CIRIA RP1074: Making B£ST better

B£ST evidence review summary

18/06/18

1. Introduction

One of the key objectives of CIRIA RP1074 Making B£ST Better project is to assess and include new methodologies/evidence related to the outcomes and monetary benefits of SuDS and natural flood management (NFM). Both SuDS and NFM play an increasingly important role in water management. There are some important differences between them in terms of location of interventions (e.g. rural or urban) and nature and scale of components (e.g. drainage or waterbody, development or catchment focus). However, they can both result in environmental, social and economic outcomes that deliver benefits for society which can be assessed and valued using B£ST.

This document presents the key output from the Review assessment approaches and evidence (Task 3) and the task to Evaluate evidence (Task 4) of the first phase of the project.

Section 2 presents an overview of the evidence considered, including approaches to assessment, quantitative and monetary evidence related to the benefit categories currently (see panel) and potentially covered by B£ST.

Benefit category	Monetised
Amenity	✓
Biodiversity and ecology	✓
Building temperature	✓
Carbon reduction and sequestration	✓
Crime	×
Economic growth	×
Education	✓
Enabling development	✓ / ×
Flexible infra./climate change adaptation	To be developed
Flooding	✓
Groundwater recharge	✓
Health	✓
Pumping wastewater	✓
Rainwater harvesting	✓
Recreation	✓
Tourism	×
Traffic calming	×
Treating wastewater	✓
Water quality	✓

Section 3 provides an initial assessment of the evidence in terms of robustness and applicability to SuDS and NFM interventions in the UK context.

Section 4 summarises the key points and outlines the potential next steps, including a process for integrating new or improved evidence into B£ST, in such a way as to ensure the new evidence is appropriately incorporated and existing functionality is maintained. It is anticipated that for Phase 1 of the project, of the suite of B£ST outputs, only the Evaluation Tool (W045a) and Technical Guidance (W045c) will need a major revision. The other components of B£ST – the Options Comparison Tool (W045b) and User Manual (W045d) may require a 'light touch' update.

2. Overview of evidence

We have undertaken a focused review of recent evidence (primarily published over the last three years) in the UK and overseas relating to the understanding and assessment of SuDS and NFM (natural flood management) interventions, including their performance and their benefits.

As B£ST is driven by an 'impact pathway' approach that focuses on the valuation of outcomes (linked to the range of benefit categories), the review has sought to encompass evidence that relates to either:

(a) qualitative evidence that supports an improved understanding of benefits from SuDS/NFM interventions;
(b) quantifiable evidence linking SuDS/NFM interventions to outcomes; or
(c) the monetary valuation of these outcomes.

We have considered evidence relating to all benefit categories, but particularly those identified in the Task 2 stakeholder engagement work as being of greatest interest.

In total, we have reviewed 96 additional papers, articles and other evidence of potential interest, as well as the suite of outputs associated with the Working with Natural Processes (WwNP) project, and the evidence that supported this. A further ten sources were considered but screened out as they were considered to be of limited value. A full list of sources is included in Appendix 1.

This review builds on the work done to support the current version of B£ST. The original (2013) review assessed over 500 quantitative and monetary values from more than 100 studies of potential relevance to SuDS in the UK. It resulted in a dataset (2015 Review of Sources) of relevant and transferable values covering each benefit category and a variety of different contexts. The current review follows the same process in terms of assessing and evaluating evidence (benefits covered, age and location of study, degree of applicability, etc), but focuses on recent (post 2013) evidence.

In undertaking the current review, we are grateful to the Environment Agency (EA) for making available a draft version of the 'Benefits Inventory', which is being developed to support valuation of improvements in ecosystem services by EA staff who are developing or assessing projects. The inventory contains values and metadata used across the EA, Natural England and Defra. It also contains values sourced from a literature review of economic benefit values on environmental quality changes. It has a particular focus on benefits relating to water quality, water quantity, flood prevention and natural flood management. For each source of evidence, it provides benefit values, including an explanation, the source and details on using the value (risks/assumptions, scale and transferability).

3. Evaluation of evidence

Table 1 provides an overview of the evidence we have reviewed, assessed and evaluated. It is linked to the benefit categories currently or potentially included in B£ST. Several sources are general in nature and relate to more than one benefit category.

Table 1: Overview of evidence considered in the review

Benefit category	No. of evidence sources reviewed	Qualitative evidence	Quantitative evidence	Monetary values	Assessment of evidence and proposed action
Air quality	5	Very limited evidence relating to role of green infrastructure generally in improving local air quality.	Some new values for air pollutant (e.g. PM10) removal rates from green roofs and trees. However, appear similar to existing values in B£ST.	UK government guidance on valuation estimates for the air pollution removal has not been updated since previous version.	Air filtration effects of vegetation useful for adding or completing existing info in B£ST, and is cited in government's 25 year Environment Plan.
Amenity	10	Fields in Trust (2018) report is based on high quality, original valuation study undertaken throughout UK in 2017. It is a primary source of UK data for valuation of benefits in amenity and health categories. Other evidence (e.g. work on natural capital accounts for London) based on similar approaches to that in B£ST currently, i.e. linking uplift in property prices as result of access to green space.	Fields in Trust report includes quantitative data on frequency of park and green space usage. No other new quantitative info available.	Fields in Trust report finds a total benefit of £30.24 per year (£2.52 per month, range £2.37 to £2.67) per individual, and includes benefits gained from using their local park or green space and non-use benefits such as the preservation of parks for future generations. In urban areas, the monthly value is £2.89. Regional values also provided. Ongoing ONS work with OS to estimate extent to which environmental amenities provided by natural capital affect house prices. Unlikely to be available within our timescales. Some new evidence related to commercial property, which is not currently considered in B£ST.	We propose including values from Fields in Trust report where local parks are created or significantly improved. Some other sources useful to validate existing approach, and can be referenced in Technical Guidance. New valuation evidence (e.g. commercial property) can be included in B£ST update.
Biodiversity & ecology	7	No new approaches or evidence.	No new quantitative evidence.	EA benefits inventory gives green RAG rating to report on 'Economic Valuation of the Benefits of Ecosystem Services (BAP)', which provides values for different habitat types.	Project team to replace existing biodiversity values in B£ST.
Building temperature	5	No new approaches, but new evidence (e.g. from UK natural capital accounts and academic work) possibly sufficient to include 'urban	Discussions and review still ongoing. Defra work on natural capital accounts for UK cites evidence suggesting that parks >3ha exert a	No new monetary evidence.	Combine existing category with evidence on urban cooling for new 'temperature' category.

Benefit category	No. of evidence sources reviewed	Qualitative evidence	Quantitative evidence	Monetary values	Assessment of evidence and proposed action
		cooling' as new sub-category or as 'user defined' benefit	cooling effect on the surrounding area (100m buffer) of 0.52 deg C.		
Carbon sequestration	5	Improved approaches to estimating carbon sequestration potential of land in various uses.	Useful evidence from Defra related to carbon sequestration. New GHG conversion factors from BEIS.	Some new work from Forestry Commission and Defra on estimating and valuing sequestration potential of land in various uses, which is being compared with existing evidence in B£ST to identify whether there is an improvement.	New information to be included.
Economic growth	2	Useful report for Defra on Green Infrastructure's contribution to economic growth, but rather generic, so can only be included as case study.	No new quantitative evidence.	No new evidence.	New information to potentially be included.
Education	1	Work ongoing by ONS/Defra	Work ongoing by ONS/Defra	Work ongoing by ONS/Defra	Will include if available in time.
Flood risk	8	Approaches and understanding of range of benefits related to flood risk reduction have improved.	Recent work by EA concludes it is currently not possible to move from m3 of storage created by schemes to a transferable benefit estimate, because each m3 storage has a different impact depending on where it is placed within a catchment.	Latest version of MCM allows assessment of some benefits that are covered by B£ST.	New information to potentially be included and will clarify and highlight potential for overlapping benefit categories and subsequent double counting.
General (>1 benefit category)	10	Natural capital approaches highlighted in 25 year Environment Plan.	No new quantitative evidence that improves on B£ST	Valuation-based evidence supporting SuDS and NFM provided in revised Green Book.	Include evidence where appropriate and potentially map benefit categories onto natural capital in next phase.
Groundwater recharge	2	No new approaches	No new quantitative evidence.	New values (inc water company-based AISCs) included in update to EA's groundwater appraisal guidance.	New and updated values from EA guidance can be included.
Health and wellbeing	29	Improved understanding of links between GI generally	New evidence for both physical and mental health,	Evidence has definitely improved, e.g. Fields in Trust report (see Amenity) and	Good evidence to support more robust assessment in this area.

Benefit category	No. of evidence sources reviewed	Qualitative evidence	Quantitative evidence	Monetary values	Assessment of evidence and proposed action
		and physical and mental outcomes.	linked to trips to green spaces.	EA report last year on economic value of physical activity that uses accessible natural environment. Also values from natural capital accounts for London can be used to support evidence already in B£ST (for interventions in London).	
Noise	3	Impacts of noise pollution on health.	Still difficult to link GI interventions to change in outcome (dBs).	Government-based estimates of value of reductions in noise pollution.	Evidence potentially sufficient to include as new benefit category.
Recreation	6	No new approaches	No new quantitative evidence, but resources (e.g. MENE) have been improved and can be better signposted.	Recent version of ORVal (Outdoor Recreation Valuation tool), plus evidence from EA Benefits Inventory provides ranges that are not currently included in B£ST. Also values from natural capital accounts for London can be used to support evidence already in B£ST (for interventions in London).	Good evidence to support more robust assessment in this area.
Tourism	1	Manchester GI strategy suggests that value can be estimated by multiplying number of additional visits by value of average expenditure per visitor.	No new quantitative evidence.	No new monetary values.	Additional evidence can be included to support qualitative assessment.
Traffic calming	1	No new evidence	New evidence (from Public Health England) linking measures to risk of road traffic collisions.	Department of Transport information on value of collisions.	Evidence potentially sufficient to support full valuation in this category.
Water quality	3	No new evidence.	New evidence (from Water UK work on valuing CSO improvements) sufficient to link SuDS/NFM measures in greater detail, to support improved quantification.	Quantitative evidence can be linked to existing valuation evidence provided by NWEBS.	To be amended.

In addition, we have reviewed the Environment Agency's Working with Natural Processes (WwNP) research framework and evidence directory.[1] The purpose of this is to identify the potential for, and need to include, appropriate NFM measures and benefits into the updated B£ST tool. Table 2 provides an initial overview of this evidence, including NFM measures and the benefit categories of potential interest for B£ST from. Only benefits over and above those already in the current version are considered. For example, many of the flood risk management benefits from use of NFM measures may already be included at least to some extent. The NFM evidence sources that have been reviewed are included in Appendix 2.

Table 2: NFM measures and benefits of potential relevance to enhanced B£ST

Measure group	**Sub group**	**NFM Benefit categories – directly relevant to SuDS**	**Other benefit categories to include from NFM benefit categories**	**Overview of aspects to consider**
River and floodplain management	River restoration	• Water quality • Flood fluvial • Low flows	• Habitat • Climate regulation • SW flood • Aesthetic	• Morphological features to be included • As part of river restoration • Ensure contribution to low flow maintenance is included • Satisfaction values
	Floodplain (and floodplain wetlands)	• Water quality • Habitat • Aesthetic and cultural activity	• Low flows • Fluvial flood	• Ephemeral value of temporary storage? • Relationship between flood-plains and SuDS value
	Wetlands	• Water quality • Habitat • Climate regulation • Air quality • Fluvial flood • Aesthetic • Cultural activity	• Low flows	• Wetlands vs, or as, SuDS? • Relative scales and when is a wetland a SuDS? •
	Leaky/woody barriers	• Flood risk fluvial • aesthetic	• Water quality • Habitat • Climate regulation • Low flows • Health • Air quality • Floods SW	• Leaky barriers as part of detention/retention/swales? New design guidance?
	Offline storage areas	• Flood SW • Flood fluvial	• Water quality • Climate regulation • Low flows	• (SuDS) detention vs offline storage? Relative scales

[1] https://www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk

Measure group	Sub group	NFM Benefit categories – directly relevant to SuDS	Other benefit categories to include from NFM benefit categories	Overview of aspects to consider
Woodland management	Catchment woodland	• Water quality • Habitat • Climate regulation • Health • Air quality • Flood SW • Fluvial flood • Aesthetic • Cultural activity	•	• Relative scales are significant. Cases in NFM guide include SuDS. • When is a SuDS related planting a (significant) woodland? • Where are the thresholds to move into larger scale benefits?
	Cross-slope woodland	• Habitat • Climate regulation	• Water quality • low flows • flood fluvial • flood SW • aesthetic	• As above, this is about relative scale • Hedgerows (as part of designed SuDS?)
	Floodplain woodland	• Habitat • Climate regulation • Flood fluvial	• Water quality • Low flows • Aesthetic	• As above
	Riparian woodland	• Climate regulation • Fluvial flood	• Water quality • Habitat • Low flows • Air quality	• Consider shade benefits • Scales as above
Runoff management	Soil and land management	• Habitat • Climate regulation	• Water quality • Low flows • Air quality • Floods fluvial • Floods SW • Aesthetic • Cultural	• Crops, planting and buffer strips may inform SuDS (RSuDS?) • Scale as above but also potential value of hedgerows? • Planting to maximise carbon storage rather than only e.g. native species (RSuDS?).
	Headwater drainage management		• Water quality • Climate regulation • Low flows • Air quality • Flood fluvial • Flood SW • Aesthetic	• SuDS/RSuDS and peatlands? • Many potential benefits from peatlands.
	Runoff pathway management		• Water quality • Habitat • Climate regulation • Low flows • Air quality • Flood SW	• Measures here are identical to SuDS but used in RSuDS context. Consider if this requires widening the scope of B£ST. Working With Nature Projects (WWNP) can increase resilience; consider lessons for what's now in B£ST.

4. Summary and next steps

In summary, the key findings from the review and assessment of new evidence are as follows.

i. The evidence underpinning the existing version of B£ST remains robust. The majority of the sources of evidence we have reviewed either relate back to the same sources that underpin B£ST, or do not significantly improve the existing evidence base.
ii. Nevertheless, there is sufficient additional evidence to support *significantly improved* assessment in some benefit categories, notably amenity, biodiversity, health, groundwater recharge and recreation.
iii. There is sufficient additional evidence to support *marginally improved* assessment in other benefit categories, including air quality, flood risk, economic growth and tourism.
iv. There is potentially sufficient new evidence to justify the inclusion of two new monetised benefit categories – noise and traffic calming.
v. There is good evidence to support improved linkages between B£ST and NFM, in particular:
    a. NFM measures and SuDS measures may be different in type and scale, but both can deliver outcomes (illustrated through impact pathways) that can be robustly and consistently valued using B£ST;
    b. A number of additional evidence sources relating primarily to the benefits of NFM can be used to inform the B£ST update (e.g. river and floodplain restoration, maintaining flows in waterbodies);
    c. There are a number of NFM examples that include elements of SuDS and could be suitable for a case study application/testing using B£ST; and
    d. Some schemes may include a combination of SuDS and NFM measures, and these can be complementary, leading to greater benefits overall.
vi. A number of evidence sources may be useful to illustrate benefits using case studies (e.g. in Technical Guidance), even where they are not suitable for supporting the tool itself with quantitative or valuation estimates.
vii. There are some 'updates' to values in the existing tool that need to be taken into account, notably:
    a. Updating all monetary values for inflation to 2017 prices; and
    b. New values published by BEIS for greenhouse gas conversion factors and energy price projection.

The project team is now in the process of defining the specific updates and revisions needed to B£ST (spreadsheet tool and Technical Guidance), both as a result of this evidence review and the stakeholder engagement work (Task 2). This has resulted in a draft 'development update', which will be used to inform the updates to be undertaken (Task 5).

Once the necessary changes to B£ST have been made, we will undertake testing of the tool, prior to releasing the update version and dissemination.

Appendix 1: List of sources

Primary B£ST benefit category	Title/Author/Date		
Air quality	Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts	Office for National Statistics https://www.ons.gov.uk/economy/environmentalaccounts/articles/developingestimatesforthevaluationofairpollutioninecosystemaccounts/2017-07-25	2017
	Urban Particulate Pollution Reduction by Four Species of Green Roof Vegetation in a UK City	Speak, A.F., Rothwell, J.J., Lindley, S.J. & Smith, C.L. Atmospheric Environment 61, 283-293	2012
	Spatial evaluation of multiple benefits to encourage multi-functional design of SuDS in BG cities	Fenner R. Water, 9,953, doi:10.3390/w9120953	2017
	Air quality considerations for stormwater green street design	Conroy K., Hunt W., Kumar P., Anderson A. Proc. 14th Int Conf. Urban Drainage. Prague.	2017
	Air quality considerations for stormwater green street design	Shaneyfelt K M., et al. Environmental Pollution 231 (2017) 768e778	2017
	James Levine & Rob MacKenzie (Director of the Birmingham institute of Forest Research)	Birmingham University	
Amenity	Open Space: An Asset without a Champion?	Gensler & Urban Land Institute http://www.gensler.com/uploads/documents/Open_Space_03_08_2011.pdf	2011
	Economic Impact of the Green City Clean Waters Program, Final Report	Sustainable Business Network http://www.sbnphiladelphia.org/images/uploads/Green%20City,%20Clean%20Waters-The%20First%20Five%20Years(1).pdf	2016
	Revaluing Parks and Green Spaces: Measuring their economic and wellbeing value to individuals	Fields in Trust	2018
	The rarity of direct experiences of nature in an urban population	Daniel T.C. Cox et al. Landscape and Urban Planning 160 (2017) 79–84	2017
	Variation in experiences of nature across gradients of tree cover in compact and sprawling cities	D.F. Shanahan et al. Landscape and Urban Planning 157 (2017) 231–238	2017
	All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting	Helen Hoyle et al., Landscape and Urban Planning 164 (2017) 109–123	2017
	Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space	Southon G E., et al. Landscape and Urban Planning 158 (2017) 105–118	2017
	TBC		2018

Primary B£ST benefit category	Title/Author/Date		
	The Hidden Value of Our Green Spaces	Land Trust http://thelandtrust.org.uk/pdfs/HiddenValueOfGreenSpace/mobile/index.html#p=1	2017
	Corporate Natural Capital Account	eftec for London Borough of Barnet, https://barnet.moderngov.co.uk/documents/s40941/Appendix%202%20Natural%20Capital%20Account%20for%20Barnet.pdf	2017
Biodiversity	Constructed wetlands for water quality improvements: Benefit transfer analysis from Ohio	N.B. Irwin, E.G. Irwin, J.F. Martin P. Aracena Journal of Environmental Management 206 (2018) 1063-1071	2018
	A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. Final Report. TEEB follow up studies	Roy Brouwer, Luke Brander, Onno Kuik, Elissaios Papyrakis and Ian Bateman. University of Amsetrdam	2013
	DEVELOPMENT OF 'LOOK-UP' ENVIRONMENTAL VALUE ESTIMATES FOR INITIAL APPRAISAL WITHIN COST-BENEFIT ANALYSIS	Eftec	2015
	Valuing Biodiversity: Discussion paper for Defra	eftec	2015
	Economic Valuation of the Benefits of Ecosystem Services (BAP)	Christie, M et al	2011
Building temp	ENHANCING THE ECONOMIC EVALUATION OF WSUD	CRCWSC Research Synthesis Discussion Paper CRC for Water Sensitive Cities	2016
Carbon sequestration	The impact of land use/land cover scale on modelling urban ecosystem services	Darren R. Grafius et al. Landscape Ecol (2016) 31:1509–1522 DOI 10.1007/s10980-015-0337-7	2016
	Greenhouse gas conversion factors	BEIS https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016#history	2016
	Developing ecosystem accounts for protected areas in England and Scotland	Defra	2015
Economic growth	VALUE (valuing attractive landscapes in urban environment)	Various http://www.value-landscapes.eu/	2012
	Green Infrastructure's contribution to economic growth: a review	eftec, Sheffield Hallam University and CRESR for Defra and Natural England http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=19056	2013
Education	UK natural capital: ecosystem accounts for freshwater, farmland and woodland	Defra/ONS	2017
Flood risk	Flood Risk Reduction Benefit Valuation for Natural Flood Management	Environment Agency	2017

Primary B£ST benefit category	Title/Author/Date		
	Flood and Coastal Erosion Risk Management appraisal guidance: Guidance on applying the scoring and weighting methodology	Environment Agency https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/487237/LIT_10350.pdf	2010
	Multi-coloured Manual: A simplified benefit:cost appraisal tool for flood risk management		2017
	Multi-coloured Manual: The Weighted Annual Average Damage (WAAD) Estimation Tool		2017
	Understanding design scales for a range of potential green infrastructure benefits in a London Garden City	Pochee H., Johnston I. Building Services Engineering Res. Tech. Vol 38(6) 728-756	2017
	Benefit-cost analysis of stormwater green infrastructure for Grand Rapids, Michigan	Erik E. Nordman et al. https://wmeac.org/wp-content/uploads/2017/01/Stormwater-document-17Aug6.pdf	undated
	Flood Management and Woodland Creation - Southwell Case Study: Hydraulic Modelling and Economic Appraisal Report	Forestry Commission	2017
	Flood Damage Assessment: Literature review and recommended procedure	Lea Olesen, Roland Löwe, and Karsten Arnbjerg-Nielsen	2016
General	25-year Environment Plan	Defra	2018
	25-year Environment Plan: Annex 1 - Supplemnetary Evidence Report	Defra	2018
	EnviTAG	Defra/EA	2018
	GI-Val	Mersey Forest http://www.merseyforest.org.uk/services/gi-val/	2018
	Green Book	HM Treasury	2018
	Green Infrastructure Toolkit	Georgetown Climate Centre http://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/introduction.html	
	SUSTAIN	US EPA https://www.epa.gov/water-research/system-urban-stormwater-treatment-and-analysis-integration-sustain	2014
Groundwater recharge	Groundwater Appraisal Guidance	Environment Agency	2018
	Estimating Monetized Benefits of Groundwater Recharge from Stormwater Retention Practices	United States Environmental Protection Agency https://www.epa.gov/sites/production/files/2016-08/documents/gw_recharge_benefits_final_april_2016-508.pdf	2016
Health	Natural Capital Accounts for Public Green Space in London	Vivid Economics http://www.vivideconomics.com/publications/natural-capital-accounts-for-public-green-space-in-london	2017

Primary B£ST benefit category	Title/Author/Date		
	Investing in natural capital	Natural Capital Committee https://www.gov.uk/government/publications/natural-capital-committee-research-investing-in-natural-capital	2015
	Physical Health Benefit Valuation for Natural Flood Management and Greenspace Creation	Environment Agency	2017
	Manchester Green Infrastructure Strategy	eftec http://www.manchester.gov.uk/info/200024/consultations_and_surveys/6905/green_and_blue_infrastructure_consultation/8	2014
	Manchester Green Infrastructure Strategy	eftec http://www.manchester.gov.uk/info/200024/consultations_and_surveys/6905/green_and_blue_infrastructure_consultation/9	2014
	Urban Green Space Interventions and Health: A review of Evidence and Effectiveness	World Health Organisation http://www.euro.who.int/__data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf?ua=1	2016
	Green Space and Health	Parliamentary Office of Science and Technology http://researchbriefings.files.parliament.uk/documents/POST-PN-0538/POST-PN-0538.pdf	2016
	Healthy High Streets: Good place-making in an urban setting	Public Health England & Institute of Health Equity http://www.instituteofhealthequity.org/resources-reports/healthy-high-streets-good-place-making-in-an-urban-setting/healthy-high-streets-phe.pdf	2018
	Local action on health inequalities: Improving access to green spaces	Public Health England & Institute of Health Equity https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/357411/Review8_Green_spaces_health_inequalities.pdf	2014
	Doses of Neighborhood Nature: The Benefits for Mental Health of Living with Nature	DANIEL T. C. COX, DANIELLE F. SHANAHAN, HANNAH L. HUDSON, KATE E. PLUMMER, GAVIN M. SIRIWARDENA, RICHARD A. FULLER, KAREN ANDERSON, STEVEN HANCOCK, AND KEVIN J. GASTON. BioScience 67: 147–155.	2017
	The evidence base for linkages between green infrastructure, public health and economic benefit	Bowen, K. J. and Parry, M. (2015). Paper prepared for the project Assessing the Economic Value of Green Infrastructure.	2015
	The Health and Social Benefits of Nature and Biodiversity Protection	ten Brink P., Mutafoglu K., Schweitzer J-P., Kettunen M., Twigger-Ross C., Baker J., Kuipers Y., Emonts M., Tyrväinen L., Hujala T., and Ojala A. (2016) A report for the European Commission (ENV.B.3/ETU/2014/0039), Institute for European	2016

Primary B£ST benefit category	Title/Author/Date		
		Environmental Policy, London/Brussels.Regions Institute for European Environmental Policy, London / Brussels	
	Green exercise: linking nature, health and well-being / edited by Jo Barton, Rachel Bragg, Carly Wood and Jules Pretty.	London ; New York : Routledge is an imprint of the Taylor & Francis Group, ISBN: 978-1-138-80764-8 (hbk)	2016
	National Planning Policy Framework: Draft text for consultation	Ministry of Housing, Communities and Local Government, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685289/Draft_revised_National_Planning_Policy_Framework.pdf	2018
	Nature 4 Health: Year 1 Impact Report	Mersey Forest	2016
	Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study	http://ec.europa.eu/environment/integration/research/newsalert/pdf/urban_design_can_promote_walking_activity_friendly_neighbourhoods_462na1_en.pdf	2016
	IWUN (Improving wellbeing through urban nature)	University of Sheffield http://iwun.uk/	2018
	Blue Health	https://bluehealth2020.eu/	
	Longitudinal effects on mental health of moving to greener and less green urban areas	Alcock, I., White, M. P., Wheeler, B. W., et al. Environmental Science and Technology, 48, 1247–1255	2014
	Green Exercise: Linking Nature, Health and Well-Being	Barton, J., Bragg, R., Wood, C., et al (eds) (2016) Routledge.	2016
	The health benefits of urban nature: how much do we need?	Shanahan, D. F., Fuller, R. A., Bush, R., et al, Bioscience, 65, 476–485	2015
	MENTAL HEALTH BENEFITS OF WATERWAYS	THE CENTRE FOR SUSTAINABLE HEALTHCARE FOR THE CANAL & RIVER TRUST	2016
	The contribution made by Sheffield's parks to the wellbeing of the city's citizens	Vivid Economics http://www.vivideconomics.com/wp-content/uploads/2016/11/Briefing-The-value-of-Sheffields-parks.pdf	2016
	Evidence Statement on the links between natural environments and human health	Defra	2017
	Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data	Mathew P. White, Ian Alcock, Benedict W. Wheeler and Michael H. Depledge, Psychological Science 2013 24: 920	2013
	Taking the bite out of wetlands: managing mosquitos and the socio-ecological value of wetlands for wellbeing		Ongoing
	Urban green spaces: a brief for action	WHO	2017

Primary B£ST benefit category	Title/Author/Date		
	Different types of exposure to natural environments are associated with different aspects of wellbeing	White, M. P., Pahl, S., Wheeler, B. W., Depledge, M. H., & Fleming, L. E. (2017). Natural environments and subjective wellbeing: Different types of exposure are associated with different aspects of wellbeing. Health & Place, 45, 77-84.	2017
Noise	Environmental Noise: valuing impacts on sleep, disturbance, annoyance, hypertension, productivity and quiet	Defra www.gov.uk/noise-pollution-economic-analysis	2014
	TBC		2018
Recreation	ORVal (Outdoor Recreation Valuation Tool)	University of Exeter http://leep.exeter.ac.uk/orval/	2018
	The Economic, Health and Social Value of Outdoor Recreation	Manchester Metropolitan University http://sramedia.s3.amazonaws.com/media/documents/ReconomicsPlusReport.pdf	2017
	Economic assessment of the recreational value of ecosystems: Methodological development and national and local application	Sen, A., Harwood, A. R., Bateman, I. J., Munday, P., Crowe, A., Brander, L., Raychaudhuri, J., Lovett, A.A., Foden, J. & Provins, A.	2014
	Reviewing Cultural Services Valuation Methodology for Inclusion in Aggregate UK Natural Capital Estimates	Ricardo for ONS	2016
Tourism	Manchester Green Infrastructure Strategy	eftec http://www.manchester.gov.uk/info/200024/consultations_and_surveys/6905/green_and_blue_infrastructure_consultation/7	2014
Urban cooling	A STUDY TO SCOPE AND DEVELOP URBAN NATURAL CAPITAL ACCOUNTS FOR THE UK	Defra http://randd.defra.gov.uk/Document.aspx?Document=14143_UrbanNC_Account_FinalReportAugust2017.pdf	2017
	How effective is 'greening' of urban areas in reducing human exposure to ground level ozone concentrations, UV exposure and the 'urban heat island effect'?	Bowler, D., Buyung-Ali, L., Knight, T. & Pullin, A.S. http://www.environmentalevidence.org/wp-content/uploads/2014/07/SR41.pdf	2010
	The impacts of WSUD solutions on human thermal comfort	CRCWSC: Green Cities and Micro-climate - B3.1 -2-2014	2014
	TBC		2018
Water quality	Benefits assessment framework for high spilling CSOs		2017
	The value of restoring urban drains to living streams	Polyakov M., et al., Water Resources and Economics. January. DOI: 10.1016/j.wre.2016.03.002	2017
	TESSA: A toolkit for rapid assessment of ecosystem services at sitesof biodiversity conservation importance	Peh et al http://www.academia.edu/15545165/TESSA_A_toolkit_for_rapid_assessment_of_ecosystem_services_at_sites_of_biodiversity_conservation_importance	2013

Appendix 2: References from NFM guidance of potential relevance to B£ST (based on NFM literature review, unless missing, in which case NFM evidence directory sourced)

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
ÅBERG, E.U. AND TAPSELL, S., 2013. Revisiting the River Skerne: the long-term social benefits of river rehabilitation. Landscape and Urban Planning, 113, 94-103.	**River restoration** Health benefits through added visits and angling. Aesthetic benefits - visitor surveys showing satisfaction rates of around 90%.	None	Only expresses generalities, but satisfaction rates may be of interest	Health Recreation Amenity	Health Aesthetic
ADDY, S. AND WILKINSON, M.E., 2016. An assessment of engineered log jam structures in response to a flood event in an upland gravel-bed river. Earth Surface Processes and Landforms, 41 (12), 1658-1670. (Also IUCN/CREW report: "River Restoration and Biodiversity" - ISBN: 978-0-902701-16-8)	**River Restoration** As above Health: River restoration creates opportunities for recreation and relaxation, particularly in urban areas. **Leaky barriers** During one flood event, 16 structures induced geomorphic responses, although only 4 of the 33 structures induced significant deposition (> +0.3m). Some measures being washed out by extreme events and thus shortening the life span of natural and engineered structures. E.g. Following restoration of the River Ravensbourne, south London, visitors to Ladywell Fields urban park increased by over 250%, and 78% of visitors felt 'safe' or 'very safe' in the park after restoration compared with 44% before."	None	Satisfaction rates and feelings of being safer after restoration may be useful especially for crime. Kentchurch Weir, River Monnow, removal case study may be helpful. Also includes Mayes Brook. The IUCN/CREW report could be the prime guidance to point to in revised B£ST technical support.	As above, plus crime	As above
ACREMAN, M. AND HOLDEN, J., 2013. How wetlands affect floods. Wetlands, 33 (5), 773-786.	**Floodplains and floods** Floodplain wetlands are better at attenuating flood flows compared with upland wetlands. However, fundamentally, landscape location and configuration, soil characteristics, topography, soil moisture status and management all influence whether these wetlands provide flood reduction services. When saturated, floodplains can become flood generating or 'contributing' areas in some cases.	None	Any quantitative information about flood risk changes should come from offline modelling.	Flooding	Flooding (fluvial)
ACREMAN, M.C., et al., 2011. Trade-off in ecosystem services of the Somerset Levels and	**Floodplain restoration** that achieves flood attenuation and promotes water quality improvements and increased biodiversity does not need to result in the loss of another ecosystem services. Inevitable that there will be some	None	There may be negative aspects of restoring floodplains in regard to ecosystem services.	Flooding Biodiversity & ecology	Flooding (fluvial) Habitats

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
Moors wetlands. Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, 56 (8), 1543- 1565.	trade-offs in restoration. Storage in floodplain ditches may have a small influence in comparison with surface storage. increasing the water levels in ditches in one case study catchment to meet ecological targets over winter would result in a loss of overall flood storage capacity (which equates to 2% of the medium annual flood volume).		Stress that there may be negative impacts as well as positive.		
ACUÑA, V., et al. 2013. Does it make economic sense to restore rivers for their ecosystem services? Journal of Applied Ecology, 50 (4), 988-997. (This reference is not in the NFM lit. review)	**River Restoration/Wood dams** increase the amount of organic matter in the river, they are also successful at retaining and breaking it down. The Blackbrook case study found that wood dams improved water quality by reducing phosphate and nitrate levels. 4 engineered log dams have reduced average P concentration by 3.6mg per litre as flows are filtered through the natural dams. Nitrate is also reduced. By 2035, it is predicted that 792m^3 of sediment will be stored in 3 ponds retained by the jams.	Ecosystem services provided by wood placement projects valued at €1·08 to €1·81 per meter (of restored river reach) per year, with the largest economic value for recreational opportunities based on a large increase in the number of fish available for angling. NB These figures are for Spanish Mediterranean.	Wood dams need to be valued in B£ST as may be used in urban watercourses to arrest flows and protect downstream areas and also provide other benefits to WQ and recreational users. However, generalizing /quantifying the pollutants trapped or increase in fish numbers is impossible. However, B£ST should promote the use of such dams as multifunctional measures.	Flood risk reduction Water quality Biodiversity and ecology Recreation	Flooding (SW) Water quality Cultural activities
BADIOU, P., et al., 2011. Greenhouse gas emissions and carbon sequestration potential in restored wetlands of the Canadian prairie pothole region. Wetlands Ecology and Management, 19 (3), 237-256. (This reference is not in the NFM lit. review)	**Wetland Restoration**: A restored wetland can sequester 2,700kg carbon per hectare per year. However, wetlands can also emit methane, a more potent greenhouse gas.	None	Need to verify that SuDS wetlands data cover this. Both the positive and potentially negative impacts.	Carbon	Climate regulation
BARBER, N., et al. 2016. The Treatment Train approach to reducing non-point source	**Sediment trapping** using traps in series captured 42% SS; 26% TP; 15% SRP; 5% NO_3 over 9 monitored storm events in Northumberland. 0.8km^2 upstream arable catchment. Eden DTC has sediment traps that in 2014 to 2015 had annual	Uneconomic to try to trap all runoff from an upstream catchment. But no general figures.	B£ST needs to include the features of traps/fences to manage diffuse pollution and	Water quality	Water quality

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
pollution from agriculture. Poster presented at the American Geophysical Union Fall General Assembly, abstract #H13D-1396.	accumulations of 263kg of sediment per hectare, 1.2kg of total phosphorus per hectare and 2.9kg of total nitrogen per hectare with a storage volume of 100m^3 (total of 2 sediment traps) from a contributing area of 1.9ha. Small traps are effective in trapping the larger fraction of suspended sediments in surface water run-off from between 63µm and 500µm in diameter. By disrupting and attenuating overland flow using traps, the time taken for the water to reach the channel can be increased, potentially reducing the flood peak. Sediment fences can do a similar job for diffuse pollution, intercepting field run-off, trapping soil and allowing water to percolate through the geotextile. CREW RSUDS guide: they are typically used on moderate slopes for high risk crops and where there is a flow with a high sediment content.		soil erosion. Consider using the figures for Eden DTC. For diffuse pollution: i.e. 263kg sediment/ha 1.2kg TP 2.9 TN all per 100 m^3 of trap. Unclear how to monetize the pollutant removals? Soil erosion reduction may be valuable, but how to quantify? Unclear where soil erosion needs to go in B£ST? Productive land category?		
BATEMAN, I.J. AND DAY, B.H., 2014. UK National Ecosystem Assessment Follow-on. Work Package Report 3: Economic value of ecosystem services. UN Environment Programme World Conservation Monitoring Centre, Living with Environmental Change, UK. (This reference is not in the NFM lit. review)	**Catchment Woodland:** only 55% of the population has access to woods larger than 20ha within 4km of their home (Quine 2011).	Planting of a substantial 100ha forest at 10 minutes' driving distance results in an average individual welfare gain of £3.02 per year, although this reduces to £0.32 when the woodland is a 20 minute drive away.	When is a woodland/forest 'substantial'? when it is >20ha?	Health	Health Access
BELL, M.J., et al., 2011 .UK land-use change and its impact on SOC: 1925–2007. Global Biogeochemical Cycles, 25 (4), GB4015; DOI: 10.1029/2010GB003881. (This reference is not in	**Soil and land management**: Land management practices including set-aside and the conversion of arable land to grassland have had a significant impact on increasing UK soil carbon storage. Green cover can provide up to 300kg of carbon per hour take up to the soil (Justes et al. 2012), while Culm grasslands store 1.8g per cm2 of carbon in soils with a given surface area, 20% more than agriculturally improved fields		Soil and land management as a category in B£ST? Could fit with soil sealing (urbanization) and erosion management, productive landscapes?	Carbon	Climate regulation

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
the NFM lit. review)					
BIRKINSHAW, et al., 2014. 45 years of non-stationary hydrology over a forest plantation growth cycle, Coalburn catchment, Northern England. Journal of Hydrology, 519, 559-573.	**Catchment Woodland**: Absolute differences in discharge between forested and logged states remained approximately constant with increasing discharge but decreased as a percentage of discharge. Relative convergence as flood frequency fell below 10% AEP for shallow soil conditions, but did not converge for deep soils. Forest cover predicted to still reduce extreme flood peaks (e.g. 1% AEP) by (30–40%). Coalburn, UK: 90% afforestation by Sitka spruce of the 150ha catchment in 1972 produced a 5–20% reduction in peak flows, declining with increasing peak size. A shift in flood frequency occurred, with an event of a return period of 13 years reducing in frequency to a return period of 20 years. Overall, flood frequency reduced by ~50% across all events. Clearfelling has potentially the biggest impact of all forestry practices by removing the tree cover, reducing water use and rewetting soils, while the soil compaction and rutting associated with poorly managed timber harvesting can greatly reduce soil infiltration and increase overland flow and sediment delivery to watercourses.	Benefit values will relate to properties protected, hence data in B£ST should be sufficient.	What magnitude of forest is required to attain this? Does the 20 ha size represent the threshold? Need to determine size of forest and nature to make a significant difference. Consider adding negative consequences of site clearance of woods, copses etc. into B£ST. Maybe more evidence we need a soil and land management category?	Flood risk reduction	Flood fluvial
BROWN, A., et al. 2012. Fishing for Answers: the final report of the Social and Community Benefits of Angling Project. Manchester: Substance. (This reference is not in the NFM lit. review)	**River Restoration** creates further opportunities for activities such as angling, which have proven physical and mental health benefits	None	Nothing new	Amenity Health Recreation	Health
DAVIES, S.R., et al., 2016. A new role for pond management in farmland bird conservation. Biological Conservation, 233, 179-191.	**Runoff pathway management**: Ponds provide habitats for a range of aquatic mammals, amphibians and invertebrates, as well as farmland birds. In England, ponds support more of NERC Act priority species than lakes, and a similar number to streams, rivers and floodplains combined (UK National Ecosystem Services Assessment 2014)	None	Should be already included in B£ST	Biodiversity and ecology	Habitats
DE JONG, K. et al., 2012. Perceived green qualities were associated with neighborhood satisfaction, physical	**Catchment Woodland**: presence of trees reduces health inequalities and mortality, and increase physical activity and general health.	None	See woodland references above	Health	Health

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
activity, and general health: results from a cross-sectional study in suburban and rural Scania, southern Sweden. Health and Place, 18 (6), 1374-1380.					
DIXON, S.J., et al., 2016. The effects of river restoration on catchment scale flood risk and flood hydrology. Earth Surface Processes and Landforms, 41 (7), 997-1008.	**Riparian woodland**: Roughening the floodplain through riparian tree planting has a greater attenuation effect than the installation of in-stream leaky barriers. Lymington River in southern England, restoration of riparian woodland along 20–40% of the total catchment area was the most effective WWNP measure tested, reducing peak flows by up to 19% for 3% annual probability of exceedance. Naturally occurring log jams account for 65% of flow resistance in forested river channels; this rose to 75–98% where the log jam was inducing a distinct step in the water profile.	None	Extent of woodland/forest in regard to catchment? Are there general rules? Would this be already modelled by flood simulations? See below.	Flood reduction	Flood fluvial
DIXON, G. AND SCOTT, M., 2017. Flood management and forestry at Southwell. Final JBA contract report to Forestry Commission. Saltaire, Shipley: JBA Consulting	**Woodland Management**: Sets out the use of the TUFLOW model to represent water use, infiltration and surface roughness processes, including an evaluation of the potential contribution of woodland planting to the economics of flood risk management. For lower events <25 yr RP surface runoff causes flooding and woodland has little effect. For the medium and larger flood events (25 to 75-year return period) the impact of woodland creation is clearer as this corresponds to the activation of several fluvial flooding mechanisms. Concludes that woodland can provide small but cost effective reductions in damages from flooding and could play a role as part of a wider NFM or traditional scheme for appropriate catchments. The wider benefits of woodland creation can add further value to any scheme.	Assuming 150ha of additional planting being distributed across the catchments: flood benefits outweigh the planting costs with a benefit-costs range between 1.0 to 8.3. This is the same for the environmental benefits (excluding flooding) with a benefit-cost range between 4.8 and 40.3 based on FCERM. No land purchase costs nor optimism bias are included in these costs.	Evidence for this catchment (at least) suggests woodlands effective only for larger events >25 yr RP.	Flood risk reduction plus 'environment al benefits'	Flood fluvial
DOICK, K. AND HUTCHINGS, T., 2013. Air temperature regulation by urban trees and green infrastructure. Edinburgh: Forestry Commission.	**Catchment Woodland**: Trees can cool cities by between 2 and 8^{o}C. Greenspaces and wider green infrastructure should be a minimum of 0.5 ha in order to achieve cooling at significant distances beyond the site boundaries.	None	Should already be in B£ST, but need to consider the urban sheltering effects of trees as well, plus shading.	Urban cooling	Climate regulation

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
(This reference is not in the NFM lit. review)					
DONOVAN, G.H., et al., 2013. The relationship between trees and human health: evidence from the spread of the emerald ash borer. American Journal of Preventative Medicine, 44 (2), 139-145.	**Catchment Woodland**: the presence of trees reduces health inequalities and mortality, and increase physical activity and general health.	none	Should already be in B£ST	Health Recreation	Health
EDMONDSON, J.L., et al., 2011. Are soils in urban ecosystems compacted? A citywide analysis. Biology Letters, 7 (5), 771-774.	**Catchment Woodland**: flow regulation, increasing soil infiltration and slowing down water movement to watercourses. Evapotranspiration and low soil compaction levels reduce direct run-off and soil erosion. Potential greater use of water with short vegetation can generate greater soil moisture deficits in summer and reduce groundwater recharge. One large tree can intercept/evaporate 1,432 gallons (5.42m^3) of water annually (Peper et al. 2007). Large-scale planting of conifer woodland poses the greatest risk, especially within dry lowland areas	None	Low flows preservation needs to be considered in B£ST. This is not only water supply it is also environmental flows.	Groundwater recharge	Low flows
ENVIRONMENT AGENCY, 2015b. The effect of peatland restoration on baseflows: Exmoor and Dartmoor Mires Project. Environment Agency hydrology report. Bristol: Environment Agency. [Not referenced in the NFM literature review]	**Headwater drainage management** Blocking drainage ditches led in one case to an average increase in the volume of water stored in peat of up to 0.004m^3 per square metre. Sphagnum species commonly found on peatland have the ability to retain up to 40 times their dry weight in water. Sphagnum provides a significantly greater resistance to overland flow than peatland grasses, suggesting that it is better at attenuating flow velocities.	None	Consider peatlands as part of source control?	Flooding	Surface water or groundwater flood
ENVIRONMENT AGENCY, 2016. Restoration measures to improve river habitats during low flows. Report SC120050/R. Bristol: Environment Agency. [Not referenced in the NFM literature	**River Restoration** Assisted natural recovery aids ecological resilience via refugia, also shade and connectivity, particularly if the restoration extends to riparian areas. Sustains low flows, particularly subsurface hydrological connectivity with floodplain. Water in channel even in droughts.	None	Inclusion of habitat provision explicitly as part of measures may need to be given more emphasis at least in guidance.	B£ST applicability appears to be linked more to biodiversity and ecology	Climate regulation

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
review]					
FLEMING, A., 2016. The importance of urban forests: why money really does grow on trees [online]. The Guardian, 12 October. Available from: https://www.theguardian.com/cities/2016/oct/12/importance-urban-forests-money-grow- trees [Accessed 18 August 2017]. [url does not work] [Not referenced in the NFM literature review]	**Catchment woodland** One large tree can absorb 150kg of carbon dioxide a year.	The presence of trees increases the value of property by an average of 20%.	Provenance impossible to establish: IGNORE	Air quality Amenity	Air quality Aesthetics
FORESTRY COMMISSION, 2014. UK Woodland Carbon Code: requirements for voluntary carbon sequestration projects; Version 1.3. Edinburgh: Forestry Commission.	**Catchment Woodland** UK Woodland Carbon Code promotes carbon trading. Trees planted under the RDP may be eligible as a woodland carbon project, providing the carbon funding sought is necessary additional funding for woodland creation. Woodlands can reduce *(sic!)* water quality by enhancing the capture of pollutants such as acid deposition and ammonia from the air, exceeding the capacity of the soil and bedrock to cope with these. These and related issues are addressed by good forest design and management practices.	None	Should already be covered	Water quality Carbon	Water quality
GIBBONS, S., MOURATO, S. AND RESENDE, G.M., 2014. The amenity value of English nature: a hedonic price approach. Environmental and Resource Economics, 57 (2), 175-196. [Not referenced in the NFM literature review]	**River floodplain restoration** Reconnecting rivers with floodplains by removing man-made embankments, restores the landscape to a more natural form. It is seen as an improvement in habitat, supporting iconic species that people can connect with. **Wetland restoration** Wetlands are generally considered desirable landscapes by the public.	House prices in UK demonstrate *(that from?)* a 1% increase in the proportion of freshwater environment including floodplains within 1km, attracting a premium of 0.36% or an average of £694. The estimated per person per trip value is £6.88 for wetlands (Sen et al. 2012), while the marginal value of extra provision on aesthetics	Consider updating the data for property value. Could be a significant paper.	Amenity	Aesthetics

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
		and amenity is £227 per hectare per year (Morris and Camino 2011).			
GILBERT, P., et al., 2014. Variations in sediment organic carbon among different types of small natural ponds along Druridge Bay, Northumberland, UK. Journal of the International Society of Limnology, 4 (1), 57-64. [Not referenced in the NFM literature review]	**Run-off pathway management** Organic carbon stored in pond sediments is highest in uncompacted sediments in permanent ponds with extensive natural vegetation (approximately 10% organic carbon), and lowest in sediments in ponds in arable or pasture fields (approximately 3% organic carbon) and in adjacent soil controls (approximately 3% organic carbon).	None	SuDS manual should have more up to date data on carbon removal using ponds	Carbon	Climate regulation
GRABOWSKI, R.C. AND GURNELL, A.M., 2016. Hydrogeomorphology–ecology interactions in river systems. River Research and Applications, 32 (2), 139-141. [NFM lit. review cites: GURNELL, A.M. AND GRABOWSKI, R.C., 2016. Vegetation-hydrogeomorphology interactions in a low-energy, human-impacted river. River Research and Applications, 32 (2), 202-215. and does not refer to Grabowski et al, 2016]	**River Restoration** Trap and stabilise fine sediment by encouraging the development of in-channel and riparian vegetation communities. Interactions between river processes, plants and large wood are an important component of river self-restoration, particularly in low energy rivers. Reinstatement of river processes, erodible channel boundaries and a cessation or reduction in sediment and vegetation management allow physical processes and vegetation to interact and rapidly achieve adjustments in channel morphology. It is important to recognise that such interactions and adjustments can occur quite quickly, even in very low energy rivers.	none	Interactive processes are important and SuDS design may need to consider this more than traditionally at least in the guidance.	Flooding Biodiversity and ecology.	Flooding (both)
JUSTES, E., et al, 2012. Réduire les fuites de nitrate au moyen de cultures intermédiaires: conséquences sur les bilans d'eau et d'azote,	**Soil and land management** Land management practices including set-aside and the conversion of arable land to grassland have had a significant impact on increasing UK soil carbon storage (Bell et al. 2011). Green cover can provide up to 300kg of carbon per hour take up to the soil. Culm grasslands store 1.8g per cm2	None	Ensure database includes this type of land cover	Carbon	Climate regulation

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
autres services écosystémiques. Paris: INRA. [Not referenced in the NFM literature review]	of carbon in soils with a given surface area, 20% more than agriculturally improved fields (Puttock and Brazier 2014, see below). Vegetated buffer strips have a cooling effect on local river temperatures.				
KADYKALO, A.N. AND FINDLAY, S.C., 2016. The flow regulation services of wetlands. Ecosystems Services, 20, 91-103.	**Wetland restoration** Floodplain wetlands serve as nature's method of flood control owing to their short- and long-term water storage capacity. Review of 28 studies found that, on average, wetlands reduce the frequency and magnitude of floods and increase flood return intervals (while maintaining higher low flows). But local observations are needed to keep uncertainties to acceptable levels.	none	The interactions between wetlands and watercourses via floodplains should be included in simulation models, at least for water quantity.	Flooding	Flooding (fluvial)
MARSHALL, M.R., et al., 2014. The impact of rural land management changes on soil hydraulic properties and runoff processes: results from experimental plots in upland UK. Hydrological Processes, 28 (4), 2617-2629.	**Cross-slope woodland** Soil infiltration rates were found to be 67 times higher within young native woodland shelterbelts compared with adjacent grazed pasture soils in Pontbren, reducing run-off volumes by an average of 78%. Of this, 48% was due to the removal of grazing pressure on the soil, with the remaining 30% attributed to the action of tree rooting and growth (becoming apparent within one year of sheep exclusion). These figures are relative to the scale of cross-slope woodland planted and so may not be directly transferable to all sites. **Soil and land management** The grazed plot had the shortest time to peak and the largest surface run-off volume, and the ungrazed plot had a shallower rising limb, smaller peak and smaller run-off volume. However, others suggest these differences could be attributed to the natural variability of run- off and infiltration rates.	none	These effects should be included in any water quantity simulation models used.		Flooding – pluvial and groundwater
MORRIS, J. AND CAMINO, M., 2011. UK National Ecosystem Assessment working paper: economic assessment of freshwater, wetland and floodplain (FWF) ecosystem services. Bedford: Cranfield University.	**Wetland restoration** Wetlands are effective at removing nutrients from water, including nitrogen, phosphorus and ammonia. Can accumulate harmful bacteria and heavy metals, creating a detoxifying effect.	Marginal value of extra wetland provision for flood control and storm buffering is £407 per hectare per year. £292 per hectare per year is derived from water quality improvements. Freshwater wetlands	This data should already be included in B£ST. However, warnings about negative impacts may be needed in guidance.	Flooding Water quality Biodiversity and ecology Amenity	Water quality Fluvial flood Habitat provision Aesthetics Cultural activities

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
[Not referenced in the NFM literature review]		have been valued at £1,300 per hectare per year (2008 prices) for their provision of water quality improvement, recreation, biodiversity and aesthetic amenity (eftec 2010). The marginal value of increased biodiversity is £304 per hectare per year. The marginal value of extra provision on aesthetics and amenity is £227 per hectare per year. Non-consumptive recreation valued at £82 per hectare per year.			
MOXEY, A. AND MORAN, D., 2014. UK peatland restoration: some economic arithmetic. Science of the Total Environment, 484, 114-120	**Headwater drainage management** Peatland restoration could bring differential benefits of between 1 tonne and 20 tonnes of carbon dioxide per hectare per year, and depending on the value of carbon based only on the value of carbon savings. But rewetted peat can increase the emissions of methane, which can partly offset the lower carbon emissions.	Paper deals mainly with costs not benefits.	Should already be included	Carbon	Climate regulation
NATURAL ENGLAND, 2015. Monitor of engagement with the natural environment: Headline report from the 2014-2015 survey. York: Natural England.	**Catchment woodland** Provide opportunities for activities including walking, biking, camping, outdoor play and exploring cultural heritage. There were approximately 417 million visits to woodlands and forests in the UK in 2014 to 2015.	none	Should already be included	Amenity recreation	Cultural
NEWMAN, J.R., et al., 2015. Do on-farm natural, restored, managed and constructed wetlands mitigate agricultural pollution in Great Britain	**Wetland restoration** Effective at removing nutrients from water, including nitrogen, phosphorus and ammonia.	None	Nothing useful	Water quality	Water quality

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
and Ireland? A systematic review. Final report WT0989. London: Department for Environment, Food and Rural Affairs. [Not referenced in the NFM literature review]					
NICHOLSON, A.R., 2014. Quantifying and simulating the impact of flood mitigation features in a small rural catchment, PhD thesis, Newcastle University. Available from: https://theses.ncl.ac.uk/dspace/bitstream/10443/2382/1/Nicholson,%20A.%2014.pdf [Accessed 11 August 2017].	**Run-off pathway management** Run-off attenuation features can be designed to intercept and store overland flow during intense rainfall. An overland flow interception bund at Belford reduced peak run-off flow from an 11ha catchment by over 50% in an extreme run-off event, with 91kg per hectare of sediment deposited.	None	Water quantity model used should include this.	Flooding	Flood – surface or groundwater
NISBET, T.R., et al., 2011b. Woodland for water: woodland measures for meeting Water Framework Directive objectives. Summary of final report from Forest Research to the Environment Agency and Forestry Commission (England). Bristol: Environment Agency. Available from: https://www.gov.uk/government/publications/woodland-for- water [Accessed 17 August 2017].	**General:** Wood (in whatever form) in rivers can provide large benefits especially to habitats and fauna. **Leaky barriers** Provide habitat diversity by creating pools and varied channel morphology. They support fish and macroinvertebrate life cycles, and provide nutrients for aquatic organisms. But, can restrict fish passage during low flows if they become blocked or are placed too close together. Large wood barriers can have a greater effect on flood flow than planting woodland vegetation alone. **Offline storage** 120,000m3 storage pond created in the Pickering catchment aims to reduce to risk of flooding from 4% to 25% in any one year. **Catchment woodland** Woodland cover is widely recognised as very effective for protecting water quality if well managed. Tree cover can also offer protection from soil erosion and slope failure. **Low flows**	Eftec (2017) Leaky barriers: Pickering: Benefits of £28 per m3 for 120,000m3. Blackbrook: ~£1.50 – £1.80 per m3 if full; 300,000m3 can be installed. Offline storage benefits: Beam washlands: £140–£175 per m3 for entire storage Guisborough: £373 per m3 based on benefit estimate from SOC; £227 based on benefit–cost ratio in CS; Holnicote: £105–£385	Consider how to include leaky barriers in B£ST Offline storage covered by SuDS ponds. Check data from Eftec (2017) and the PV estimates in the table below. Woodlands – consider relative scale compared with SuDS benefits from trees – albeit water quantity (flood and low flows) should be estimated from modelling, and possibly water quality enhancements as well. SuDS Buffer strips need	Biodiversity & ecology Flooding	Habitat provision Flood – surface or groundwater Water quality Low flows

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
	Large-scale planting of conifer woodland poses the greatest risk to low flows, especially within dry lowland areas. **Cross-slope woodland** Beneficial for water quality as it reduces sediment and nutrient loading from upslope land. For example, a study in Poland found that concentrations of nitrate in groundwater within shelterbelts adjacent to cultivated fields were reduced by 76–98%. **Riparian woodland** intercepts diffuse pollutants and removes nutrients; Riparian buffers also reduce phosphorous levels and trap sediment, with a site in the USA intercepting an average of 4.8 tonnes of sediment per hectare per year (Tomer et al. 2007). Refers to 1990s work on urban buffer strips. Riparian shade helps fish such as trout and salmon survive hot temperatures. High tree density that prevents light penetration may affect productivity and river bank vegetation. can slow flood flows, increasing surface water retention and soil infiltration, which could help to maintain low flows.	per m3; Lustrum Beck: £5.50–£20 (depending on breakdown between conventional and NFM) See ES PV for Pickering below	to include these NFM measures. Reductions in soil erosion are potential benefits not in B£ST. Also maintenance of low flows related to tree species.		

Table 2: Indicative ecosystem service present values (£k at 2011 prices) for the woodland creation (85 ha) and LWD dam (150 dams) measures

	Low (£k)	**Central (£k)**	**High (£k)**
Habitat creation	£1,630	£2,773	£4,459
Flood regulation	£88	£175	£292
Climate regulation	£923	£2,800	£5,464
Erosion Regulation	£0	£5	£10
Education and knowledge	£0	£1	£6
Community development	£0	£16	£62
Agricultural production	-£1,113	-£911	-£306
Forestry Costs	-£710	-£539	-£369
Net Present Value	**£819**	**£4,321**	**£9,618**

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
NISBET, T.R., et al., 2015. Slowing the Flow at Pickering. Final report for Phase2 for Defra FCERM Multi-objective Flood	**Leaky barriers** Wood barriers create additional water storage capacity, which can capture overland flow. Upstream of Pickering, 104 barriers provide a total of ~1,020m3 of potential flood storage.	benefit–cost ratios for the set of woodland only measures were estimated to range from 1.5 to 3.0 for flood regulation (for reducing the chance of flooding	Woody barriers – see above. Unlikely to have	Flooding Building temperature	Flood – surface or groundwater Climate regulation

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
Management Demonstration project RMP5455. London: Department for Environment, Food and Rural Affairs.	**Riparian woodland** Woodland measures at Pickering, including riparian woodland planting and installing LWD, had a benefit–cost ratio of 5.6:1. Climate regulation contributed the greatest value, followed by flood regulation and habitat creation. Riparian woodland shade can help to counteract the predicted rise in water temperatures and heightened risk of thermal stress to freshwater life. Shade provided by trees in the New Forest reduced water temperature by up to 5.5°C on hot summer days compared with open grassland sections, preventing it from rising above the lethal limit for brown trout.	from 25% to <4% in any given year).	significant tree coverage that building temperatures can be protected.		
PUTTOCK, A. AND BRAZIER, R., 2014. Culm grasslands proof of concept phase 1: developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands. Exeter: Devon Wildlife Trust.	**Floodplain woodland** Devon: the water retention capacity of Culm grassland stores more water than intensively managed grasslands (~241 litres per m2 compared with 62 litres per m2 surface area), scrub and woodland. **Soil and land management** Culm grasslands store 1.8g per cm2 of carbon in soils with a given surface area, 20% more than agriculturally improved fields. (study site was within a unique ecological area known as the Culm National Character Area and the findings may not be applicable to other landscapes)	None	Data may not be transportable. Quantification should be dealt with using natural catchment simulation models.	Flooding carbon	Flooding Climate regulation
QUICK, T., etv al., 2013. Developing place-based approaches for payments for ecosystem services. London: URS. [Not referenced in the NFM literature review]	**Headwater drainage management** Stopping peatlands from emitting greenhouse gases, in addition to utilising their storage capacity, is particularly valuable.	At a carbon price of £20 per tonne CO2e, restoring severely degraded peatland to a moderately degraded state could provide a carbon revenue of around £600 per hectare per year.	Need to ensure that B£ST includes value from maintaining wetted soil.	Carbon	Climate regulation
QUINE, C., 2011. Woodlands. In UK National Ecosystem Assessment: Technical Report, Chapter 8, pp. 241-294. Cambridge: UN Environment Programme – World Conservation Monitoring Centre. [Not	**Catchment woodland** A quarter of all NERC Act priority species are associated with trees and woods. Diversity of woodland structure and species is especially beneficial for biodiversity. Total carbon stock in UK forests (including soils) is around 800 million tonnes (Mt) of carbon (2,900Mt of carbon dioxide equivalent, CO2e) and is estimated to be a further 80Mt of carbon in timber and wood products. At peak growth, coniferous forest can sequester around 24 tonnes	the marginal benefits of woodland estimated @ 35p per housed per year for enhanced biodiversity in 12,000ha (1%) of commercial Sitka spruce forest, 84p per household per year for a 12,000ha increase in Lowland New Broadleaved Native forest, and £1.13 per		Biodiversity and ecology Carbon Amenity	Habitat provision Climate regulation Health Access Aesthetics Cultural activities

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
referenced in the NFM literature review]	of CO_2 per hectare per year, with a net long-term average of around 14 tonnes of CO_2 per hectare per year. Rates of around 15 tonnes of CO_2 per hectare per year have been measured in oak forest at peak growth, with a net long-term average likely to be around 7 tonnes of CO_2 per hectare per year. Trees can cool cities by between 2 C and 8 C. Only 55% of the population has access to woods larger than 20ha within 4km of their home (Quine 2011). **Floodplain woodland** landscape diversity and quality is enhanced by restoration of this.	housed per year for a similar increase in Ancient Semi-natural Woodland (Willis et al. 2003). Planting of a substantial 100ha forest at 10 minutes' driving distance -average individual welfare gain of £3.02 per year, although this reduces to £0.32 when the woodland is a 20 minute drive away (Bateman and Day 2014). Recreational visits are valued at £484 million (2010). Landscape value of woodland estimated at £185 million in 2010.			
ROSS, S. AND HAMMOND, G., 2015. United Utilities Sustainable Catchment Management Plan: final report. Buxton: Penny Anderson Associates Limited. [Not referenced in the NFM literature review]	**Headwater drainage management** Drain blocking generally improves water quality. It traps sediment, reduces levels of organic carbon, nitrates and sulphates, and decreases raw water colour production.	None	Drain blocking should be modelled for water quantity and quality separately from B£ST	Water quality	Water quality
SEN, A., et al.,, 2012. Economic assessment of the recreational value of ecosystems in Great Britain. CSERGE Working Paper 2012-01 Norwich: Centre for Social and Economic Research on the Global Environment, University of East Anglia. [Not referenced in the NFM literature review]	**River floodplain restoration** Restoring the historic landscape and enhancing the preservation of water features provides additional attractions for visitors. Recreational activities such as shooting, bird watching and angling are enhanced by the presence of wildlife. **Wetland restoration** The aesthetic value of wetlands is particularly significant in urban areas. The creation of the London Wetland Centre increased the value of adjacent, overlooking property significantly. **Catchment woodland** A view of trees is, along with the availability of natural areas nearby, the strongest factor affecting people's satisfaction with their neighbourhood. **Headwater drainage management**	The estimated per person per trip value of freshwater and floodplain environments is £3.35. The estimated per person per trip value is £6.88 for wetlands. Estimate of the per person per trip value for woodlands is £6.10. The value per person per trip for mountains, moors and heathlands has been estimated at £9.19, higher than most landscapes.	Check the data in B£ST includes these figures	Amenity	Cultural activities Aesthetics

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
	Uplands offer a range of recreational activities including walking, biking, climbing, horse riding and wildlife watching.				
THE RIVERS TRUST, 2013. River Improvement Fund – Phase 1, 2 and 3. Economic evaluation summary of main findings. Callington, Cornwall: The Rivers Trust. [Not referenced in the NFM literature review]	**River restoration** Removing barriers to fish migration and delivering a range of in-stream habitat enhancement outcomes have been estimated to have cost–benefit ratios of between 25:1 and 43:1.	No detailed information provided	May be an important biodiversity and ecology value in B£ST, but reference not sufficient alone (see Vardakoulias & Arnold. (2015) below)	biodiversity and ecology	Habitat provision
TINCH, R., DUTTON, A. AND MATHIEU, L., 2012. Valuing ecosystem services: case studies from lowland England. Annex 2 – Reconnecting the Broads and Fens: Norfolk. York: Natural England. [Not referenced in the NFM literature review]	**River floodplain restoration** Floodplains can act as a carbon sink by protecting carbon-storing soil. They can rapidly accumulate carbon during the initial 100 years of floodplain soil formation, with rates exceeding 100g per m2 per year (= 1 tonne of carbon per hectare per year). Significant in peatland areas, such as the Norfolk Broads, where the soil stores 38.8 million tonnes of carbon.	The value of creating an extra 50ha of floodplain in the Broads is estimated at £1 million over 100 years. Recreation was the largest estimated benefit of reconnecting rivers to the fens, valued at £27 million over 100 years. This is mainly due to the impact of reconnection on supporting healthy fish populations for angling.	SuDS and floodplains may be equivalent to exceedance flow management. Need to link modelled exceedance flow pathways and temporary storage areas to the additional value in B£ST. Recreation will already be included.	Carbon Recreation	Climate regulation Cultural activities
References of relevance but not included in the NFM reviews above:					
Vardakoulias & Arnold. (2015) The returns on investment of river improvement projects: A Cost-Benefit analysis of WRT's					

Reference	**NFM measure**: Quantitative information	Financial information	Potential significance for B£ST	B£ST category (ies)	NFM category (ies)
interventions in Cornwall and Devon April 2015 The returns on investment of river improvement projects: A Cost-Benefit analysis of WRT's interventions in Cornwall and Devon. New Economics foundation.					