problems caused by discharges from storm overflows considered to operate at too high a frequency (other than those designed to meet bathing and shellfish water standards). A risk based approach was developed to deliver this, with prioritisation according to environmental considerations, public visibility and spill frequency. This approach utilises event duration monitoring (EDM) for the high or medium significance CSOs, to identify those assets whose performance is most likely to impact on an environmental and/or amenity based use and proactively engage with stakeholders.

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<sup>2</sup> <http://www.fwr.org/UPM3/>

The new framework includes a step in which there is an assessment of the options (costs and benefits) (including BTKNEEC analysis) with reference to the wider drainage strategy where applicable. The review presented here aims to inform the cost and benefits assessments to enable the marginal benefits of improvements to be valued as part of the process.

#### Use of SuDS and GI for surface water management

A growing understanding that alternatives to piped drainage systems can and will provide added benefits to society via the use of GI components in sustainable drainage systems (SuDS) has spurred a number of initiatives to understand how these added benefits can be brought about. At the core of the evaluation are ecosystem services (ES), which provide a means to value environmental factors, many of which can now be monetised (EA, 2016b). Social impacts are also included.

Drivers for the use of GI and SuDS in relation to main drainage relate mainly to flood alleviation and CSO abatement. In some UK sewerage undertakers plans there are aspirations to fully separate their systems over time utilising SuDS as appropriate (e.g. Wood, 2012) but this is not the norm.

Most studies in the UK related to the use of GI consider ES and the associated value from using GI. Many of these may be useful where multiple land use or the provision of multi-functional assets is being considered, as in the Rotterdam floodable City Squares (see below). However, bringing multiple parties together requires prodigious efforts if each is to understand the benefits for their statutory functions and be willing to provide funding.

As an example of the lack of connectivity, O'Sullivan et al (2017) consider UK highway verges as prime opportunities for the support of ES and biodiversity. Inevitably 'drainage' does not figure in their analysis even though the use of SuDS in verges is likely to be a prime opportunity for multifunctional use.

#### Valuing benefits from the use of SuDS and GI

The most recent report that reviews how benefits can be provided by SuDS is the literature review produced for the development of BeST (CIRIA, 2016). The literature review encompasses all aspects of SuDS benefit valuation and draws on GI, ES and valuation tools dealing with health and social benefits from green and blue infrastructure. CSOs were not considered explicitly although case studies for BeST have been included regarding the retrofitting of SuDS to enhance CSO performance (Ashley et al, 2017).

In this, a case study for CSO reduction in the Roundhay Park in Leeds catchment is analysed. In the business-as-usual analysis, the main benefits found from retrofitting SuDS in public spaces in the catchment are to property values (similar to the UKWIR, 2014 findings below). The water quality benefits, which are the primary objective for the scheme, are the third greatest of the benefits as the flooding benefits are also larger than these. The traditional approach using below ground storage tanks provides the single water quality benefit required, but costs some one-third of the SuDS option. However, the tank option has a large negative NPV (Net Present Value, over 40 years at a 3.5% discount rate), whereas the SuDS option has a positive NPV.

When four future climate and economic scenarios are considered over the next 100 years, the primary benefit from the SuDS option is the flood risk reduction as the property price increase occurs only in the first year. The SuDS option has the greatest flexibility in that it is easiest to adapt in the light of future changes. The tank is inflexible and costly to adapt.

Information relating to beneficiaries is increasingly available using tools such as BeST. For example, in one of the BeST case studies, the planting of 1,000 trees rather than the originally planned 250 trees in the Roundhay Park catchment results in health benefits increasing from less than £500,000 to some £3,500,000 (Ashley et al, 2017). In this case, the local Health Board (as well as inhabitants) will benefit and this should be better recognised in the decisions as to who should pay and whether the scheme should be implemented.

There is a need to move beyond the 'here-and-now' design process, that uses 'business-as-usual' (single predicted future) to consider how environmental systems, socio-economics and other system changes might affect the design planned today within its lifetime. The example above for Roundhay Park CSO alleviation shows how potential futures could be explored using a standard scenario planning approach. This begins with defining the drivers-pressures-state-impacts-potential responses (DPSIR) under these scenarios for evaluation of how the schemes under consideration may perform. In future that may be different 'publics', different decision makers and different responsible bodies. This is especially true when considering multiple benefit outcomes as shown by Xue et al (2015) for ES, where changes to ES are inferred using a DPSIR framework to determine how multiple ES can be sustained in a Chinese case study.

In 2013, UKWIR commissioned a review of UK SuDS needs (Ashley et al, 2013) which considered the entire perspective on SuDS in the UK and how SuDS were relevant to the water industry. A number of areas were identified as requiring further research and development, particularly in regard to the performance and costs and benefits. Maintenance was identified as a particular area requiring further development.

UKWIR (2014) considered the *Broader Justification of sewerage Schemes* and reviewed the potential benefits and value of these beyond the more direct flooding and water quality improvements. It was concluded that the evidence for the wider benefits of GI (SuDS) schemes was strongest in relation to temperature regulation and air quality. Mental and physical health benefits were recognised but quantification of these was limited in publications at the time. Monetisation of marginal benefits, was believed to be most readily achievable for air quality improvements.

Improving understanding of biodiversity and pollination benefits were considered important to help increase support for SuDS amongst potential partners. The same was true for the mental and physical health benefits, where these are demonstrable, in order to influence the health sector to support SuDS interventions, especially in areas where health inequality is an important issue; although even evidence-based Parliamentary reviews often fail to link human health to the need for more green and open spaces in urban areas (e.g. House of Commons Health Committee, 2015).

UKWIR (2014) considers how to engage with Health Boards more effectively. It provides details of some of the potential financial benefits, including reducing noise levels, a function that SuDS

may assist with (e.g. Hoang et al, 2016). Whilst UKWIR (2014) provides data to show the financial value of £125 per household per db reduction in night time transport noise; work to identify the contribution of SuDS to noise reductions is still under development. Hoang et al (2016) do not attempt to monetise such benefits, instead they provide comparative changes in benefits due to the use of GI.

The planned 'Greener Grangetown' (Arup, 2013) is used as a case study example to demonstrate the financial value of the wider benefits. The scheme will reduce (not eliminate) the need for sewage pumping and potentially CSO spills. The valued benefits are: Outdoor Experience; Health & Wellbeing; Transport & Connectivity; Water Efficiency; Carbon Footprint; Climate Change Resilience; Green Spaces; Economic Effect.

UKWIR (2014) warn that there are problems of double-counting due to the sources used for the benefits assessment and that the separate individual benefits should not therefore be added together to obtain an overall financial value. The overall review of the Greener Grangetown valuation is sceptical, but points out the need for further evidence especially for estimating uplifts to property prices – determined to be equal to the capital cost of the scheme in this case.

Water company WTP studies (PR14 work is summarised in Accent, 2014) provide the most comprehensive and reliable evidence related to many of the benefits associated with storm overflow improvements. This evidence is included in the spreadsheet database, and provides regionally based values for benefits related to water quality, flow improvements, reduced pollution incidents, avoided flood risk and other areas.

The Environment Agency's National Water Environment Benefits Survey (NWEBS), described in the Water Appraisal Guidance (EA, 2016a) provides probably the most comprehensive and reliable source of usable valuation evidence related to many of the benefits associated with storm overflow improvements.

#### The Thames Tideway Tunnel

In the past decade there has been considerable focus on the Thames Tideway in London, where some 39 million tonnes has overflowed from CSOs around 50 to 60 times a year (Defra, 2015, 2015a). Although a new Lee Tunnel has reduced this, the conclusions from various studies were that the remaining CSO problems could only be solved in a way that was timely, effective and affordable by constructing a new tunnel running mainly beneath the River Thames.

Construction has now started on the tunnel. The early studies of the potential use of GI SuDS to alleviate the CSO spills culminated in an assessment for three contributory catchments published as Appendix E of the 2009 published plans (Thames Water, 2009). This study was not aimed at estimating the economic or other benefits, but whether or not the use of SuDS would be effective and costs acceptable. Certain types of SuDS, including infiltration systems were excluded.

The overall findings were that the retrofitting of SuDS would potentially provide some reduction in CSO spills (Stovin et al, 2013), but that these would take some time and be difficult

to fit due to the multiplicity of land owners involved, and for the entire catchment, be more costly than the tunnel option. Subsequently, economic assessments have been undertaken to consider the costs and benefits of the tunnel option (e.g. Defra, 2015a; Eftec, 2015; NAO, 2017).

The original WTP study was undertaken in 2006 and the results updated in an Eftec (2015) report that brought the financial and demographic figures up to 2015. There was a positive WTP in both the studies. The 2006 survey asked 875 respondents in England how much they would be willing to pay per year for the narrowly focused and limited aesthetic, ecological and health benefits the Tunnel was predicted to deliver<sup>3</sup>. This has since been extrapolated to cover all English households over 120 years based on their demographic characteristics and distance from the river. Approximately 60% of the estimated annual benefits accrue to households outside of Thames Water’s service area, although only Thames Water customers will pay towards the Tunnel’s costs. A major benefit of the tunnel not included in the BC analysis is the avoided fines it would prevent due to non-compliance with regulations.

The NAO (2017) report uses data from the Eftec (2015) report to illustrate the importance of appropriate definition of the beneficiary population and aspects thereof in the analysis of the BCR for the tunnel as shown in Table A1. Eftec (2015) draw on the 2006 stated preference study that applied a contingent valuation design to establish the benefits of the tunnel in terms of household WTP to reduce the impact of CSOs on the Thames Tideway. The benefit-cost ratios and the benefits estimated for each of four scenarios are shown in Tables A1 and A2 respectively

*Table A1: Sensitivity analysis of the Tunnel’s estimated benefit-cost ratio and economic indicators (NAO, 2017)*

Scenario	Benefit-cost ratio	
	Considering benefits to Thames Water households alone	Considering benefits to all English households
Scenario A: 2014 income and population levels fixed for appraisal period	0.7	1.8
Scenario B: Benefits updated with forecast population growth	0.8	2.2
Scenario C: Benefits updated with forecast household income	0.9	2.5
Scenario D: Benefits updated with forecast population and household income growth	1.1	3.1

Source: Eftec, Update of the Economic Valuation of Thames Tideway Tunnel Environmental Benefits, 2015; National Audit Office analysis

*Table A2 Aggregate benefit estimates – present value terms (2014, £) (Eftec, 2015)*

<sup>3</sup> The benefits in these categories were not as well understood in 2006 as they are today. These benefits for the tunnel are small compared with what the equivalent for the SuDS would be as illustrated in Philadelphia (Stratus Consulting, 2009).

Scenario	Administrative jurisdiction (Thames Water region)	Benefits jurisdiction (National population)
Scenario A	£2.7 bn	£7.4 bn
Scenario B	£3.4 bn	£9.1 bn
Scenario C	£3.8 bn	£10.1 bn
Scenario D	£4.7 bn	£12.7 bn

Notes: Present values calculated based on: 3.5% discount rate for years 0 - 30; 3.0% rate for years 31 - 75; and 2.5% rate for years 76 - 120 (HM Treasury, 2003).

These results show how the boundary set in the analysis, in this case comparing Thames Water households with English national households as beneficiaries, makes a significant difference to the outcomes, moving from negative to strongly positive BCRs.

In the updated stated preference study, WTP for stormwater improvements is reviewed. No equivalent analysis has been undertaken to evaluate the benefits and costs of alternative options to the tunnel in London, as was undertaken in Philadelphia (see below).

#### Examples of valuing SuDS in London

In a later London study, Ossa-Moreno et al (2017) examine the economic benefits of SuDS in the context of the Decoy Brook catchment. Although CSOs were not considered explicitly, potential SuDS were positioned using a GIS based planning tool (Voskamp & van de Ven, 2015) aimed mainly at flood risk reduction and the potential financial and other benefits assessed using BeST. Local willingness to pay was also considered (e.g. Baptiste et al, 2015) in that the benefits accruing potentially to households were identified and benefit-cost ratios determined for investments in rain water tanks.

As well as using green SuDS, wetlands, basins and infiltration strips, the disconnection of house roofs into 4m<sup>3</sup> rainwater barrels was included in one option (SuDS 3, Table A3). In the use of BeST, recreation and water quality benefits were not calculated as it was believed there would be a risk of double counting due to the similarities of these categories of benefits as used in BeST. The actual benefit values are provided in the spreadsheet database accompanying this report.

*Table A3: Stakeholders accruing benefits from the optional SuDS schemes (Ossa-Moreno et al, 2017)*

	SuDS 1	SuDS 2	SuDS 3
Residential properties	51.8%	93.8%	83.1%
Non-residential properties	16.4%	2.6%	2.7%
Electrical Infrastructure	0.0%	2.2%	9.6%
School Infrastructure	0.0%	0.0%	0.2%
Road Infrastructure	22.4%	0.0%	0.0%
London Underground	6.3%	0.0%	0.0%
Emergency Infrastructure	1.4%	1.1%	4.0%
Society	1.1%	0.0%	0.1%
Water Utility Company	0.5%	0.2%	0.2%

SuDS 1: Infiltration strips along the main roads of the catchment (A502 and A598), an urban wetland to the south west corner and a rainwater tank for Golders green station.

SuDS 2: A 7500 m<sup>3</sup> basin at Hampstead Heath Extension (east basin) and a 1000 m<sup>3</sup> basin at Princess Park (west basin).

SuDS 3: Infiltration strips and roof disconnection in the Police Station Sub-catchment, and a swale to the north of the catchment.

As much of the economic benefits were found to accrue to 350 residential properties where the roof drainage was connected into the new rain water tanks, the relative value of investing in this (£630 per tank) was considered and the benefits to the householders is shown in Table A4.

*Table A4: Financial benefits to individual households from investment in rain water tanks with a lifespan of 17 years*

	Household point of view	Whole project
Investment	£ 530	£ 630
Surface Water Charges Reduction	£316	£316
Water Supply Fees Reduction	£508	£508
Flood Risk Reduction in the Area	£379	£379
NPV	£673	£573
BCR	2.3	1.91

In Table A4 the benefits are presented for individual households and also for the project as a whole that show there are clear financial incentives for the investment both for householders and also even more so for the LLFA.

Beam Parklands is a multi-functional greenspace in the Borough of Barking & Dagenham in London. Eftec (2015a) present a natural capital accounting analysis for the Parklands. The benefits include flood risk reduction via a flood storage area; local community benefits: recreation, amenity, education, health, opportunities to the local population (reduced community severance and volunteering)<sup>4</sup>; and biodiversity benefits.

Although no direct impacts from or on CSOs are mentioned, flow regulation means that surface water is kept out of the combined sewer system. These benefits are, with the exception of flood risk reduction, provided by green space proximity. The flood risk reduction benefits were estimated based on the avoided damage due to exceedance flows being stored in the Beam Parklands for 25 year return period events.

Whereas the local community benefits were calculated assuming a 3% property value uplift to the properties in the vicinity. The biodiversity benefits have been estimated in terms of habitats and wildlife benefits. This followed the standard natural capital accounting procedure

<sup>4</sup> Eftec (2015a) state that despite many of these benefits being within the ES definition of cultural services, the Land Trust, who manage the area prefer to term these “local community benefits”

of using land cover types classified in terms of biodiversity, habitat extent and condition, species presence and soil type.

It is acknowledged that in the monetary evaluation some of these benefits will overlap with the local community benefits and double-counting needs to be considered. Overall the estimated benefits per year are: £591,000 for flood risk reduction/warning; £770,000 in community benefits and 'significant' biodiversity benefits. There were no reported public engagement studies to support these valuations.

#### Valuing benefits in an integrated urban wastewater system

Theoretical modelling of an integrated urban wastewater system by Casal-Campos (2015) considered future socio-economic scenarios up to 2050 and the relative performance of green and grey strategies in a catchment with CSOs. The aim was to evaluate the relative robustness of the options, given the uncertainties for the four scenarios considered. Robustness was defined as the strategy with the 'least regret' i.e. that which has the least missed opportunities regarding choice of an alternative strategy or action. Logically, least-regret options are likely to be sub-optimal in terms of considering 'today's' design or solution; i.e. that emerging from a business-as-usual analysis(BAU)<sup>5</sup>, and requiring trade-offs in desired criteria or outcomes.

Although no financial benefits were considered, indicators were defined to assess the relative performance of a number of groups of green and grey options, including receiving watercourse impacts included in the weightings given to define the preferred benefits. Options considered included: permeable pavements; bioretention systems; rain gardens; surface water (separate) sewers for 50% of the catchment; improved existing combined sewers and storage; on-site sewage treatment in decentralised systems for 50% of new developments. The impact categories that were subjectively weighted in importance were: sewer flooding; river flooding; river dissolved oxygen; river ammonium; health and aesthetics; greenhouse gas emissions; cost; acceptability.

The results showed that grey (conventional) options were effective at addressing specific individual objectives such as CSO reduction and sewer flooding but these are compromised by costs and downstream impacts. This results in the grey options being less robust than the green options, especially due to the compromised downstream effects in scenarios where lifestyles are important. The GI options require fewer trade-offs than the grey options, being more robust in performance satisfaction across the impacts, i.e. have lesser regrets and are more adaptable to future shifts in valuation objectives and physical changes.

Hence, overall the GI options were found to be more robust than the grey options. These findings reflect the CIRIA BeST case study results (Ashley et al, 2017) when considering future socio-economic scenarios and for which monetised benefits were determined for four future scenarios.

#### Summary – using SuDS and GI for surface water management

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<sup>5</sup> Horton et al (2016) – latest BeST technical guidance defines BAU as designing for conditions today and considering future expected changes including to urban development and climate.

There are numerous papers, articles and guidance documents already produced that point the way to managing surface or stormwater in a cost-beneficial way. More case examples continue to emerge as the new tools, techniques and analyses are applied. Many of these fail to include uncertainties and, given the pace of change in both drivers like climate and expectations and demands from society, should be considered cautiously as a consequence.

There is a perception that predicting the performance of GI SuDS is fraught with greater uncertainties than the equivalent performance of traditional piped drainage systems; i.e. the physical aspects of performance are less certain. This perception also extends to the economic aspects of SuDS, both the costs and the benefits.

While there is less direct experience regarding SuDS usage and performance in the UK than in a number of other countries, there is much evidence from international use of SuDS/WSUD/GSI about performance that means that it is possible to design and operate SuDS with as much confidence as the equivalent traditional piped drainage (Ashley et al, 2016).

However, there is less certainty about the costs and benefits of SuDS in the UK context due to lack of experience and consistent collection of long-term data. Therefore the greatest uncertainties in regard to the use of GI for stormwater management relate to the economics of SuDS. The recent development of an understanding of the costs and benefits of ES and natural capital, much of which is directly applicable to SuDS can be utilised in evaluating the costs and benefits of GI based SuDS, using the widest range of potential benefits as for flood and coastal erosion risk management accounting in the UK (e.g. Eftec, 2013).

SuDS and stormwater related GI need to be considered as assets under the Drainage Strategy (DS) guidance (Halcrow, 2013). This refers explicitly to uncertainty and includes it as a principle in the strategy: *“Where future performance is uncertain (e.g. because of sensitivity to climate change)... (WaSCs)... should explain how adaptive approaches will be used to ensure outcomes are met. The uncertainty in predictions of future risks should be recognised and accommodated within decision making.”*

Thus the explicit consideration of uncertainty and adapting to future challenges is not an option but a requirement. The approach suggested is to assign ‘confidence’ to the data and processes used. One very important point made in the DS guidance is that certain options will have lesser degree of confidence in their outcomes. This should not be confused with the uncertainty in the various components of the impact assessment; it may be that the selected SuDS are more likely to provide the required performance.

The DS guidance states that the strategy *“should identify low-regrets interventions (i.e. ones that are robust no matter what the future holds) and ensure that solutions can be adapted if greater certainty is achieved. For example, through quickening the pace of SuDS retrofit activities...”* Here, ‘low-regrets’ options are those that can be modified readily in the light of future change and without excessive cost, i.e this relates directly to the points made in the theoretical example above (Casal-Campos et al, 2015) about adaptability and flexibility. As stated above, SuDS are inherently more flexible and adaptable than buried piped drainage systems and hence they need to be used more extensively to avoid future regrets.

The latest version of the CIRIA BeST (Horton et al, 2016) includes an approach to explicitly consider uncertainty that follows the EA FCERM recommended process for FDGIA applications (Ashley et al, 2017). This includes the use of socio-economic scenario analysis (Brisley et al, 2015).

Sinnett et al (2017) provide a review titled “Global green infrastructure - How is green infrastructure research translated into practice outside the UK?” In this they review both scientific journals and also the grey literature for uptake of R&D. One of the findings from their review of case studies from a number of countries is that it is important to work with communities to gain local expertise, understand their needs for the GI and how they will use it so that something is delivered that meets their requirements and reduces conflicts.

ES include aspects of equity in that one of the four groups of ES is cultural services. Vulnerability is also included regarding provision of food and freedom from drought or flood risks. In Mayesbrook Park in a highly deprived area in North East London, ES valuation was used to justify investment in a flood alleviation scheme, estimating a BCR of 7:1, for which 93% of the financial benefits were provided from added cultural services. These benefits facilitated co-funding of the scheme from a number of sources, including an insurance company (see case study Appendix in Digman et al, 2012).

## **The wider benefits of green infrastructure**

### Overview of the main developments related to CSO abatement

Much of the literature around the valuation of benefits related to storm overflow improvements focuses on the role of green infrastructure (GI) and its potential for delivering multiple benefits.

Whilst there have been few published documents dealing *specifically* with the valuation of the benefits arising from reducing CSO spills, many documents deal with GI where storm or surface water may or may not be a part of the analysis (e.g. Molla, 2015). Some studies present ‘green stormwater infrastructure’ results for storm or surface water drainage where there are separate sewerage systems and CSOs are not necessarily included (e.g. Leuckenhoff & Brown, 2015; Sinnett et al, 2017).

Impact analyses using life-cycle analysis (LCA) are considered by: DeSousa et al (2012) for a New York application comparing grey and green; Hengen et al (2016) compare various SuDS options impacts in South Dakota, and Slagstad & Brattebo (2014) provide LCA for the water and wastewater systems in Trondheim and Tavakol-Davani et al (2015) to consider life cycle costs (LCC) for the use of widespread rainwater harvesting in CSO abatement for the City of Toledo, USA.

Each of these concentrates on the impacts, as assessed by the LCA, with no benefit assessments other than potential reductions in impacts such as due to lower carbon utilisation.

There are many more examples of how the benefits of CSO reduction can be assessed and achieved by using traditional grey piped drainage systems (e.g. the UK's UPM manual). In the traditional approach the benefits are fewer, although important, and include human and environmental health benefits comprising: flood protection; water quality enhancement; aquatic habitat improvements and optimisation of the wastewater process train regarding flows pumped, treated and effluents returned to receiving water bodies. There are few comparators other than Casal-Campos et al, (2015) who consider both grey and GI in CSO spill management.

Some sources of information focus on stormwater albeit they are from a land use perspective. For example (ASLA, 2017) provide a growing list of stormwater case studies from GI projects State by State, despite being aimed at Landscape Architects. There are numerous summaries of actual built stormwater GI projects most of which include costs but few with other than general details of benefits.

In other studies, CSOs are included as being part of the general value of using GI based schemes. These include Meerow & Newell (2017) who consider mainly the urban planning aspects of GI in Detroit and how this can be managed to enhance ES benefits with the inclusion of CSO spill reduction as an outcome rather than being valued. However, they do point out that there are trade-offs between the best siting of GI to maximize stormwater management versus the important landscape connectivity for aesthetic and ecosystem needs.

There are a number of field and model studies showing how the use of various types of GI can alleviate CSOs, e.g. for St Louis Green Alleys programme (Alyaseri & Zhou, 2016) but for which no financial benefits are assessed. Similarly, although the GI retrofits were commissioned in 2015 in Barton King County, and these are estimated as reducing the untreated discharge from CSOs from 4.3 million gallons per year to 0.5 million gallons per year on average, no other quantitative benefits or financial estimates have been made for the value of this (Harbaugh, 2015).

There are other plans for GI retrofits in the USA where these are seen as having the potential for improving the areas for the most vulnerable in the communities at the same time as tackling priority CSO problems.

Columbia University (2013) developed a detailed vulnerability scoring system for GI (and some grey) retrofits to manage the CSO pollution in New York. The scoring and weighting system is based on: Urban Heat Island Reduction; Energy Reduction; Improved Air Quality and Improved Quality of Life. This was then used to show that an area in the Bronx had both the highest vulnerability and was also a priority for CSO reductions. The study is being used to leverage funding for a range of GI schemes of various physical extent and scale.

There is also literature on 'green-grey' infrastructure focusing on domains other than water (e.g. Tiwary & Kumar, 2014 deals with concrete and steel vs green spaces). In Europe, increasingly there are reports as to how ES approaches can be used to address the implementation needs of the Water Framework Directive (e.g. Vlachopoulou et al, 2014).

Work continues to be published on the various 'values' of GI use in specific domains: housing values (Westerman, 2017); public health (e.g. Kondo et al, 2015; Coutts & Hahn, 2015). The growth in knowledge and advocacy for linking public health benefits to green spaces in urban areas is notable. WHO (2017) point out that in regard to human health: "...there is promising evidence for.. (the use of) ...GI for managing storm water impacts in urban and suburban areas."

Also, how people and communities value aspects of GI (e.g. street trees, Giergiczny & Kronenberg, 2014) is increasingly considered. There are new studies on the 'insurance' value of GI; i.e. it's value as a buffer against future climate change impacts.

Green et al (2016) consider the 2000AD multi-stakeholder London Biodiversity Action Plan and subsequent plans to demonstrate that in London there are distinct moves to promote the use of diverse GI for ES and thus 'insure' future security of services to Londoners. They apply a similar lens to similar plans for Vancouver. However, no monetisation attempts are made nor are links drawn to and from other infrastructure plans such as for wastewater.

Various studies report the hydrological, hydraulic, water quality and/or other physical performance aspects of the use of SuDS and or ES provision.

For some of these, explicit analysis has considered the usage of SuDS/GI in e.g. alleviating CSO impacts (e.g. USA: Autixier et al, 2014), or flooding (e.g. UK: Ellis et al, 2016; USA: Atkins, 2015; worldwide: UFCOP, 2016; World Bank, 2016) and in contributing to resilience at the same time as reducing CSO spills in New York (McPhearson et al, 2014), where the resilience of the ES is considered.

For most of these, the benefits estimated are for 'avoided impacts'. For example, the Atkins (2015) study estimated that the avoided damages benefits from using GI to alleviate flooding across the USA average have a PV of some \$30m – \$65m per year over the period 2020-2040 based on a 3% discount rate.

Roseen et al (2011) consider avoidance costs for sewer systems, which for the city of Portland comprises the annual O&M costs to pump and convey stormwater through the existing combined sewer system as \$0.0001 per gallon treated and \$0.0001 per gallon pumped. In addition, for the CSO system the relationship between project capital costs and stormwater volume removed from the CSO system is considered based on the cost-effectiveness 'point' for projects/programmes that remove stormwater volume from the CSO system as \$4 per gallon as the avoidance cost of constructing a larger CSO tunnel. In life-cycle analyses, these "savings" can reduce the capital costs of other LID facilities that the city builds for objectives other than CSO control (e.g. water quality improvements, basement flooding relief), but still removes stormwater.

It is not all 'good news' in that the enhancement of certain ES by use of GI can be at the expense of certain other ES (e.g. Haase et al, 2014; Demuzere et al, 2014). There are also co-benefits and overlapping benefits to identify in such a way that any accounting process avoids double or multiple accounting of the same benefits.

However, the importance of trade-offs in the way in which CSO discharges have been dealt with using traditional grey infrastructure approaches has often been overlooked in the past. Casal-Campos et al (2015) for example point out in a UK case study that traditional CSO alleviation has typically compromised downstream wastewater system performance and costs related thereto due to singular focused objectives, when compared with an alternative GI approach (see below).

### Interacting systems

Increasingly, the interaction between the various urban systems and the complexity of these is being recognised. Given that it is now understood that SuDS benefits can be realised by using them as part of multi-functional systems and in the multi-use of land space (Demuzere et al, 2014), these interactions need to be considered especially for the interdependencies (e.g. Hoang & Fenner, 2015). For maximum benefit value to be achieved these interactions and interdependencies need to be managed effectively.

### Tools for valuing SuDS and GI benefits

A range of support tools are now available to help decide upon the most valuable combinations of SuDS, green and grey infrastructure systems for any specific site or at a catchment scale (e.g. Chow et al, 2014, Jayasooriya & Ng, 2014). Increasingly these models and tools are incorporating GIS platforms that assist in the location of the GI measures for maximum utility and in some cases, benefit (Wurster & Artmann, 2014; Segaran et al, 2014; Voskamp & Ven de Ven, 2015). Many of these do not specifically utilise financial benefit values in their multi-criteria analysis, as most use weighted scoring systems (e.g. Casal-Campos et al, 2015; Voskamp & Ven de Ven, 2015; Hoang et al, 2016).

### Willingness to pay and engagement

There are numerous UK examples of WTP investigations related to the wider benefits of GI. For example, Mell et al (2013) consider the WTP of a range of people for GI retrofits in the urban core of Manchester, focusing on street trees. In a separate study Armson et al (2013) monitored street tree pit runoff in Manchester to demonstrate that compared with impervious surfaces, runoff was reduced by more than 60%. WTP was found by Mell et al (2013) to be directly related to the size and greenness of the proposed investment and participant perceptions of added value. 75% of respondents were WTP with a preference for larger and physically greener investments. Payment values ranged from £1.46 to £2.33. 'water runoff' improvements were rated important by only 5% of those surveyed, with street improvements being the most important attribute. Although GI investments vary in size and function, respondents considered the specific and wider value of green infrastructure resources when asked how much they were WTP to fund and maintain such investments.

Separately Mell (2013) considered how hard infrastructure was perceived in relation to green, softer infrastructure and how some developers exploit the ambiguity in this; i.e. by presenting hard landscapes as contributing to sustainability/liveability, despite not contributing to green resources. A survey of perceived value and WTP for GI in Sheffield showed that public open spaces, trees and landscapes were all highly valued based on their visible 'greenness'. When

asked about the hard landscaped areas provided for flood alleviation, respondents did not value these in the same way as they were not green. Mell (2013; 2015) also concludes that there is ambiguity in the management of water and use of GI for this in the UK. He recommends a new narrative based on grey-green infrastructure and taking into account public valuation of 'greenness' over 'greyness'.

Greater engagement with local surface water drainage is required on the part of many communities and citizens in future. As these systems are increasingly surface based, community operation and management will be increasingly likely where the additional and wider multifunctional benefits are to be sustained. Examples of how to encourage and build capacity for this engagement are evident in the USA (e.g. WEF, 2014) where such systems are now relatively common.

In many parts of the world economic and other incentives are provided for cities, communities and individuals to fit GI SuDS for stormwater management. In some cases even regulatory compulsion is used to enforce the retrofitting of SuDS such as in Toronto.

However, worldwide there is a move to engage with citizens and those most affected by changes in urban landscapes such as due to surface based SuDS instead of buried piped drainage systems. This is both in response to citizens becoming more interested in such engagement and also because service providers wish to ensure that the services provided is what society requires and wants.

Having stormwater drainage on the surface using SuDS and exceedance measures has made surface water more obvious to communities and more active engagement necessary, not least to avoid any additional hazards that new bodies of surface water may bring (such hazards are considered in the CIRIA SuDS manual; Woods-Ballard et al, 2015).

### Summary

For SuDS and GI to become routinely spread in the UK, it will be necessary for land owners, property owners, dwellers and users of property and land to become more engaged with these systems than has been necessary for traditional piped drainage systems. This is especially important for source control SuDS such as rainwater harvesting and SuDS on private property. Evidence from Scotland suggests that this is feasible, although the extent to which such stewardship – by owning, managing, maintaining and or funding – is feasible will depend on local circumstances, incentivisation and how effectively people are engaged with.

In England, the water service providers are required by Ofwat to engage with 'customers' to ascertain their preferences for asset management and to utilise these in developing all aspects of their business plans. As for piped drainage systems, the property owner is responsible for their own curtilage drainage unless it is shared with another property.

Typically many property owners in England and Wales have not engaged in managing or maintaining their curtilage drainage unless a problem has occurred. Many are unaware of their responsibilities in this regard and many are not aware of what their drainage assets comprise. Surface based SuDS will make these systems more visible and the need to be aware of their efficient functioning more apparent. However, failure to maintain these effectively may lead

to overflow problems on neighbouring properties or other impacts such as water course pollution. Such surface based systems are also more susceptible to vandalism and misuse (Shandas, 2015).

## **Benefits valuation in different countries**

### Valuing GSI (green stormwater infrastructure) in the USA

The greatest use of non-piped drainage systems for CSO and storm drainage system control continues to be in the USA, where it is mandatory in many States and nationally the US Environmental Protection Agency (USEPA) has continued to support a shift from grey to green via analytical tools such as SUSTAIN (System for Urban Stormwater Treatment and Analysis INtegration), guidance documents and direct financial incentives (e.g. EPA, 2015).

The uptake of GI, GSI (green stormwater infrastructure) or LID (Low Impact Development, the planning framework) is driven by both regulatory requirements and the desire to 'do the right-thing', as well as to increase property values and minimise taxes on the part of property owners and developers in the USA (NRDC, 2015). The EPA (2011) provide a planning tool to assist with the control of CSOs using GI for small communities. This gives simple volumetric reduction formulae and information as to the cost implications for local households and the local affordability of CSO control in this way. It does not provide any estimates of financial benefits as such. An overview of the use of GI for stormwater management, together with examples in the USA is given in WEF (2014).

Many of the benefit assessments published from US applications utilise the CNT (2010) GI benefit values tool which is one of the most comprehensive in coverage of the range of benefits (Ashley et al, 2013).

#### *Case examples - overview*

The most developed case example continues to be in Philadelphia where the Green City, Clean Waters programme is progressing, with some 1100 new SuDS being constructed since 2011 with the aim to reduce the CSO impacts from 50% of the City catchments<sup>6</sup> by creating: Green Streets 38%; Green Schools 2%; Green Public Facilities 3%; Green Parking 5%; Green Open Space 10%; Green Industry, Business, Commerce, and Institutions 16%; Green Alleys, Driveways, and Walkways 6%; Green Homes 20%. Providing City-wide financial benefits of more than \$2bn (Philadelphia Water Department, 2011).

Take-up of GI for stormwater management varies from State to State and City to City in the USA and is also being promoted via non-Federal Agencies such as the NRDC (Natural Resources Defense Council) charity.

As an example of the latter, NRDC (2013) guidance is provided to support commercial property investors to go for GI for direct commercial benefits. These are substantial, quantified and

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<sup>6</sup> [http://phillywatersheds.org/what\\_were\\_doing/documents\\_and\\_data/cso\\_long\\_term\\_control\\_plan](http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan)

encompass: Increased rents and property values; increased retail sales; energy savings; Stormwater fee credits, with other unquantified benefits including reduced infrastructure costs; reduced costs associated with flooding; reduced water bills; increased mental health and worker productivity for office employees; and reduced crime.

Cases cited claim total benefits of \$2m for both an office building and a retail site discounted over 40 years, although some of these benefits could also be obtained from using piped rather than LID drainage. For these cases, substantial volumes of stormwater are managed at source via green roofs, bioswales and rain gardens and substantial adjacent impervious areas are also connected to the SuDS to take the first 25mm of any runoff from them.

Many cities in the USA are pushing GI programmes as a means of managing stormwater at less cost than using piped drainage systems (Chini et al, 2017). The latter undertook a survey of 27 US cities regarding their plans for GSI. 21 Cities have a specific GI plan, three have a less formalized plan, and three do not have a plan. Those with plans typically have a multi-layered approach, promoting retrofits and new build GSI at all spatial scales and by using a range of incentives.

Table A5 illustrates that in each and every plan, multiple benefits are expected from the use of GSI. Of the cities contacted, only five explicitly included water quality improvements due to CSO reductions without this being mandated, although there were nine cities with a 'EPA consent decree' reason for improving water quality (legal mandates stating that the city is lawfully bound to decrease CSO volumes).

*Table A5: US City GI plan motivations (Chini et al, 2017)*

Green Infrastructure Motivations															
Cities	Water Quality				Economic				Environmental			Social			
	EPA Consent Decree	Reduce CSOs No Consent Decree	Clean up Local Waterways	Improve Drinking Water Quality	Increase Property Values	Promote Green Jobs	Decrease Floods and Basement Backups	Reduced Wastewater Treatment Costs	Conserve Energy	Mitigate Urban Heat Island Effect	Improve Ambient Air Quality	Adapt to Climate Change	Provide Habitat for Local Wildlife	Reduce Violent Crime	Improve Public Mental and Physical Health and Safety
Atlanta, GA				✓	✓							✓		✓	✓
Austin, TX			✓				✓								
Baltimore, MD			✓				✓		✓	✓		✓			✓
Boston, MA			✓				✓		✓		✓			✓	✓
Charlotte, NC			✓		✓							✓		✓	
Chicago, IL	✓		✓				✓				✓				
Cleveland, OH	✓		✓									✓			
Dallas, TX			✓												
Denver, CO			✓				✓		✓	✓	✓				✓
Detroit, MI	✓		✓		✓								✓	✓	✓
Honolulu, HI							✓	✓							
Indianapolis, IN	✓		✓												
Kansas City, MO	✓		✓	✓			✓							✓	
Los Angeles, CA			✓	✓											
Milwaukee, WI		✓	✓				✓								
Minneapolis, MN		✓	✓				✓								
New Orleans, LA	✓		✓						✓						
New York, NY	✓		✓							✓					
Philadelphia, PA	✓		✓												✓
Portland, OR		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Providence, RI				✓			✓								
San Antonio, TX			✓				✓								
San Francisco, CA						✓	✓	✓	✓	✓	✓	✓		✓	✓
Seattle, WA		✓	✓		✓				✓	✓	✓				
St. Louis, MO		✓	✓		✓						✓				
Tampa, FL			✓												
Washington, DC	✓		✓	✓	✓	✓	✓	✓	✓	✓					✓

### New York

In New York, Department of Environmental Protection has runoff reduction goals of removing 10 % of what comes from impervious surfaces in the City by 2030. There is an average 1.33 m of rain on the City annually; with some 644,000 m<sup>3</sup> falling on the city’s community gardens, of which some 492–541,000 m<sup>3</sup> can be prevented from becoming runoff using GI (Gittleman et al, 2017). Although the wider benefits of these gardens are highlighted, in this case no economic assessment has been undertaken.

In further studies in the City, Cohen & Wijsman (2014) present information about the value of GI and how urban agriculture can be promoted in conjunction with GI: “Municipalities should coordinate GI investments with municipal urban agriculture goals to most effectively support both”, although no benefit estimates are provided, Brooklyn Grange, is a rooftop farming company, with “the world’s largest roof- top soil farm” covering approximately 0.4 ha, and as a result of this permeable rooftop farm and agricultural activities, this manages over 3,785,411 litres of stormwater per year, helping to reduce the amount of CSO spills.

### City of Lancaster

In the City of Lancaster, Pennsylvania, specific estimates have been made of the value of using GI to manage CSO discharges using the same approach as was used in the earlier analysis for

Philadelphia based on the CNT GI valuation tool (CNT, 2010; Potts et al, 2015). The City has both a combined sewer system, with CSOs<sup>7</sup> and also a separate surface water sewer network that discharges directly into watercourses (EPA, 2014). The analysis assumes that 67% of the total area managed by GI will be located within the combined sewered area, and the reduction in CSO spill volume will be some 75% of the reduction in stormwater runoff volume in this area. Therefore, CSO discharges will be reduced to 25% of what is discharged currently. The GI installed within the combined area will capture 706 million gallons of stormwater runoff annually, and reduce CSO discharges by an average of 529 million gallons/year.

In terms of the combined sewer network, the retrofitting of GI is estimated to provide some \$2.8 million benefits in energy, air quality, and climate-related benefits annually and to reduce grey infrastructure capital costs by \$120 million and reduce wastewater pumping and treatment costs by \$661,000 per year. The associated costs range from \$51.6 million for GI projects integrated into planned improvement projects (i.e. mainstreamed) to \$94.5 million if GI projects were implemented as stand-alone projects. When both the combined and separate systems are considered this provides a total of some \$4.2 million in energy, air quality, and climate related benefits annually. The GI reduces grey infrastructure costs in both the combined and separately sewered areas. Accounting for the reduced cost of GI in the separately sewered area would increase the value of avoided costs beyond the \$120 million estimated for the combined system area only. Achieved at an estimated cost of \$77 million if GI were integrated into planned improvement projects to \$141 million if it were implemented as stand- alone projects. In both the combined and separately sewered areas, the environmental and economic benefits provided by GI would continue to accrue year on year. Three individual as-built case examples are provided. In each case the greatest benefits were those estimated to the avoided grey infrastructure costs, although the GI benefits continue to recur year-on-year.

#### City of Ohio

The City of Ohio has set out a clear description of how the various 10 co-benefit added values from using GI for stormwater management are anticipated to benefit the City (Northeast Ohio Regional Sewer District, 2015). The benefits for Community and Environment are quantified but not monetised in nine case examples, of which only two do not include separation of the combined sewers. The monetised financial benefits comprise only the energy savings from avoided wastewater treatment and the potential value of Jobs and Economic Development. The overall benefits for the sewer district considered are shown in Table A6 for managing 209 million gallons of stormwater, and as well as the new GI, include 10 miles of new sewers within respective drainage areas, together with some 63 acres of land improvements at the GI Feature Sites.

*Table A6: Overall benefits valued for the North-East Ohio Regional sewer district*

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<sup>7</sup> discharging some 750 million gallons per year (<http://cityoflancasterpa.com/resident/stormwater-management>)

Key Indicators			Program Totals
Community Benefits	Community Engagement	Number of People within Walking Distance to Site	10,261
	Recreational Benefits	Acres of New Public Space	39
	Potential Property Value Increases	Number of Existing Parcels Adjacent to the GI Site	231
	Aesthetic Improvements	Acres of Distressed Properties Repurposed	29
	Quality of Life Benefits	Number of Households with New Local Infrastructure	2,812
Environmental Benefits	Ecological Benefits	Number of New Trees	1,508
	Ecological Benefits	Acres of Natural Areas	18
	Climate Change Mitigation	Acres of Shaded and Pervious Surface Area	39
	Climate Change Mitigation	Metric Tons of Potentially Reduced Greenhouse Gas at WWTP	187
	Air Quality Benefits	Kilograms of Potentially Reduced Air Pollutants	3,022
Financial Benefits	Energy Savings	Annual Energy Cost Savings at WWTP	\$156,328
	Jobs and Economic Development	Annual Economic Impact (indirect)	\$654,466

It is concluded that for this application, the GI has a higher life-cycle cost than the grey infrastructure and that the location for GI projects is crucial for maximising the numbers of people who are likely to benefit. Benefits estimated (quantified and those monetised) were related to the numbers within a 5-minute walking access of the scheme and also to the proportions of different demographic groups: young people; seniors; low income and minority groups. The value of providing new jobs for both the GI and grey aspects of schemes is also an important consideration as shown in Table A2, with the value of job creation being higher than for economic development for each of the nine schemes.

Onondaga County, New York

In a major review of 169 completed 'Save the Rain' GI projects for Onondaga County, New York, (CH2M, 2015) evaluated a large number of benefits. Of these, the monetised benefits are shown in Table A7.

*Table A7: Summary of Economic Benefits Calculated for 169 Constructed GI Projects in Onondaga County (CH2M, 2015)*

Benefit Category	Specific Benefit	Average Annual Economic Benefit	Cumulative 40-Year Economic Benefit
Water quantity	Wastewater treatment cost savings	\$93,380	\$3,735,200
	Increased groundwater recharge/imperviousness	\$300	\$12,000
	Reduced potable water usage cost savings	\$36,100	\$1,444,000
Operation and Maintenance	Operation and maintenance cost savings at Metro WWTP	\$34,520	\$1,380,800
Reduced energy usage	Electricity savings due to tree plantings	\$400	\$16,000
	Natural gas savings due to tree plantings	\$0 <sup>a</sup>	\$0 <sup>a</sup>
	Electricity savings due to reduced wastewater treatment	\$2,130 <sup>b</sup>	\$85,200 <sup>b</sup>
Air quality (direct and indirect benefits)	Total reduced criteria pollutant savings (NO <sub>2</sub> , SO <sub>2</sub> , O <sub>3</sub> , PM <sub>2.5</sub> )	\$4,530	\$181,200
Climate change (direct and indirect benefits)	Reduced atmospheric CO <sub>2</sub> savings due to tree plantings	\$54,745	\$2,189,800
<b>Total Economic Benefit of all benefits quantified not including avoided gray infrastructure</b>		<b>\$223,975</b>	<b>\$8,959,000</b>

<sup>a</sup> The value of the natural gas savings due to trees rounds to less than \$1.

<sup>b</sup> The energy cost savings due to reduced water treatment needs are included in the wastewater treatment cost savings. Total economic benefit does not include these values to avoid double counting.

In addition to the economic benefits in Table A7, quantified analyses were carried out separately for the environmental benefits. Quantification of the benefits was undertaken using i-Tree<sup>8</sup> Hydro for watershed-scale analysis of vegetation and impervious cover effects on hydrology; i-Tree Eco for the estimates of environmental benefits from trees; and SWMM to estimate the reductions in runoff to sewer systems and subsequent sewer system discharges based on GI implementation.

The economic benefits (Table A7) were estimated using the metrics shown in Table A8.

*Table A8: Metrics used in evaluating the economic benefits for the Onondaga County (adapted from CH2M, 2015)*

Benefit category	Metric used for economic assessment	Cost/benefit
Water Quantity	Avoided costs of wastewater treatment	2014 cost of wastewater treatment \$0.0023/gallon
Increased groundwater recharge	Willingness to pay for healthier aquatic ecosystems (stated preference conjoint analysis)	\$0.30 per annum per percentage improvement in infiltration

<sup>8</sup> "i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefits assessment tools." <https://www.itreetools.org/>

Potable water savings	Savings in costs of potable water as a current unit cost	\$0.0025/gallon
Energy usage	Reduced electricity consumption due to cooling from new trees	Current charge rates: Basic service charge \$0.047/kWh + Incremental state surcharge \$0.003/kWh + Delivery charge adjustment \$0.001/kWh + Supply charge \$0.066/kWh = \$0.117/kWh
	Reduced gas usage due to heating from new trees	Current charge rates: Basic service charge \$0.36/therm + Supply charge \$0.35/therm = \$0.71/therm
Air quality	Reduced emissions of pollutants related to changes in health and mortality rates of population from new trees	From i-Tree Eco and BenMap: NO <sub>2</sub> \$0.00007/m <sup>2</sup> /year O <sub>3</sub> \$0.05/m <sup>2</sup> /year SO <sub>2</sub> \$0.00007/m <sup>2</sup> /year
Climate change	Economic damages avoided by reducing carbon emissions from use of GI	\$0.043/lb carbon in 2012 to \$0.088/lb of carbon reduced in 2052

Further social benefits were identified but unquantified in the analysis: enhanced public environmental education opportunities; green job opportunities; pavement useful life due to tree shading; roof useful life due to green roofs; retention and attraction of businesses and residents; publicity; recreational opportunities; and community aesthetics; safer pedestrian intersections/enhanced traffic calming; decreased need for application of de-icing salts on porous pavements; curb extensions and green streets; increased private property values and rental income; decreased crime; increased retail sales; reduced infrastructure costs; reduced flooding damages; improved worker productivity; general quality of life improvements, etc. Many of these were derived from the CNT (2010) benefits tool.

#### *Citizens' perception and engagement*

Empirical evidence has been collected about changes in human perceptions as a result of a large-scale GI intervention aimed to divert stormwater from the traditional underground sewer and pipe system for the Portland Metropolitan region (Oregon, USA). This looked at the implications of retrofitting the stormwater system at the neighbourhood scale on human perceptions and behaviour. Portland was selected as it has one of the largest mature green stormwater systems in the USA which has been under development for decades. (Shandas, 2015).

It was found that residents in the community with higher income and education levels were more likely to participate in stewardship of their local GI SuDS. Engagement that introduced to the community the value of these systems as bringing 'nature' back into urban areas were effective but it was found that a multi-stimulus approach was required that included learning

by doing. There was overall an initial negative perception of neighbourhood facilities and services immediately following the construction of the GI SuDS facilities<sup>9</sup>, but conversely, high levels of anticipation for their construction. It was suggested that related research will be needed to enable those who manage human-dominated landscapes (with surface based systems) to respond effectively to increasing uncertainty using infrastructure systems that are embedded within communities that can attend to their care.

Portland is similar to other cities in the USA in that citizens distrust their Governments. Hence, whether or not these findings are applicable elsewhere, where governments are more trusted is open to question.

A study in Syracuse, New York (Baptiste et al, 2015) of citizens' knowledge and willingness to implement GI in two neighbourhoods showed that a targeted approach can be taken to encourage the implementation of GI measures: *"The profile of the most likely person to target includes those that are low income, desire to improve the overall aesthetic of their community and their personal space, and those whose financial commitments will not be strained."*

This study was part of the CSO reduction programme outlined in Section 5.1 for improving the water quality for Onondaga Lake and for which willingness to pay for improvements was a major consideration (CH2M, 2015). The Baptiste et al (2015) study included an assessment of public willingness to pay. Some 35% refused as they were unsatisfied with municipal policy and many think current taxes are already too high (28%).

However, overall a significant group (39%) were willing to pay on average \$15 per household per year. Some thought the issue unimportant or believed it did not have priority for municipal expenses (16%). There was also a group who either did not have enough money because of unemployment, or preferred another way of contributing e.g. through community initiatives (21%). The study confirmed what is found in other studies that preferences were affected by the information intervention that was contained within the engagement process itself. The research processes, by providing information in order to elicit meaningful engagement, altered the preferences in a way that enhanced the expressed willingness to pay.

The information presented about how GI SuDS can assist in addressing climate change had the greatest affect in enhancing willingness to pay. It was found to be important that the engagement demonstrated that GI is multifunctional, providing recreational and aesthetic benefits. It was concluded that public support can be obtained not only by making people aware of climate change impacts but also by providing information on the multiple benefits of GI SuDS and by tailoring the choice of GI to local preferences.

Mayer et al (2012) present results from engaging citizens via an economic incentive to retrofit rain gardens and rain barrels onto their properties in a 1.8 km<sup>3</sup> catchment near Cincinnati, Ohio using a reverse auction, supported by a comprehensive information campaign. Over the

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<sup>9</sup> In Bradford Yorkshire, two SuDS wetlands were retrofit offline to watercourses as part of an EU Project called NORIS. A number of local residents were engaged with prior to and immediately after construction and were adamant that these would lead to the death of one or more young person. After a year or more, these same local residents were of the view that the ponds were 'marvellous'.

six year period 83 rain gardens and 176 rain barrels (four 284-litre rain barrels and a single 16 m<sup>2</sup> rain garden per property) were retrofit to more than 30% of the properties making a noticeable difference to the runoff from the catchment. However, it was concluded that storm water management interventions needed to be at a certain scale, inter-connected and have long- term monitoring periods in order to realize and be confident of their full potential.

### *Social Equity*

In terms of equity, there is now evidence that retrofitting of GI for stormwater and CSO management in certain cities in the USA is focussing preferentially on also delivering benefits for vulnerable and disadvantaged communities (e.g. CH2M, 2015; Heckert & Rosen, 2016) and a process and set of criteria have been developed for this (Columbia University, 2013). WHO (2017) explicitly considers studies that included equity and the use of GI. However, it concludes that *“there is too little evidence to....draw firm conclusions regarding the impact of (GI) interventions on a range of equity indicators.”* In the review WHO used the PROGRESS-plus framework (NCCMT, 2015) for defining equity indicators. PROGRESS indicators cover: Place of residence; Race/ethnicity/culture/language; Occupation; Gender/sex; Religion; Education; Socioeconomic status; Social capital. Use of PROGRESS ensures that the design or management of any system takes adequate account of equity or inequities in health. As yet there are no published examples of applications considering GI.

In another application, Heckert & Rosen (2016) present a GI Equity Index for Philadelphia (mentioned above) to help identify communities that would most benefit from GI investment as critical for equitable GI planning. Although aimed at indirect benefits, the two benefit groups used were: socioeconomic, related to disadvantage and vulnerability, and second, environmental factors, related to both exposure to environmental risks and access to environmental amenities. GIS mapping provided a visual means to identify areas most likely to benefit from new GI.

### Summary

The cases set out above are in addition to the reviews of US usage of GI/GSI/LID utilised in the development of the BeST tool in 2013 (Ashley et al, 2013); for example, a range of US case examples that include benefits is provided in Roseen et al (2011). Application of GI to alleviate CSOs is summarised for Portland, Kansas City, Chicago and New York. However, the benefits considered are limited primarily to the avoided costs as illustrated above, nevertheless it is concluded that *“utilizing a combination of grey and GI strategies for CSO management can be considerably more economically viable than using grey infrastructure alone”*, even when considering primarily the comparative scheme costs for grey vs green.

The lack of consideration of uncertainties is especially notable in the applications in the USA, despite the utilisation of G(S)I and evaluation of their wider benefits becoming virtually *de rigeur*. Montalto et al (2012) in developing an LID rapid assessment tool (LIDRA) for GSI benefits in the context of stormwater management, points out the need to consider uncertainty in the assessment and presents results in terms of a 3 dimensional 90% confidence interval for cost-effectiveness of GSI that includes stormwater runoff volume reduction and present value costs and benefits.

## Netherlands

### *Valuing GI and SuDS*

The focus has been on the application of ecosystem services approaches in the Netherlands. TEEB (The Economics of Ecosystems and Biodiversity) is an international project to study the economic significance of biodiversity and ES. The Netherlands took part through the national TEEB NL programme, of which TEEB City forms part. The TEEB City project has begun as a joint initiative of central government, eleven local authorities and an engineering consultancy. In 2016, two government ministries (Economic Affairs and Infrastructure & Environment) and seven local authorities signed the City Deal “Values of green and blue in the city”. Together with other (semi)private partners, they aim to better quantify the value of natural capital in the city in monetary terms. To achieve this aim, local authorities, private parties and knowledge institutes share user experiences and knowledge to refine, integrate and better match the TEEB City Tool to implementation practice.

In the TEEB City project, a tool was developed to demonstrate the benefits of GI (TEEB City project, 2012). Local authorities participating in this project applied the tool to specific projects within their jurisdictions. The size and nature of the projects ranged from a large-scale area development in Delft to the construction of a park in Apeldoorn, or the introduction of more green amenities in the inner city, as in Almelo. A number of notable benefits emerged from these projects which a local authority can work with straight away. For example, the costs of measures to improve biodiversity turned out to be very modest in some cases. Ideas for pavement planting or neighbourhood greening by organising a seed-sowing day are actions that citizens can easily take themselves, and that local authorities can encourage. It was also noted that the benefits of greening were substantial in densely populated neighbourhoods with limited or poor quality green amenities.

### *Example case application in the City of Zwolle*

In a design study for Zwolle, the TEEB City tool has been applied to demonstrate that well designed green areas have eco-system value (Van Peijpe, 2016). This design study has explored the benefits of greening by increasing the amount of high quality urban green.

Three spatial conceptual models were proposed to differentiate the outputs, including the Singelstad model. This proposal consists of a refined green-blue structure based on the existing waterways in Zwolle. They are being extended, widened, connected and enriched into an extensive and biodiverse landscape of flows. This was done by incorporating all adjacent existing public spaces of waterways and transforming these into high quality green spaces, namely: wild meadows and playgrounds, rich banks, small wet forests and urban farms.

Altogether the amount of high quality urban green increased to almost 30% of the city surface. Along with the increase of water, the green-blue network proportionally goes up to 60% of the soft surface, just by smartly transforming the existing public space.

The impact of this proposal has been monetised with the TEEB City tool. For this purpose, the Singelstad model has been quantified into added amounts of water volume, reeds surface,

number of trees and overall green percentages. The application of the TEEB City tool has shown that green-blue space possesses the potential to add real economic value to the city, and to cut costs on infrastructural investments by combining them into inclusive space design. For example, the monetised benefits of the Singelstad model amount to a present value of € 1.8 billion over period of 30 years. This includes € 43 million of avoided investment costs to upgrade the waste water treatment plant.

Separately, the BeST has been applied in Zwolle to evaluate the with the objective of improving the living spaces (liveability) for the population by retrofitting blue-green measures. An example at street scale has been used, together with a pan-City perspective for a major urban redevelopment. SuDS measures are to be introduced into drainage catchments of residential neighbourhoods around the City to reduce heat stress and manage surface water exceedance as well as improving spatial quality and access to greenery. Lindestraat (drainage area 17ha) has been used as a pilot study for the more widespread introduction of SuDS. The retrofit of SuDS will also reduce the surface water load on the combined sewer network and the CSO spills. However, this analysis has not yet been completed. The selected Option reduces street runoff, the primary objective, thus reducing flood risks. The largest positive financial impacts are for health and amenity benefits due to the increased access to greenery and an improvement of spatial quality in this dense urban area. Education benefits dominate the value as the project is a learning laboratory exemplifying the alternative street design which will be constructed and used to demonstrate the value of widespread upscaling across the City; i.e. as a means to engage with the local population.

#### *Elsewhere in the Netherlands*

The compelling case for added benefits demonstrates why green-blue space deserves to shift from the 'last item' of the expenditure budget to a priority factor of significance in investment decisions—as being aspired with the Dutch City Deal “*Values of green and blue in the city*”.

TEEB City (2012) presents overviews of Dutch GI projects that have been able to utilise the TEEB tool to demonstrate the economic and other benefits of using GI for stormwater and other city improvements. Four funding strategies are set out aimed at Dutch municipalities: 1) direct commercialisation and revenue generation from the GI scheme; 2) PPP – public-private finance where there is an agreement to share funding between the municipality and private developers, this could include investments in e.g. transport infrastructure that the developer can add GI to adjacent land; 3) Co-creation: intelligent 'nudging' is where civil society organisations deliver services like maintaining GI more effectively than municipalities or others can; 4) Ploughing back social benefits from new revenue streams after identifying where there are beneficiaries of GI who are not providing appropriate payment for these services, as it is much easier to identify these people now that tools like TEEB and BeST have been developed.

As an example of the many Dutch studies Derkzen et al (2015) quantified the ES for the extant green spaces in Rotterdam. The conclusion showed that not all green space is equal, in that in urban areas where it is intended to support ES with new or enhanced green space, careful

consideration is needed to ensure this is as effective as possible, i.e. has the right composition and connectivity. A finding relevant to GI SuDS provision.

A separate Rotterdam WTP study found that people's willingness to pay for GI (to deal with climate and flooding risks) was mostly related to income and ethnicity (Derkzen et al, 2017) rather than information. Although people's awareness of climate impacts and understanding of GI benefits were found to define their preferences for GI measures. Citizens were found willing to support climate adaptation through GI provided the GI is multifunctional especially including recreational and aesthetic benefits. Tarwewijk and Kralingen-West were used in the study as they represented typical Rotterdam neighbourhoods; one in the lower socioeconomic strata and one middle-class. Each area had similar housing types but differed in extent of existing GI.

Some two-thirds of respondents were willing to pay for GI measures at €15 per household per year. Respondents who were not willing to pay believed it not worth their money (35%), or were not satisfied with municipal policy, finding current taxes already too high (28%) (Similar to the US case example above). Others found it unimportant or believed it does not have priority for municipal expenses (16%). Additionally, some did not have enough money because of unemployment, or preferred another way of contributing e.g. through community initiatives (21%).

## Denmark

In Denmark the use of large-scale, open urban drainage systems (OUDS) is being promoted as an alternative strategy to small-scale systems which local property owners could implement on their own properties. The concept of OUDS implies that SUDS are concealed as green recreational sites, which are designed to have the additional function of serving as a temporary detention sink for precipitation (Zhou et al 2012). This could imply transforming the urban landscape, e.g., by creating small lakes and green spaces. Appropriately designed such large-scale OUDS could provide a range of recreational services, which the small-scale SUDS do not.

Zhou et al (2012) applied a hedonic valuation model to capture the local economic gains or losses from more water bodies in green areas (see also Panduro & Veie, 2013). Using this framework, they estimated a potential house price change of 223 million DKK for the northern part of the city of Aarhus, Denmark. This increase accounts for 1.48% increase in value of the affected properties. In addition to this, part of the resulting welfare change from the environmental amenity changes will be reflected in increasing property taxes. The additional value acquired by the municipality from property taxes sums to 177 million DKK over a 100-year period. As for the flood reduction, the Expected Annual Damage decreased with 11.5 million DKK per year with the implementation of the OUDS. When framing the analysis to include these potential benefits, the OUDS turned out to be the best of the options considered.

## Australia

Drought and heat stress have been high on the agenda in Australia for the last two to three decades. Originally aimed at effective water supplies and wastewater disposal, surface water drainage and receiving water impacts became parallel concerns in developing asset management in Australia. These have been some of the reasons for the emergence of the integrated approach to water management termed Water Sensitive Urban Design (WSUD). Australia has been in the vanguard of promoting and utilising GI as part of WSUD for at least twenty years (e.g. AECOM, 2017).

Installation of rainwater tanks has been encouraged for property owners across Australia for decades. Zhang et al (2015) examined the capitalised value of tanks installed in Perth in order to demonstrate that the net private benefits are negative, thus justifying State of other financial support for their fitting. Using hedonic price analysis, it was found that there was a significant premium attached to having these tanks when houses were sold (\$18,000 Aus). This premium was concluded to include a range of non-financial as well as financial benefits and to exceed the net costs to home owners of researching and then retrofitting the tanks. Hence no premiums for widespread installation were therefore necessary, rather that informative and well engaged programmes of encouragement should be used to promote their fitting.

### The Cooperative Research Centre on Water Sensitive Cities

In 2012 the Australian Government commissioned a \$120m (AUD) project to develop the concept of the Water Sensitive City. The project has involved 100s of researchers and practitioners, not only in Australia but also worldwide<sup>10</sup>.

#### *Communities and the Water Sensitive City*

Research shows that communities in Australian cities value the multiple benefits that WSUD can provide (see CIRIA, 2013 for application in UK). 'Liveability' is a main goal of WSUD for Australian cities. Community commitment is demonstrated by positive and consistent willingness-to-pay for the additional benefits that using WSUD can bring. Research undertaken by the Cooperative Research Centre for Water Sensitive Cities has indicated that communities are willing to pay or assign monetary value to specific outcomes of WSUD. These outcomes can be summarised as: 1) freedom from water restrictions; 2) reducing local peak summer temperatures; 3) protecting healthy waterways; and, greening streets and suburbs.

These desired outcomes and the value that communities put on these benefits are summarised here for healthy waterways and greener streets and suburbs, as the most relevant benefits to CSO abatement. Note that there are few combined sewers in Australia even in the larger urban conurbations, with 85% of the systems being separate in 1988 (Carleton, 1990).

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<sup>10</sup> <https://watersensitivecities.org.au/>

CRCWSC research indicates that Australian citizens generally identify themselves as being 'environmentally sustainable' and this is reflected in a willingness-to-pay for stormwater management actions that protect local waterways. This benefit has two elements. One element is the enhancement in environmental condition (e.g. water quality conditions) to enable ecological protection or human uses such as swimming.

Stated preference surveys (Brent et al., 2016) have been undertaken in Melbourne and Sydney to value the environmental services associated with stormwater management. These experiments showed that there is significant economic support for actions that maximally improve stream health: A\$ 104 to A\$ 278 per household per year.

Another element is the restoration of urban drains into 'living streams' which transform local landscapes by introducing more natural channel form and vegetation. A revealed preference (hedonic pricing) study (Polyakov et al., 2016) has been undertaken in Perth to estimate the value of restoring urban drains to living streams. This study revealed that after a natural wetland ecosystem has established, the median home within 200m of the restoration site increased in value by A\$17,000 to A\$26,000 above the trend increase in house values in the area, or 4.4% once the restored area became fully established.

Other CRCWSC research shows the preference of individuals to live in green streets and suburbs, which is expressed as a willingness-to-pay to live near GI. This value is mostly clearly reflected in house prices, with market values of houses in proximity to 'GI' bringing higher sales prices. It was found that these benefits can be delivered at a range of scales, with even the introduction of individual street trees and rain gardens providing measurable value.

A revealed preference (hedonic pricing) study across Australia (Rosetti, 2013) has demonstrated the value of GI: a one standard deviation increase in the Enhanced Vegetation Index leads to an increase in sales prices of 8.62% to 15.57%. For an average house this translates to an increase of A\$ 32,139 to A\$ 57,991. In a different study, the ES of street trees were quantified, including air pollution, carbon, stormwater management and heat mitigation during an extreme heat event (Thom, 2015). The monetised benefit was determined by relating units of environmental ES to associated marginal economic values. The current tree population in the city of Monash was valued at A\$ 12.9 million for a year that included an extreme heat event. Doubling the tree cover provided a 72 % increase in economic benefit, valued at A\$ 9.3 million. In comparison, halving the tree cover resulted in an equal (50 %) loss in economic benefits, valued at A\$ 6.5 million. Where trees suffered poor health, an estimated 10 % reduction in economic value was estimated.

Such beneficial outcomes are also estimated for other areas such as by AECOM (2017) who provide a triple-bottom-line analysis for greening of a city square in Sydney, albeit using an engaging 'dart-board' representation of the criteria used to evaluate the relative benefits of the extent of tree canopy cover.

In the 450ha Little Stringybark Creek catchment near Melbourne, a reverse auction has enabled significant volumes of stormwater to be taken out at source by property owner retrofits of source control measures<sup>11</sup>. This has reduced the phosphorus load to the Creek.

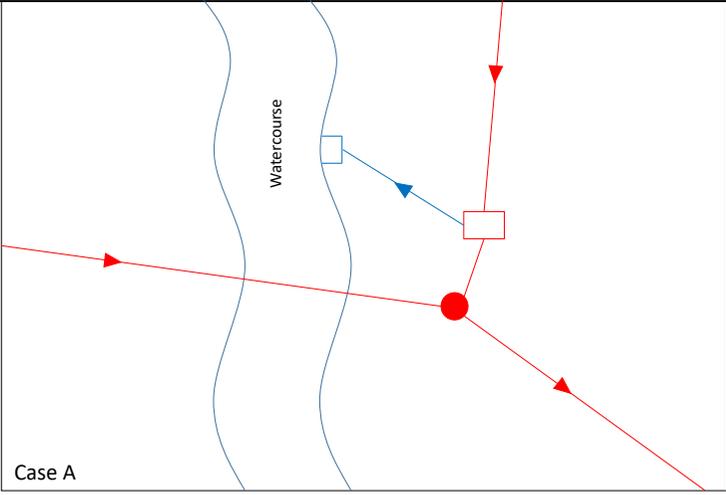
In summary, in Australia, tools, including economic and other valuations of specific benefits, are being developed to select the options which provide the best community outcomes. This is part of the shift in economic assessment from a focus on the lowest cost options to those that provide the best value. Evaluating an investment always begins with an understanding of the 'return' that is required. This holds for WSUD projects: State and other Governments need to define what outcomes they want from WSUD projects followed by how much they are prepared to spend to get these benefits.

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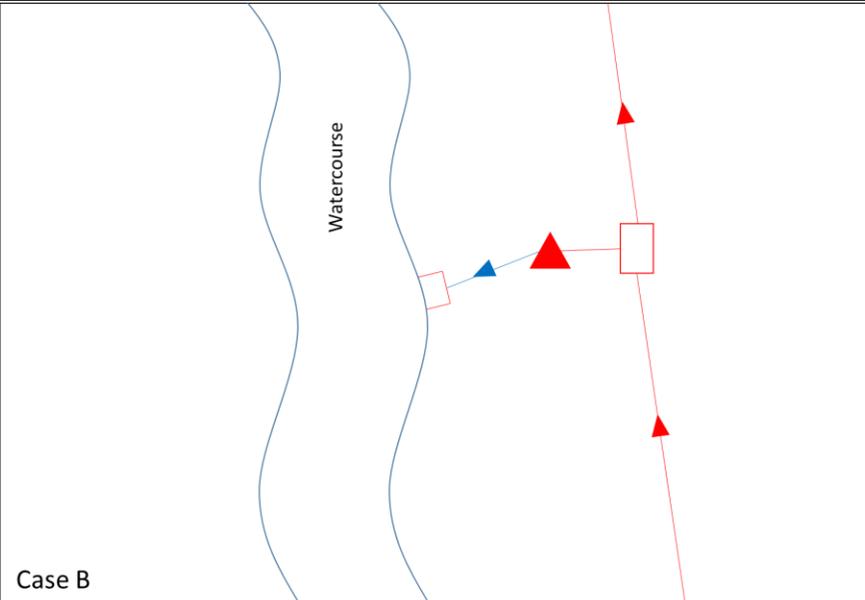
<sup>11</sup> <https://urbanstreams.net/lsc/>

## Appendix 2: Case Study Results

### Case Study A

<b>Set Decision Making Context</b>	Identified for action to meet WFD requirements. Aim is to reduce combined sewer overflow (CSO) spills to river in most cost-beneficial way.		
<b>Identify options</b>	CSO is located 1km south west of town centre. Outfall pipe size is 525mm, CSO is a big spiller into a reasonable size river and other CSOs upstream could influence WFD outcomes. Baseline water quality in river is moderate. Due to its location, identified option is a large tank in the grass field near it to reduce the spills from 118 currently to 67 post option. PV cost estimated at £6mn.		
<b>Undertake screening (screening questions)</b>	The maximum length of improved watercourse is assumed to be 5km and the potential improvement expected is 'moderate' to 'good'. The relevant value is £27,200 per km. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits = $5 \times 27,200 \times 5/6 \times 21.355 = £2.4$ million. PV costs are expected to be £6 million. Therefore benefits are expected to be (a) significant, but (b) less than costs. BCR is 0.4, below 0.5 threshold. Other benefits are not expected to be important. Therefore, a detailed assessment is not required.		
<b>Undertake screening (potential benefits matrix)</b>	N/A		
	 <p>The diagram, labeled 'Case A', illustrates a watercourse system. A blue wavy line represents the 'Watercourse'. A red line represents the 'Combined' sewer system, which includes a red circle representing a 'Pump' and a red square representing an 'Overflow' tank. A blue line represents 'Surface water' flowing from the overflow tank into the watercourse. A brown line represents 'Foul' water. A legend on the right side of the diagram defines the symbols: a red square for 'Overflow', a red triangle for 'Pump', a blue line for 'Surface water', and a brown line for 'Foul'. The 'Combined' sewer system is shown as a red line with arrows indicating flow direction.</p>		<p>Spill count: 118</p> <p>Amenity Class: Low</p> <p>WFD Classification: Moderate</p> <p>Outfall Pipe Size: 525 mm</p> <p>Subcatchment: Urban (Village)</p> <p>Legend:  <span style="display: inline-block; width: 10px; height: 10px; border: 1px solid red; margin-right: 5px;"></span> Overflow  <span style="display: inline-block; width: 0; height: 0; border-left: 5px solid transparent; border-right: 5px solid transparent; border-bottom: 10px solid red; margin-right: 5px;"></span> Pump  <span style="display: inline-block; width: 10px; border-bottom: 2px solid blue; margin-right: 5px;"></span> Outfall  <span style="display: inline-block; width: 10px; border-bottom: 2px solid red; margin-right: 5px;"></span> Combined  <span style="display: inline-block; width: 10px; border-bottom: 2px solid blue; margin-right: 5px;"></span> Surface water  <span style="display: inline-block; width: 10px; border-bottom: 2px solid brown; margin-right: 5px;"></span> Foul</p>

## Case Study B

<b>Set Decision Making Context</b>	<p>79 spills over the last 10 years. Close to beach and discharges to transitional water that is heavily modified. Option to be assessed is storage tank, along with treatment to oxygenate river and screen overflow. Suggest cost is £3M. Benefit primarily to the river, with little amenity value. Say 2.5km (is a large river and tidally influenced) and currently meets its WFD requirements (but we assume it does not for purposes of case study assessment).</p>		
<b>Identify options</b>	<p>Option is tank - 12.5m diameter shaft tank with pumped return – 857 m<sup>3</sup> storage. 20 l/s pumped return flow. Spill flow directed into shaft tank on existing storm overflow pipeline with weir to storm overflow for 3 or less spill frequency events. Pumped flow to new manhole on 1400mm x 900mm sewer upstream. Modelling is based on 10 year Time Series Rainfall (TSR). The output was to reduce the spills to 30 in the 10 years, hopefully averaging 3 per bathing season</p>		
<b>Undertake screening (screening questions)</b>	<p>The maximum length of improved water body is 2.5km and change from moderate to good. The maximum value is 24,900/km/yr. This is also expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits = 2.5 x 24,900 x 5/6 x 21.355 = £1.11 million. PV costs are expected to be circa £3m, therefore BCR = 0.37 and NPV -ve. There will be no added benefits and pumping costs will increase. However, detailed assessment is undertaken for illustration.</p>		
<b>Undertake screening (potential benefits matrix)</b>	<p>No other benefits other than to river water quality</p>		
	 <p>The diagram illustrates the proposed infrastructure for Case B. It shows a blue wavy line representing the 'Watercourse' on the left. A red line representing the 'Combined' sewer runs from the watercourse towards the right. At the watercourse, there is a red square symbol for an 'Overflow'. Further along the sewer, there is a red triangle symbol for a 'Pump'. After the pump, the sewer continues to the right, where it meets a blue line representing 'Surface water'. At this junction, there is a blue square symbol for an 'Outfall'. A grey line representing 'Foul' sewer is also shown at the bottom right, connecting to the main sewer line. The text 'Case B' is located in the bottom left corner of the diagram area.</p>	<p>Spill count/ year: 79 (over 10 years) Amenity Class: High WFD Classification: Moderate Outfall Pipe Size: 1500 mm Subcatchment: Urban (Town)</p> <p>Legend:   Overflow   Pump   Outfall   Combined   Surface water   Foul</p>	

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Water quality (WFD status)	Estimated improvement (mod to good)	spills down to 3 per bathing season	£23,423 (from BeST)	£510,000	100% assumed for quantity and 100% for monetary	-
Pumping	less pumping as reduced runoff to pumping station	8 spills a year down to 3.	Pumping added from zero to manage 20l/s			5 events a year captured. Say tank fills each time, then 5x857 = 4285 cu.m pumped to empty per year. At 20l/s that is 60 pumping hours per year.
Water quality (water treatment)	increased flow to works			BeST works category 6	75% for both quantity and valuation	Extra flow to works 4285cum/yr ie 11.7cum/day.

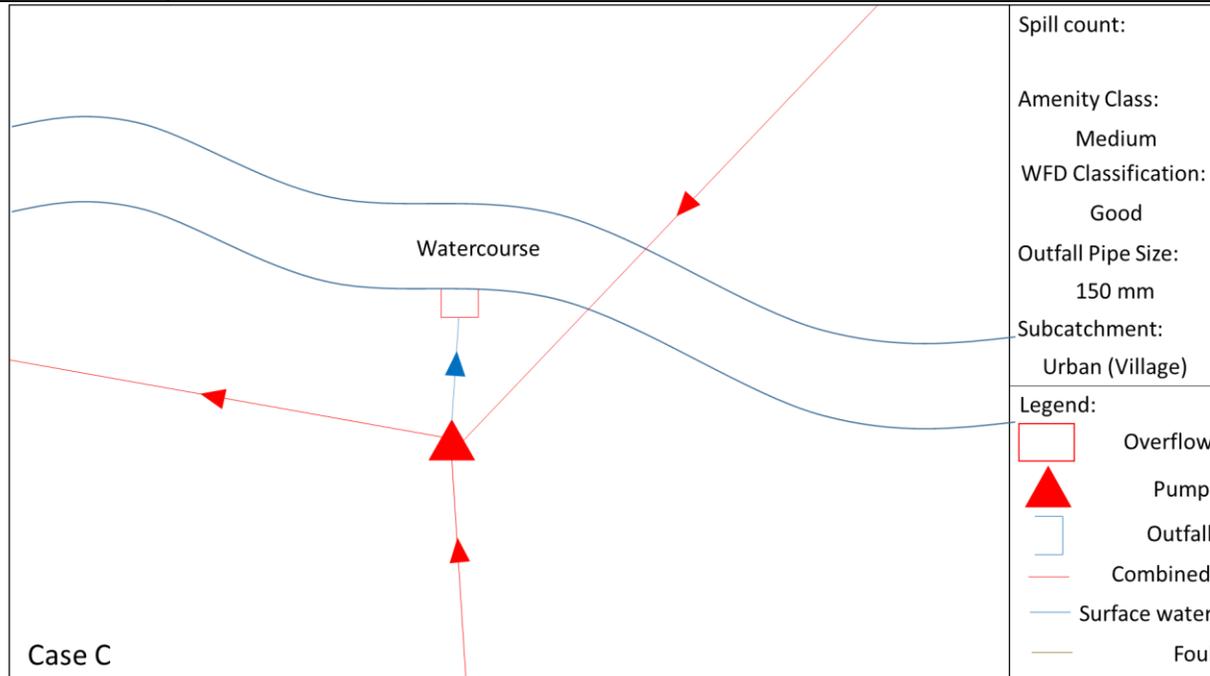
Collate results (using CIRIA's Benefits of SuDS Tool (BeST)).

Present Value Assessment Stage	Total PV Benefits	Total PV Costs	Net Present Value	Benefit Cost Ratio	Flexibility score
Present Value before confidence applied	£ 975,926	£ 3,000,000	-£ 2,024,074	0.3	#DIV/0!
Present Value after confidence applied	£ 975,926	£ 3,000,000	-£ 2,024,074	0.3	#DIV/0!
Present Value sensitivity - low	£ 122,938	£ 3,000,000	-£ 2,877,062	0.0	#DIV/0!
Present Value sensitivity - high	£ 737,626	£ 3,000,000	-£ 2,262,374	0.2	#DIV/0!

NPV negative at £2m and BCR 0.3.

**Case Study C**

<b>Set Decision Making Context</b>	The waterbody currently doesn't meet the water quality objectives for WFD, the SuDS retrofit will aim to fix this, whilst reducing flows to the terminal station along with an arbitrary reduction in pumped flows and flows to work.
<b>Identify options</b>	Planters on 300 properties and street side SuDS, such as roadside swales, trees and rain gardens would cost around £1.25mn. In addition to this, there is the possibility to disconnect 35% of Storm Water sewers draining to foul or combined sewers.
<b>Undertake screening (screening questions)</b>	2km of water body will improve from 'moderate' to 'good', giving a maximum value = £24,900/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £0.89 million with PV costs circa £1.5m, therefore CBA <1 and NPV -ve. However, significant other benefits due to SuDS and major savings for WaSC due to large reductions in pumping costs as well as treatment efficiencies. Therefore, detailed assessment required.
<b>Undertake screening (potential benefits matrix)</b>	There is expected to be significant impacts to: aesthetics, macroinvertebrates, water quality, natural hazards, aesthetic values, recreation, health, carbon sequestration and biodiversity. It is thought there will be major savings for the WaSC from the large reductions in pumping costs as well as treatment efficiencies.



Spill count:  
 Amenity Class:  
 Medium  
 WFD Classification:  
 Good  
 Outfall Pipe Size:  
 150 mm  
 Subcatchment:  
 Urban (Village)

Legend:  
 [Red Square] Overflow  
 [Red Triangle] Pump  
 [Blue Line] Outfall  
 [Red Line] Combined  
 [Blue Line] Surface water  
 [Brown Line] Foul

Case C

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Pumping	less pumping as reduced runoff to PS	167693cu.m/yr from 223590cu.m/yr	Original pumping for 1% of the time: 88hrs hr/yr reduced to 66 hr/yr power 45kW		100% assumed for quantity and 100% for monetary	
Water quality (water treatment)	Reduction in flow reaching works as a result of option	reduction 55897.6 cu/m/yr	down from 612.6 to 459.4 cu.m/day	BeST works category 6	100% assumed for quantity and 100% for monetary	Population is 5000, circa 1500 properties. Each property has average paved plot size of 100m <sup>2</sup> . Also a further municipal paved area of some 2ha. Original runoff from e.g. design event of 30mm per hour maximum is therefore $+2.7*30*(1500*100+2*10000)/10000 = 283.5$ litres/sec. reduced runoff is 75% of this. However, this is maximum, so reduce by 50%: Original runoff 141.8 litre/sec and reduced runoff is 106.3litre/sec. annually assume rainfall for 5% of the time. i.e. a reduction of 55898cu.m/yr

Natural hazards (flood damage)	1500 original properties	Assume SuDS remove 12.5% of flood susceptible properties, taken as 50. i.e. enhance 6 property resilience	assumed £60,000 pa reduced to £5000 pa AAD		100% assumed for quantity and 100% for monetary	
Aesthetic values (property value) (AMENITY IN BEST)	Street scene quality will improve and some properties will benefit.	Using BeST, 0 detached houses, 50 other houses and 10 flats will benefit. Use average house prices of £300K (detached), £220K (other houses) and £110K (flats)	2500 residents in green streets up to 3000; 25 homes overlooking ponds up from 5; 50 others houses and 10 flats in public open space		Quantity: 100%; valuation 50-75%	
Recreation (enjoyment)	Small increase in (coarse) fishing as a result of the option (angling more sensitive to water quality/quantity than say general recreation). There may also be more street cafes in summer periods	200 added coarse and game fishing trips per annum.	original visit nos. 1000 now up to 1200		100% assumed for quantity and 100% for monetary	
Health	Replacing 25% of paved area brings health benefits, although existing area is already very green. Assume additional visits outdoors	Views over green spaces up to 1200 from 1000; wetland adults pop. Unchanged from 5000; nos. using non-countryside green space up to 4500 from 4000			75% for both quantity and valuation	
Carbon sequestration	added suds potentially help with this		trees planted in BEST classes: 20/20/10/10		75% for both quantity and valuation	

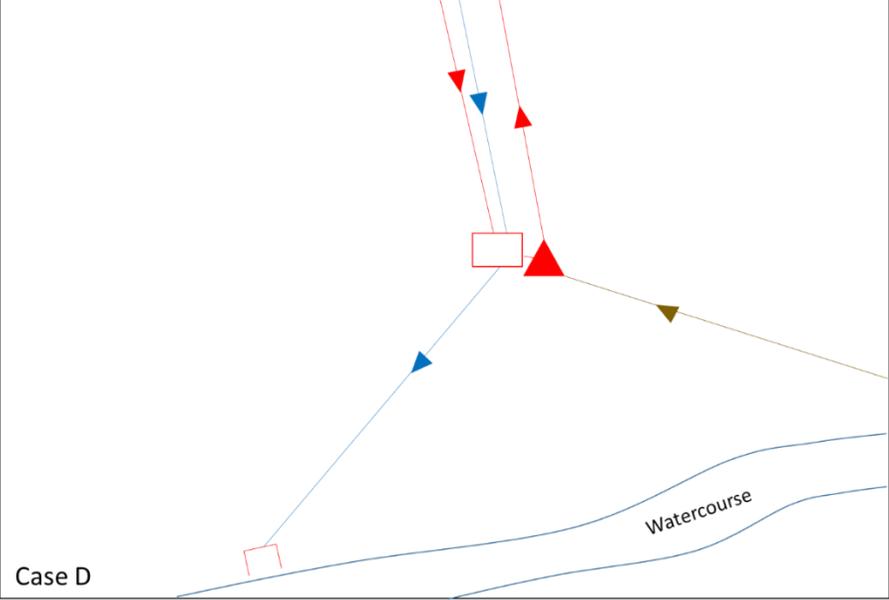
Biodiversity (habitats)	Some improved quality of habitat to suburban area - domestic gardens, grass verges, some open space	If interconnected the new green spaces could provide ecoroutes for species. Assume added area as 1.5ha	Parkland suburban up from 10ha to 20ha		50% for both
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Collate results

Present Value Assessment Stage	Total PV Benefits	Total PV Costs	Net Present Value	Benefit Cost Ratio	Flexibility score
Present Value before confidence applied	£ 6,965,126	£ 1,500,000	£ 5,465,126	4.6	38%
Present Value after confidence applied	£ 3,982,159	£ 1,500,000	£ 2,482,159	2.7	37%
Present Value sensitivity - low	£ 123,768	£ 1,500,000	-£ 1,376,232	0.1	0%
Present Value sensitivity - high	£ 741,778	£ 1,500,000	-£ 758,222	0.5	0%

From this, the PV benefits has increased from the initial screen estimate of £0.89m up to some £3.9m. Thus the BCR for this is 2.7 and NPV £2.5m. However, the dominant benefit is health at some £2.4m, which is sensitive to assumptions especially confidence scores. Without this, the BCR is just above par, as is the NPV.

**Case Study D**

<p><b>Set Decision Making Context</b></p>	<p>The CSO spills 45 times a year, discharging into a watercourse with 'poor' overall WFD classification. It is assumed the changes will achieve a 50% spill reduction.</p>		
<p><b>Identify options</b></p>	<p>The option includes small scale SuDS retrofit to reduce discharge to CSO, affecting roughly 60 houses with the introduction of rain gardens. The scheme is expected to cost £400k, increasing the water quality from 'poor' to 'moderate'.</p>		
<p><b>Undertake screening (screening questions)</b></p>	<p>The improvement will impact around 2km of water body, at an expected benefit of £15,500/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £552,000 whilst PV costs = circa £400,000, therefore CBA = 1.4 and NPV +ve.</p>		
<p><b>Undertake screening (potential benefits matrix)</b></p>	<p>Water quality, Aesthetic value, recreation, health, carbon sequestration and biodiversity will all see improvements, whilst there are expected to be major savings for the WaSC due to reduction in pumping costs as well as treatment efficiencies.</p>		
	 <p>The diagram illustrates the layout of Case D. It shows a watercourse with an overflow (red rectangle) and a pump (red triangle) connected to a combined sewer line (red line). The combined sewer line also connects to an outfall (blue rectangle) which discharges into the watercourse. Surface water (blue line) and foul water (yellow line) are also shown. The text 'Case D' is in the bottom left and 'Watercourse' is written along the watercourse.</p>	<p>Spill count: 45 (2016) Amenity Class: Medium WFD Classification: Poor Outfall Pipe Size: 300 mm Subcatchment: Rural</p>	<p>Legend:   Overflow   Pump   Outfall   Combined   Surface water   Foul</p>

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Water quality (WFD status)	Estimated improvement (poor to moderate), albeit only 50% of spills assumed removed.	Expect that annually the option reduces the numbers of spills by 50% and total volumes spilled by 25%. Improves 2km pf river.			100% assumed for quantity and 100% for monetary	
Water quality (water treatment)	No change to current dry weather flow - presumably the sewer will have some reduction in combined flows due to surface water removal	reduces to 52981cu.m/yr from 70956 cu.m/yr	145cum/day to 194cum/day		100% assumed for quantity and 100% for monetary	Population is 554, circa 60 properties impacted. Each property has average paved plot size of 100m <sup>2</sup> . Also a further municipal paved area of some 0.5ha. Original runoff from e.g. design event of 30mm per hour maximum is therefore $+2.7*30*(60*100+0.5*10000)/10000 = 89$ litres/sec. reduced runoff is 75% of this at 67 litres/sec. However, this is maximum, so reduce by 50%: Original runoff 45 litre/sec and reduced runoff is 34litre/sec. annually assume rainfall for 5% of the time. i.e. a reduction of 23litre/sec or 36266cum/yr
Aesthetic values (property value)	Street scene quality will improve and some properties will benefit.	Using BeST, 0 detached houses, 10 other houses and 0 flats will benefit. Use average house prices of £300K (detached),	250 residents in green streets up to 300; 5 homes overlooking ponds up from 4; 0 others		Quantity: 75%; valuation 75%	

(amenity in best)		£220K (other houses) and £110K (flats)	houses and 0 flats in public open space			
Recreation (enjoyment)	Small increase in (coarse) fishing as a result of the option (angling more sensitive to water quality/quantity than say general recreation). There may also be more street cafes in summer periods	20 added coarse and game fishing trips per annum.	original visit nos. 100 now up to 120		100% assumed for quantity and 100% for monetary	
Health	Replacing 25% of paved area brings health benefits, although existing area is already very green. Assume additional visits outdoors	Views over green spaces up to 120 from 100; wetland adults pop. Unchanged nos. using non-countryside green space up to 45 from 40			75% for both quantity and valuation	
carbon sequestration	added suds potentially help with this		trees planted in BEST classes: 5/5/2/1		75% for both quantity and valuation	
Biodiversity (habitats)	Some improved quality of habitat to suburban area - domestic gardens, grass verges, some open space				75% for both	

#### Collate results

Present Value Assessment Stage	Total PV Benefits	Total PV Costs	Net Present Value	Benefit Cost Ratio	Flexibility score
Present Value before confidence applied	£ 1,056,734	£ 400,000	£ 656,734	2.6	35%
Present Value after confidence applied	£ 718,687	£ 400,000	£ 318,687	1.8	28%
Present Value sensitivity - low	£ 82,849	£ 400,000	-£ 317,151	0.2	#DIV/0!
Present Value sensitivity - high	£ 497,096	£ 400,000	£ 97,096	1.2	#DIV/0!

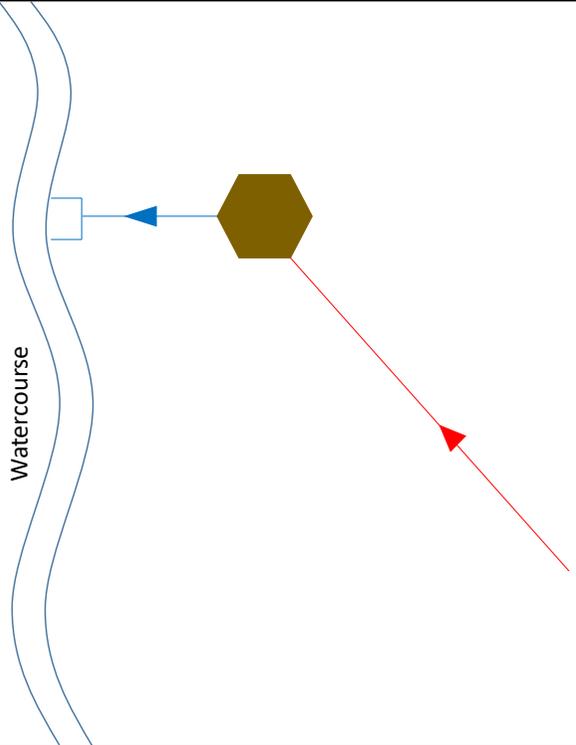
From this, the PV benefits has increased from the initial screen estimate of £552,000 up to some £719,000. Thus the BCR for this is 1.8 and NPV £319,000. The dominant benefit is WQ at some £0.5m, which is sensitive to assumptions especially confidence scores.

**Case Study E**

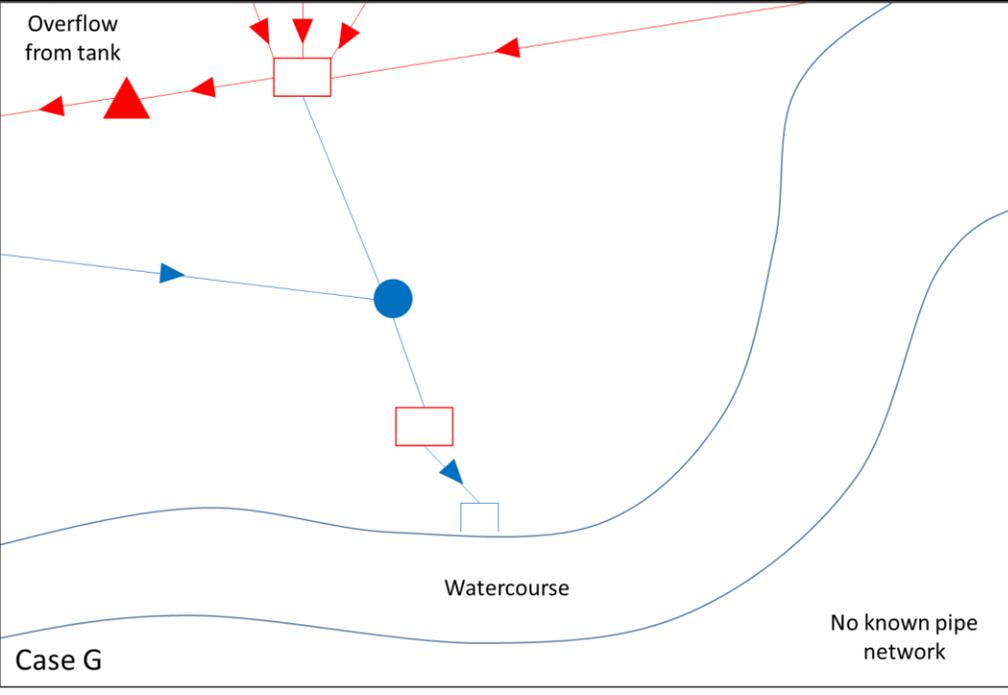
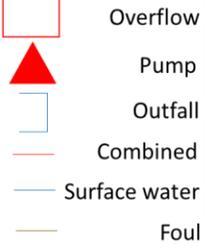
<p><b>Set Decision Making Context</b></p>	<p>The CSO discharges close to the town centre, near a heavily used riverside walk. The aim of this scheme is reduce the CSO spills to the water body, meeting WFD requirements (currently moderate), and to identify if the proposed scheme is cost beneficial, albeit it may be difficult to quantify as several other CSOs spill to the same body. The CSO currently spills 59 times a year, however there is limited space for waste water storage hence a combination of green and grey SuDS will be used.</p>		
<p><b>Identify options</b></p>	<p>It is assumed that 500 properties will be retrofitted with storm water planters (half of which will enhance the current gardens), with an estimated 5 street scape SuDS. The cost for this is estimated at £2mn.</p>		
<p><b>Undertake screening (screening questions)</b></p>	<p>A 2km stretch of water body will be improved, with an associated cost of £19,300/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. PV benefits = £687,000. PV costs = circa £1.93m. The BCR is 0.36, and below the 0.5 threshold. However, other benefits (e.g. health) could be significant, so detailed assessment required.</p>		
<p><b>Undertake screening (potential benefits matrix)</b></p>	<p>There is considerable uncertainty about potential benefits for flood defence (not included) and impacts on fish (included), however no fish kills are noted. There is also potential scope for reputational benefits (both for implementing organisations and private hotels) Therefore, a detailed assessment of the fish impact is needed. Additional benefits include: Water quality health, carbon sequestration and amenity improvements.</p>		
<p>Case E</p>			<p>Spill count: 59 (2016) Amenity Class: Medium WFD Classification: Moderate Outfall Pipe Size: 375 mm into 770 mm SWS Subcatchment: Urban (Town)</p> <p>Legend:  <span style="border: 1px solid red; display: inline-block; width: 10px; height: 10px; margin-right: 5px;"></span> Overflow  <span style="color: red; font-size: 1em; margin-right: 5px;">▲</span> Pump  <span style="border: 1px solid blue; display: inline-block; width: 10px; height: 10px; margin-right: 5px;"></span> Outfall  <span style="color: red; font-size: 1.2em; margin-right: 5px;">—</span> Combined  <span style="color: blue; font-size: 1.2em; margin-right: 5px;">—</span> Surface water  <span style="color: brown; font-size: 1.2em; margin-right: 5px;">—</span> Foul</p>

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Amenity - Quality of space	People's enjoyment affected by street / garden improvements	1800	1.72	£59,646	£14,911	Use of BeST assumptions £1.72/ per person
Carbon sequestration	Benefit from trees			£ 343	£ 257	BeST assumptions
Health	View of green space			£ 700,504	£ 175,126	1/2 the gardens benefit from enhanced planting - affects emotional well being of 1 adult per household - BeST lowest value
Water quality including fish	Change Moderate to Good	2	5,933	£253,414	£298,971	Values based on NWEB apportionment.
Collate results Total benefits = £1,013,906 Total cost = £1,932,367 BCR = 0.52 NPV = -£918,461						

**Case Study F**

<p><b>Set Decision Making Context</b></p>	<p>The spills are originating from a small rural treatment works, subject to an ongoing investigation under NEP. Subject to the results of this, a scheme may be required to reduce spills from the current level of 79 in 2016.</p>		
<p><b>Identify options</b></p>	<p>Options include natural improvements to the water course and reed bed treatment.</p>		
<p><b>Undertake screening (screening questions)</b></p>	<p>The maximum length of improved watercourse (assuming low base flows) is expected to be 2km. The watercourse is already assessed as good status. The relevant value for the Water Company (good to high) is £0 per km. Therefore, minimal benefits are expected and a detailed assessment is not required.</p>		
<p><b>Undertake screening (potential benefits matrix)</b></p>	<p>N/A</p>		
<p>Case F</p>	 <p>The diagram illustrates the layout for Case F. On the left, a wavy blue line represents a 'Watercourse'. To its right is a small blue square labeled 'Outfall'. Further right is a brown hexagon labeled 'WWTW (with overflow)'. A blue line with an arrow points from the WWTW to the outfall, representing 'Storm Water'. A red line with an arrow points from the WWTW towards the right, representing 'Combined' flow.</p>	<p>Spill count: 79 (2016) Amenity Class: Low WFD Classification: Assumed Good Outfall Pipe Size: (Treatment Works) Subcatchment: Rural (Village)</p>	
<p>Legend:</p> <ul style="list-style-type: none"> <li> WWTW (with overflow)</li> <li> Outfall</li> <li> Storm Water</li> <li> Combined</li> </ul>			

### Case Study G

<b>Set Decision Making Context</b>	The catchment is urban, predominantly comprising of residential properties and bathing areas (beaches). It is substantially combined and protected by a storm interceptor tunnel. Investment is required to achieve a spill frequency of 20/yr.		
<b>Identify options</b>	The preferred option is a combination of grey and green and reduces discharges from the storm interceptor by optimising the operation of existing assets, providing reduced storage near key pumping stations and reducing the amount of surface water that enters the sewer network using surface water separation (including reed bed and disconnection of highways, commercial and residential areas) and SuDS (bioretention swales, planters and rain gardens). Outfall pipe size is 1,200mm.		
<b>Undertake screening (screening questions)</b>	5km of water body is expected to be improved from 'moderate' to 'good' at a cost of £21,000/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits = £1.87 million and PV costs = circa £10 million. BCR is 0.19, below 0.5 threshold. However, other benefits are expected to be important and a detailed assessment is required.		
<b>Undertake screening (potential benefits matrix)</b>	Based on the modelling work and preliminary assessment undertaken, a number of benefit categories are expected to be important: Water regulation (pumping), Water quality (WFD status, water treatment), Natural hazards (flood damage), Aesthetic values (property value), Recreation (enjoyment), Education (learning), Biodiversity (habitats).		
 <p>Case G</p> <p>No known pipe network</p>		Spill count: 27 (modelled) Amenity Class: Unclassified WFD Classification: Moderate Outfall Pipe Size: 1200 mm Subcatchment: Urban (Town)	Legend: 

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Water regulation (pumping)	Option expected to result in reduced pump run times. However, impact has not been modelled and is not known. Therefore, this impact cannot currently be quantified.	-	-	-	-	-
Water quality (WFD status)	Option expected to lead to reduced volume pumped to sea and improved bathing water quality (not currently able to value in framework). Also a small water quality improvement in river, but not considered significant.	-	-	-	-	-
Water quality (water treatment)	Option expected to lead to reduced flow to treatment	Baseline (16,500m <sup>3</sup> ), option (4,700m <sup>3</sup> ). Use BeST to quantify impacts	Automatically calculated in BeST	From BeST, PVs are: £1.21 m (operating), £0.24 million (energy), £0.01 million (carbon, elec) and £0.1 million (carbon, process). Total PV £1.56 million	50% confidence applied to quantity, 100% to monetary value	Storage volumes used as proxy for reduced flow to treat. 40 year assessment period assumed. Assume large (Cat 6) works and UWWTD driver
Natural hazards (flood damage)	Option expected to lead to reduced flood risk to properties and improved highway drainage in areas where separation is undertaken. However, impact has not been modelled and is not known. Therefore, this impact cannot currently be quantified.					

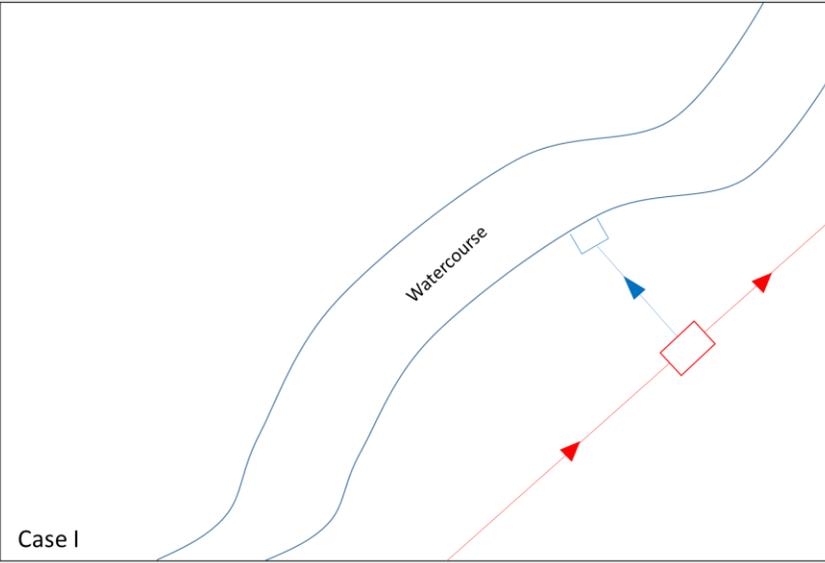
Aesthetic values (property value)	Bioretention areas and two open green spaces within a residential area provide the majority of attenuation requirement. New surface water sewers carry surface water from local highway and roof drainage into the SuDS. They consist of an infiltration system formed by below ground geocellular storage, sized for 1 in 1 month storage, and a swale on the surface to convey excess flows. Landscaping and planting provide amenity benefits.	Total of 600 properties	Automatically calculated in BeST	From BeST, PV is £2.4 million	50% confidence applied to quantity, 75% to monetary value	Use BeST to estimate property price increase as a result of enhancement to parks. Assume 300 properties benefit from 'local public park enhancement' and 300 properties benefit from 'public open green space enhancement', both evenly split by detached houses, other houses and flats. Assume average prices £300K (detached), £200K (other houses) and £150K (flats)
Recreation (enjoyment)	The addition of water to Park is a key feature for the regeneration of the park. These works were co-designed with City Council and involved the 'friends of the park' community group. Option also includes extending footpaths and planting. Therefore, option expected to lead to enhanced enjoyment of and/or participation in informal recreation.	5,000 additional recreational visits per year	£2 (low), £4 (central) and £6 (high) per visit	From BeST, PV is £0.15 million	50% confidence applied to quantity, 75% to monetary value	40 year assessment period assumed.
Education (learning)	Rainwater planters planned for schools, providing amenity benefit and an educational opportunity. These contain a planted soil mix and underdrain filter system. Lined timber boxes are positioned close to building roofs and intercept rainwater down pipes. They are designed to store a 1 in 1 month	2 schools benefitting, assume 600 additional students visiting SuDS each year (300 per school)	£20.16 per trip (from BeST)	From BeST, PV is £0.09 million	50% confidence applied to quantity, 75% to monetary value	40 year assessment period assumed.

	rainfall event and overflow back to the existing drainage system. Works to a school pond within a central courtyard included a hibernaculum (newt hotel). A rain garden improved circulation of water within the pond and provided a newt habitat. Project includes workshops on the construction process and the water cycle to encourage engagement.					
Biodiversity (habitats)	SuDS measures proposed include wildflower meadows within detention basins along the river separation route and attenuation site.	Assume 10ha improved	£1,400 per ha per year (value for 'inland marsh' from BeST)	From BeST, PV is £0.15 million	75% confidence applied to both quantity and monetary value	40 year assessment period assumed.
Collate results Total PV benefits are £4.03 million, giving a NPV of -£5.97mn and BCR of 0.4.						

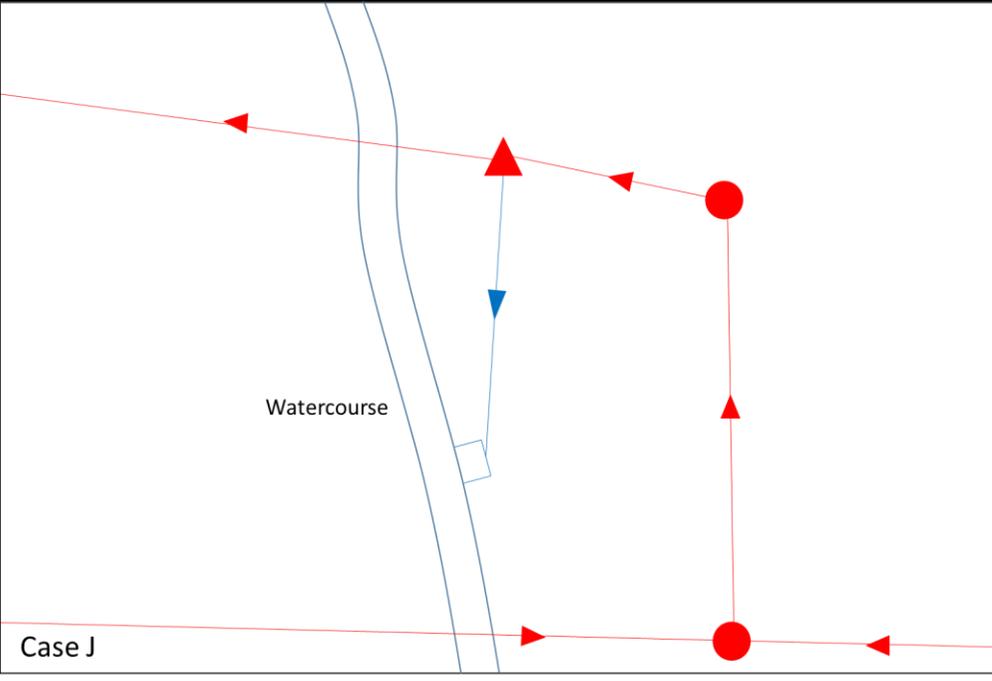
**Case Study H**

<p><b>Set Decision Making Context</b></p>	<p>The areas has been identified for action to meet WFD requirements, improving the environmental quality impacted by the 86 spills a year. The spills are close to a pumping station, serving a treatment works and with the increased flows during winter, the SPS is overwhelmed. The village has a population below 1000, with a surrounding area designated as an 'Area of Great Landscape Value'.</p>		
<p><b>Identify options</b></p>	<p>The option would be an online screen and reed bed treatment, costing approximately £500,000. However the ecological change would be neutral, with no great amenity benefits with the exception of litter and odour for 10 nearby cottages.</p>		
<p><b>Undertake screening (screening questions)</b></p>	<p>The length of watercourse to be improved is 2km, however retained at a 'moderate' and with an expected benefit of £31,900/km/yr. impact on aesthetics only expected, therefore take 1/6 of NWEBS value. PV benefits = £227,000 based on aesthetics alone with PV costs = circa £500k. The BCR is 0.45, and below the 0.5 threshold. Other benefits not expected to be important and a detailed assessment is not required.</p>		
<p><b>Undertake screening (potential benefits matrix)</b></p>	<p>In addition to WFD water benefits other benefits relating to health and amenity (house values) for those with neighbouring properties could be considered but high risk of double counting aesthetics (litter and odour) and house values or house view amenity. The ecological value is expected to be neutral.</p>		
	<p>Case H</p>	<p>Spill count: 59 (2016) Amenity Class: Medium WFD Classification: Medium Outfall Pipe Size: 225 mm Subcatchment: Rural (Village)</p> <p>Legend:   Pump and overflow   Outfall   Combined   Surface water   Foul</p>	

**Case Study I**

<p><b>Set Decision Making Context</b></p>	<p>This area has had SOAF guidance to address 'high spilling' overflows, with options, where cost beneficial, applied to meet the requirements of the Urban Waste Water Treatment Regulations (UWWTR), with the aim to achieve a spill frequency of 20 spills per annum.</p>
<p><b>Identify options</b></p>	<p>Additional storage at a cost of £2mn will be employed. Estimated water course improved= 2km (downstream reach to STW). There may be additional amenity / biodiversity benefits. NOTE issue is macro-invertebrate - severe impact only from SOAF assessment - this is due to decline from High to Good macro-invertebrate status (change in WFD class). Aesthetic impact is Low. Overall water body status is moderate, Ecological element is moderate due to fish status, physio-chemical is moderate (phosphate is poor), Supporting elements (Surface Water is moderate).</p>
<p><b>Undertake screening (screening questions)</b></p>	<p>The maximum length of improved watercourse is assumed to be 2.0km with a benefit of £31,900/km/yr however there is no change expected to the overall improvement. Although assumed macro-invertebrates will be restored from Good to High, the overall status of the water body is driven by other elements. For the purposes of this exercise it may be beneficial to assume Moderate to Good overall status change associated with the implementation of this option. The option is expected to have an impact on macroinvertebrates alone (i.e. take 3/6 of NWEBS value). Therefore, PV benefits = £681k and PV costs = £2,000k. BCR is 0.34, below the 0.5 threshold.</p>
<p><b>Undertake screening (potential benefits matrix)</b></p>	<p>Other benefits limited to amenity along this reach as well as on biodiversity due to presence of downstream nature reserve. Given estimated PV benefits and BCR ratio, with limited likely benefits elsewhere, a detailed assessment is not required.</p>
<div style="display: flex; align-items: center;"> <div style="flex: 1;">  <p style="position: absolute; top: 10px; left: 10px;">Case I</p> </div> <div style="flex: 0.5; border: 1px solid black; padding: 5px;"> <p>Spill count: 18 (2013), 72 (2014), 13 (2015)</p> <p>Amenity Class: Medium</p> <p>WFD Classification: Moderate</p> <p>Outfall Pipe Size: N/A</p> <p>Subcatchment: Urban (City)</p> <p>Legend:</p> <ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 15px; border: 1px solid red; margin-right: 5px;"></span> Overflow</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: red; clip-path: polygon(50% 0%, 61% 35%, 98% 35%, 68% 57%, 79% 91%, 50% 70%, 21% 91%, 32% 57%, 2% 35%, 39% 35%); margin-right: 5px;"></span> Pump</li> <li><span style="display: inline-block; width: 15px; height: 15px; border: 1px solid blue; margin-right: 5px;"></span> Outfall</li> <li><span style="display: inline-block; width: 15px; border-bottom: 1px solid red; margin-right: 5px;"></span> Combined</li> <li><span style="display: inline-block; width: 15px; border-bottom: 1px solid blue; margin-right: 5px;"></span> Surface water</li> <li><span style="display: inline-block; width: 15px; border-bottom: 1px solid brown; margin-right: 5px;"></span> Foul</li> </ul> </div> </div>	

## Case Study J

<b>Set Decision Making Context</b>	<p>The pumping system appears to be the head of the station so a SuDS retrofit would be employed here to reduce flows to this. There is currently low base flow in brook, with WFD said to be 'moderate'. This will be improved too 'good' for both categories however there are minimal other benefits due to the rural setting.</p>		
<b>Identify options</b>	<p>Two options can be used: combining reed bed treatment and small SuDS property level retrofit of rain gardens for disconnection to roughly 50 properties. The cost of the option is around £250K, through disconnection and rainwater barrels for harvesting will take out base loads and reduce pumping in dry/wet weather for further savings.</p>		
<b>Undertake screening (screening questions)</b>	<p>The maximum length of improved watercourse is assumed to be 2km. For the water body, the maximum value is £31,900/km/yr. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality. Therefore, PV benefits are estimated around £1.14 million with PV costs circa £0.25m, therefore BCR around 4.5 and NPV around £0.9m. There are expected to be many other benefits due to the retrofit of SuDS throughout the community. There will also be major savings for the WaSC as there will be large reductions in pumping costs as well as treatment efficiencies.</p>		
<b>Undertake screening (potential benefits matrix)</b>	<p>There will be expected impacts on: aesthetics, macroinvertebrates and water quality in addition to major savings for the WaSC with large reductions in pumping costs and an increased treatment efficiency.</p>		
<p>Case J</p>	 <p>The diagram illustrates the watercourse system for Case J. A blue line represents the 'Watercourse' flowing from the top left towards the bottom right. A red line represents the 'Combined' sewer system, which includes two red circles representing pumps with overflow. A blue line represents 'Surface water' entering the system from the bottom. A legend in the bottom right corner defines the symbols: a red triangle for 'Pump with overflow', a blue square for 'Outfall', a red line for 'Combined', a blue line for 'Surface water', and a green line for 'Foul'. The text 'Case J' is written in the bottom left corner of the diagram area.</p>	<p>Spill count: 71 (2013), 78 (2014), 51 (2015) Amenity Class: Unclassified WFD Classification: Moderate Outfall Pipe Size: N/A Subcatchment: Rural (Village)</p>	<p>Legend:   Pump with overflow   Outfall   Combined   Surface water   Foul</p>

Detailed assessment						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Water quality (WFD status)	Estimated improvement (moderate good) is probably similar to a conventional storage option.	Expect that annually the option reduces the numbers of spills by 50% and total volumes spilled by 25%. Improves 2km of river.			100% assumed for quantity and 100% for monetary	
Pumping	less pumping as reduced runoff to PS	33586 cu.m/yr from 44702 ccu.m/yr	Original pumping for 1% of the time: 88hrs hr/yr reduced to 66 hr/yr power 45kW		100% assumed for quantity and 100% for monetary	Population is 650, retrofit 50 properties. Each property has average paved plot size of 100m <sup>2</sup> . Also a further municipal paved area of some 0.2ha. Original runoff from e.g. design event of 30mm per hour maximum is therefore $+2.7*30*(50*100+0.2*10000)/10000 = 56.7$ litres/sec. reduced runoff is 75% of this. However, this is maximum, so reduce by 50%: Original runoff 28.4 litre/sec and reduced runoff is 21.3litre/sec. annually assume rainfall for 5% of the time. i.e. a reduction of 11116.4 cu.m/yr
Water quality (water treatment)	Reduction in flow reaching works as a result of option	reduction 11116.4 cu/m/yr	down from 122.5 to 92 cu.m/day	BeST works category 6	100% assumed for quantity and 100% for monetary	see above

Rainwater harvesting	each property will collect water and in this area it could be valuable					Collect 50% of the reduced volumes i.e equivalent to 15.2cu.m/day
Aesthetic values (property value) (amenity in best)	Street scene quality will improve and some properties will benefit.	Using BeST, 0 detached houses, 10 other houses and 0 flats will benefit. Use average house prices of £300K (detached), £220K (other houses) and £110K (flats)	no change to green streets; 15 homes now overlooking wetland up from 5; 5 other houses and 0 flats in public open space			Quantity: 100%; valuation 50-75%
Recreation (enjoyment)	Small increase in (coarse) fishing as a result of the option (angling more sensitive to water quality/quantity than say general recreation). There may also be more street cafes in summer periods	20 added coarse fishing trips per annum.	Original visit nos. 1000 now up to 1200			100% assumed for quantity and 100% for monetary
Education	reedbed will provide opportunity	not sure which schools etc in vicinity				
Health	Replacing 25% of paved area brings health benefits, although existing area is already very green.	Views over green spaces unchanged; wetland adults pop. Increased from 15 to 45; nos. using non-countryside				75% for both quantity and valuation

	Assume additional visits outdoors	green space unchanged				
Carbon sequestration	added suds potentially help with this		trees planted in BEST classes:5/1/1		75% for both quantity and valuation	
Biodiversity (habitats)	Some improved quality of habitat to suburban area - domestic gardens, grass verges, some open space	If interconnected the new green spaces could provide ecoroutes for species. Assume added wetland area as 0.2ha	Parkland suburban up from 1ha to 1.2ha		75% for both	

#### Collate results

Present Value Assessment Stage	Total PV Benefits	Total PV Costs	Net Present Value	Benefit Cost Ratio	Flexibility score
Present Value before confidence applied	£ 1,529,919	£ 250,000	£ 1,279,919	6.1	26%
Present Value after confidence applied	£ 851,618	£ 250,000	£ 601,618	3.4	26%
Present Value sensitivity - low	£ 136,553	£ 250,000	-£ 113,447	0.5	0%
Present Value sensitivity - high	£ 827,592	£ 250,000	£ 577,592	3.3	0%

The detailed assessment based on BeST results show a decrease in NPV and BCR compared with the screening approach. From a BCA of 4.5 to a BCA of 3.4 and NPV of £0.9m to NPV of £0.6mn. However, option still appears to be good value.

### Appendix 3: Completed Appraisal Summary Table (AST)

<p><b>Scheme details:</b> Yorkshire Water investigated the potential of different options to reduce combined sewer overflow (CSO) spills in Roundhay Park in Leeds, as part of its plans for the 2014 Periodic Review. The aim was to compare the costs, immediate and wider benefits of a SuDS and conventional drainage approach.</p>						
<p><b>Option name:</b> A SuDS approach in public areas to disconnect surface water from the combined system and pass it through the conveyance and storage SuDS. This used a combination of swales, detention basins, geocellular storage and connecting pipes.</p>						
<p><b>Screening:</b></p> <p>1. <b>Screening questions</b>          The maximum length of improved watercourse is 2.5km and the potential improvement expected is 'moderate' to 'good'. The relevant value for the Humber is £25,800 per km. The option is expected to have an impact on aesthetics, macroinvertebrates and water quality, in a high amenity receiving water body. Therefore, PV benefits = 2.5 x 25,800 x 5/6 x 22.17 = £1.19 million. PV costs are expected to be £9.3 million. Therefore benefits are expected to be (a) significant, but (b) less than costs. However, other benefits are expected to be important (an earlier assessment suggested these could be several million pounds). Therefore, a detailed assessment is required.</p> <p>2. <b>Potential benefits matrix</b>          Based on the earlier assessment, a number of benefit categories are expected to be important: Water quality (WFD status, water treatment), Natural hazards (flood damage), Aesthetic values (property value), Recreation (enjoyment), Biodiversity (habitats).</p>						
Benefit category	Qualitative description	Quantitative assessment (1)	Value taken (2)	Monetary valuation (1x2)	Sensitivity	Assumptions
Water quality (WFD status)	Estimated improvement (mod to good, Humber region) is slightly greater than that under the conventional option due to improvements to other CSOs downstream, and cleaner, more balanced flow being discharged over the year.	2.5km	£25,800 per km	£515,819 PV after confidence applied	50% confidence applied to quantity, 100% to monetary value	
Water quality (water treatment)	Reduction in flow reaching works as a result of option	Modelling suggests a reduction of 49,770 m <sup>3</sup> /yr flow, (and we assume	Values in BeST for operating, energy and	Using BeST, PV benefit is £25,481	75% confidence applied to quantity, 100%	Large (cat 6) urban works UWWTD

		75% using the confidence values) passes through combined sewer system for treatment.	carbon cost savings		to monetary value	
Natural hazards (flood damage)	Protection of properties from flooding as a result of additional natural storage	32 properties. Given that there is some slope across the area, we assume that 50% of properties will benefit from reduced flood risk.	Based on outputs from assessment using MCM	£345,152 per year (£3.6 million PV after confidence applied)	For low sensitivity, assume 25% (16 properties) and for high, assume 75% (48 properties).	Annual weighted damage used for residential properties with 10cm of flooding, including disruption, blight, distress etc.
Aesthetic values (property value)	Improvements to local park, as option will turn unused green space into amenity location that is attractive and can be used.	Using BeST, 74 detached houses, 840 other houses and 73 flats will benefit. Use average house prices of £300K (detached), £220K (other houses) and £110K (flats)	Use % property premium from BeST	Using BeST, one-off benefit is £4,718,135	50% confidence applied to both quantity and monetary value	Mix of planting anticipated but low (conservative) value selected from range of monetary values. Assumed well looked after.
Recreation (enjoyment)	General recreation improvements around Roundhay Park due to WQ leading to increase in visitors. Also small increase in (coarse) fishing as a result of the option (angling more sensitive to water quality/quantity than say general recreation).	10,000 additional general recreation visits per year, 365 additional coarse angling trips	£5.36 per visit for general recreation, £4.59 per visit for angling (using BeST)	£279,641 PV after confidence applied	50% confidence applied to both quantity and monetary value (general recreation), and 75%/100% applied for fishing	Very difficult to find estimates of current recreation in residential areas or likely increase associated with SuDS measures. However, recreation may increase in Roundhay Park, so assume approx 1% increase in number of visits from current situation (in region of 1 million visits per year). Only 1% because most visits not dependent on, and not sensitive to small improvements in, water quality/quantity. For angling, assume 10% increase in number of

						visits per year as a result of the option (angling more sensitive to water quality/quantity than general recreation).
Biodiversity (habitats)	Improved quality of habitat to suburban area - domestic gardens, grass verges, some open space	1.3 ha improved	£1,684 per ha per year	£11,420 PV after confidence applied (general recreation), £26,244 (angling)	50% confidence applied to both quantity and monetary value	Habitat quality is Medium - Provides good potential habitat for range of species. Connectivity is Poor - surrounded by hard-standing areas (concrete, paths, roads). No 'green space' present.

The graph (right) shows a comparison of the PV costs and PV benefits for all 4 options.

For option 3, the estimated benefits are marginally higher than the costs, and the central estimate after confidence is applied gives a benefit cost ratio of 1.0. The main benefits are associated with amenity, flood risk and water quality. Amenity benefits relate to creating a park with a detention basin and general street greening, replacing grass verges with bio-infiltration swales.

Further details, including the distribution of benefits, impact of uncertainty (through application of confidence intervals) and sensitivity analysis, are available on the susdrain web site

[http://www.susdrain.org/files/resources/BeST/best\\_case\\_study\\_roundhay\\_v2.pdf](http://www.susdrain.org/files/resources/BeST/best_case_study_roundhay_v2.pdf)

The different options are associated with a large range in net present value. Option 1 reduced the CSO spills, was lowest cost but offered limited other benefits. Option 2 provided similar levels of drainage performance in the sewer network as option 3 and 4, but created fewer benefits having underground infrastructure only, and was also less resilient to climate change. Options 3 and 4 included distributed SuDS features across the catchment, creating a second drainage network to manage surface water, in turn creating wider benefits to the community and environment. These options had similar costs and benefits. Overall, only the 'SuDS public' option 3 generated a positive NPV (benefits greater than costs).

