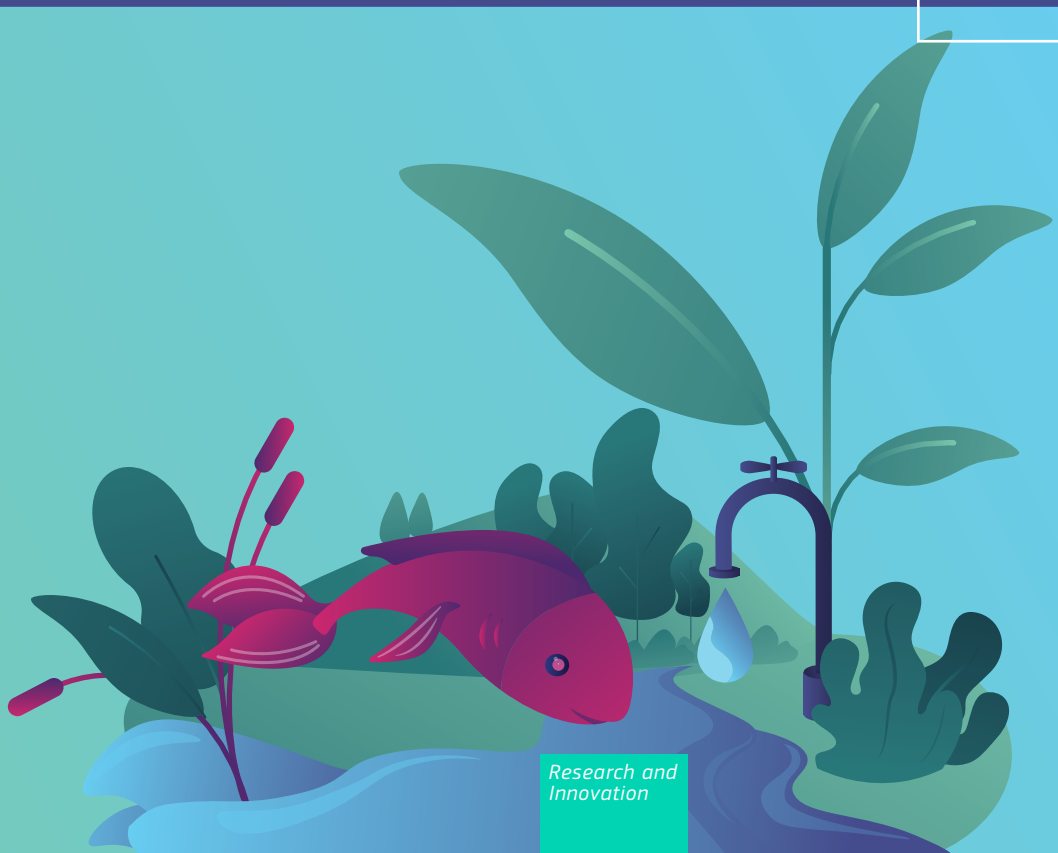
European Commission

Nature-based Solutions
Improving Water Quality & Waterbody Conditions

Analysis of EU-funded projects

Independent
Expert
Report



Research and Innovation

Nature-Based Solutions Improving Water Quality & Waterbody Conditions
Analysis of EU-funded Projects

European Commission
Directorate-General for Research and Innovation
Directorate C — Healthy Planet
Unit C3 — Climate and Planetary Boundaries

Contact Tiago Freitas
Email tiago.freitas@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

Manuscript completed in April 2020

This document has been prepared for the European Commission, however it reflects the views only of the authors, and the European Commission is not liable for any consequence stemming from the reuse of this publication.

More information on the European Union is available on the internet (http://europa.eu).

PDF ISBN 978-92-76-18198-9 doi:10.2777/2898 KI-01-20-260-EN-N

Luxembourg: Publications Office of the European Union, 2020

© European Union, 2020

The reuse policy of European Commission documents is implemented based on Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39). Except otherwise noted, the reuse of this document is authorised under a Creative Commons Attribution 4.0 International (CC-BY 4.0) licence (https://creativecommons.org/licenses/by/4.0/). This means that reuse is allowed provided appropriate credit is given and any changes are indicated.
For any use or reproduction of elements that are not owned by the European Union, permission may need to be sought directly from the respective rightholders.

EUROPEAN COMMISSION

Nature-Based Solutions
Impacts on Water Quality & Waterbody Conditions

Analysis of EU-funded projects

Tom Wild

Valorisation of NBS projects

The initiative to analyse the impacts of EU-funded projects in the area of NBS and valorise their results in terms of EU added value and policy relevance was initiated in December 2019. Six policy reports and a final consolidated report were produced and can be found at https://ec.europa.eu/research/environment/index.cfm?pg=nbs.

The present report aims to provide an overview of results from EU-funded NBS projects and how they support policy implementation in relation to water quality and waterbody conditions.

2020 Directorate-General for Research and Innovation EN

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 3

2. PURPOSE OF THIS DOCUMENT AND BACKGROUND TO THE PROJECT 5

3. OVERVIEW OF MAIN RELEVANT WATER POLICY DEVELOPMENTS 7

4. HOW NBS PROJECTS ADDRESS WATER POLICIES AND SUPPORT IMPLEMENTATION 14

5. THE EVIDENCE BASE ON NBS AND THEIR RELATIVE COST-EFFECTIVENESS 16

5.1. Point sources of pollution including combined sewer overflows 16
5.2. Urban drainage, stormwater quality and urban diffuse pollution control 20
5.3. Agricultural pollution, drainage and soil erosion in rural catchments 26
5.4. Hydro-morphology and the restoration of modified waterbodies 32
5.5. Wider relationships with cohesion, regeneration, health and wellbeing 36

6. BUSINESS MODELS AND FINANCING OF NBS FOR WATER MANAGEMENT. 39

7. INNOVATIVE GOVERNANCE OF NBS FOR WATER MANAGEMENT 41

8. POLICY RECOMMENDATIONS AND KNOWLEDGE GAPS 43

8.1. Recommendations and gaps specific to NBS for water management 43
8.2. Broader NBS policy recommendations and knowledge gaps 45

9. REFERENCES 48

10. ANNEX 1. LIST OF REVIEWED PROJECTS 60

11. ANNEX 2. ABBREVIATIONS AND ACRONYMS 63

1. EXECUTIVE SUMMARY

1.1 Water legislation is important. Water management laws in European countries stem back centuries and are a central concern for civilisations throughout the ages and across our planet. However, human-induced global warming, climate change and environmental degradation caused by pollution and habitat loss have all placed greater emphasis still on how societies organise the management of access to, or protection from, water - along with interest in the legal frameworks handling water-related disputes between people, communities, cities, regions and countries or even continents.

1.2 This document summarises outcomes relating to water quality and waterbody conditions from the EC initiative on the valorisation of projects on Nature-based Solutions (NBS). EU research and innovation projects were scanned for results pertaining to key areas such as Water Framework Directive (WFD) implementation, cross-compliance with the Common Agricultural Policy, catchment management, diffuse pollution and waterbodies. Evidence from the reviewed projects is framed within knowledge from the literature in the realm of water policy, to give as full a picture as possible about the state of the art with relevant NBS.

1.3 EU Directives such as the WFD and Floods Directive (FD) represent significant developments in a long line of attempts to manage catchments sustainably, and water-relevant NBS can be usefully viewed in this context. EU water policy has delivered significant improvements to water quality over the past four decades (EC, 2019a): According to the EC, "it is increasingly possible to reconcile life in a densely populated continent, and a growing economy, with a progressive improvement of water quality". From a scientific perspective, WFD implementation has greatly increasing knowledge on the ecology of Europe's waterbodies, supported by masses of data generated for this purpose (Hering et al., 2010). The WFD is one of very few regulatory frameworks requiring comprehensive monitoring of environmental impacts (Schleyer et al., 2015).

1.4 Contextualised information is provided on policy developments, research results and key lessons. The resulting evidence base includes figures and monetary values showing the relative cost-effectiveness of NBS, and exploring how they support water policy implementation, on: (1) *Point sources of pollution including combined sewer overflows (CSOs)*; (2) *Urban drainage and stormwater quality – including urban diffuse pollution control*; (3) *Agricultural pollution, land drainage and soil erosion in rural catchments*; (4) *Hydromorphology and the restoration of modified waterbodies*; and (5) *Wider relationships with cohesion, regeneration, health and wellbeing*.

1.5 NBS interventions in urban environments can deliver cost savings due to reduced stormwater flows and CSO spills, outperform hard infrastructure on cost grounds, and provide valuable co-benefits including improved environmental quality, better health and wellbeing outcomes and inclusive socio-economic regeneration results. Similarly in rural communities, integrated valuations of NBS for water purification and flood risk management show they can outperform grey infrastructure alternatives, at a similar cost, whilst providing additional benefits such as wildlife habitat and recreational opportunities.

Nature-based Solutions to societal challenges are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based Solutions must benefit biodiversity and support the delivery of a range of ecosystem services.

For more information visit the European Commission webpages on Nature-based Solutions
https://ec.europa.eu/research/environment/index.cfm?pg=nbs

2. PURPOSE OF THIS DOCUMENT AND BACKGROUND TO THE PROJECT

This report summarises outcomes relating to water quality and waterbody conditions from the EC's 'Valorisation of NBS Projects' initiative, analysing results of EU funded research and innovation projects in this area. Full details of the methods used can be found in the full report 'Nature-Based Solutions: State of the Art in EU-funded projects' (Wild et al. (Eds.), 2020) and annexes. EU projects were scanned for results pertaining to key areas such as Water Framework Directive (WFD) implementation, cross-compliance with the Common Agricultural Policy, catchment management, diffuse pollution and waterbodies. Stakeholders' priorities for this work were to analyse EU NBS projects and their transferable results. EU NBS projects' evidence is framed within knowledge from the literature in the realm of water policy, to give as full a picture as possible about the state of the art with relevant NBS.

On commencement of the project, a stakeholder workshop was held in Brussels (on 3rd December 2020) with a range of experts, policy officers and research managers. During this workshop it was agreed that main priorities for this review would include a range of policy development priorities, practical implementation opportunities and challenges, and knowledge gaps stemming from EU NBS projects and the wider literature. The priorities discussed by the stakeholders and experts were as follows:

1. information is needed on decision support protocols based on real cases of NBS implemented as well as examples demonstrating the integration of green and grey infrastructure and their contributions in addressing city challenges.

2. guidelines are needed to help translate evidence into local action, by providing summaries of findings in ways that can support knowledge exchange across sectors and disciplines.

3. stakeholders highlighted requirements for information on NBS' status impacts (chemical, ecological, hydro-geomorphology, temperature etc.) and contextual data regarding the state of the environment within cities and regions.

4. specific evidence is sought about the removal of pollutants by vegetation and soil (in both urban and rural environments).

5. it is important to gain better insights into how NBS projects improve the conditions for life, for instance in heavily modified water bodies, by improving aquatic and riparian habitat e.g. spawning ground, and for instance by mitigating impacts in water levels (baseflows, etc.).

6. evidence in the form of robust case studies is needed about how regions organise and link with end-users, e.g. in promoting source control, stormwater treatment, and comprehensive catchment management approaches.

7. a cross-cutting issue affecting all of the above priorities is to understand how successes in natural water treatment systems are being scaled up, what are the constraints to this, and how are those limitations being addressed.

8. a greater emphasis should be provided about areas where there is convergence on evidence (e.g. on drivers, pressures, state, impacts and responses), rather than areas where little is known or there is uncertainty.

9. key knowledge gaps and evidence needs should be summarised, not withstanding the desired primary focus on areas of consensus and knowns.

During the Brussels workshop (December 2020) it was also determined that the information from NBS projects should be situated within this knowledge from the literature to give as full a picture as possible about the state of the art with NBS, within this realm of water policy (noting that flooding is covered in a separate section of the full report (Wild et al. (Eds.) 2020) from this project). Thus these nine priorities should themselves be seen within the wider context of key policy developments, synopsis documents as outlined above, and review papers signposting current knowledge and future directions.

3. OVERVIEW OF MAIN RELEVANT WATER POLICY DEVELOPMENTS

Water management laws in European countries stem back centuries (for instance in England, dating back at least to the 1427 Sewers Act) and probably beyond codifications of rules and measures in Roman times to prevent illness among the population by public sanitation measures. Urban water management interventions for foul and surface water management are clearly viewable at Minoan sites in Crete. The terracing of land and aqueducts at Machu Picchu in Peru demonstrate advanced knowledge of the relationships between water retention, erosion and agricultural productivity. Conversely, the legal oversight of ditches dug to drain the Romney Marshes in the UK's South East dates back to the 13th century.

Water management can therefore be seen as a central concern for civilisations throughout the ages and across our planet. However, human-induced global warming, climate change and environmental degradation caused by pollution and habitat loss have all placed greater emphasis still on how societies organise the management of access to, or protection from, water - along with interest in the legal frameworks handling water-related disputes between people, communities, cities, regions and countries or even continents. EU Directives such as the WFD and the FD therefore represent significant developments in a long line of attempts to manage water sustainably, and relevant NBS can be usefully viewed in this context. Water laws are important.

EU water policy has delivered significant improvements to water quality over the past four decades (EC, 2019a): According to the EC, "it is increasingly possible to reconcile life in a densely populated continent, and a growing economy, with a progressive improvement of water quality" and that this has been achieved thanks to EU water law, the efforts of Member States and support through EU funding. It can be added that technological developments and increased understanding has also been partly responsible for these improvements. Furthermore, NBS innovations offer new opportunities to further respond to the increasingly important WFD challenges and remaining water management problems e.g. harmful diffuse pollution and hydro-morphological damage, and the rising costs involved in fixing their impacts.

Hering et al. (2010) note that from a scientific perspective, the implementation of the WFD has greatly increasing knowledge on the ecology of Europe's waterbodies, supported by masses of monitoring data generated for this purpose. According to the OpenNESS project, the WFD is one of very few regulatory frameworks requiring comprehensive systems for measuring environmental impacts (Schleyer et al., 2015). The policy analysis undertaken by that project includes a useful summary of the main characteristics of the WFD (Winkler & Schleyer, 2015).

The EU Water Legislation Fitness Check (EC, 2019b) and supporting study (Trinomics & Wood, 2019), provides a comprehensive policy evaluation of: the WFD, the Floods Directive, the Environmental Quality Standards Directive (EQSD), and the Groundwater Directive (GWD). It is closely linked to the evaluation of the Urban Waste Water Treatment Directive, UWWTD).

The Fitness Check assessed whether the Directives were fit for purpose by examining performance against five (Better Regulation) criteria: effectiveness, efficiency, coherence, relevance and EU added value. It concluded that the Directives have led to a higher level of protection for water bodies and flood risk management than could have been expected without them, but on the other hand, that implementation has been significantly delayed and less than half of the EU's water bodies are in good status, even though the deadline for achieving this was 2015 (bar exemptions). Factors contributing to the effectiveness of the Directives in progressing towards their objectives include: (a) the list of priority substances; (b) the (binding) cross-references to WFD objectives in other EU policies; (c) EU funding; (d) the widely applicable non-deterioration principle; and (e) the Directives' monitoring requirements (EC, 2019b).

Hindering factors to successful implementation reported in the Fitness Check include national and local governance frameworks, and possibilities and models for public participation in the WFD River Basin Management Plans (RBMPs). Important from an NBS perspective, it notes that good status depends not only on mitigating new and emerging pressures, but also on retrofitting restoration measures.

Also of relevance to the NBS agenda is the Fitness Check's conclusion that slow progress to meet WFD objectives is partly due to insufficient funding and inadequate integration of environmental objectives in sectoral policies. Finally, good status of water bodies also critically depends on the full implementation of other EU legislation (e.g. Nitrates Directive and UWWTD) and better integration of water objectives in other policy areas such as agriculture, which has not yet happened at the scale necessary. The analysis finds that there are trade-offs between the required flexibility, cost-effectiveness of measures, and the resulting complexity (EC, 2019b).

Box 1. Based on FP7 MARS project outcomes, Carvalho et al. (2019) highlighted significant strengths of the WFD in its integrative approach to ecosystem health, and in how it promotes comparable EU-wide assessment. They suggest that WFD outcomes assessment does not adequately address causes of failure, and that the 'one-out-all-out approach' whereby water class is downgraded (from high or good ecological status to moderate, poor or bad) using a wide range of parameters, is over-precautionary.

Carvalho et al. (2019) note that an important success of the WFD is that it provides the conditions for integrative management at the river basin scale, and in its dealing with point source pollution problems - but they also emphasise that insufficient measures have been taken to address diffuse pollution and combined sewer overflow problems. Perhaps most importantly for NBS, they stress the need for much stronger implementation of measures, notably those involving mechanisms to improve engagement and those incorporating ecosystem-based approaches.

The 'one-out-all-out' protocol may have unintended consequences of exacerbating environmental degradation, in areas where significant polluting industries were clustered (Fairburn et al., 2005; 2009) and where communities already suffer from the loss of ecosystem services. It may also lead to 'winner takes all' scenarios whereby cherished waterbodies in more affluent areas receive greater protection, thereby worsening social and environmental injustice. Notably, the key exception to the ambitious WFD target for all water bodies to reach good status is the derogation in place for heavily modified water bodies (HMWBs) which, as a result of physical alterations by human activity, are substantially changed in character and cannot, therefore, meet "good ecological status" (see also Steyaert & Ollivier, 2007).

Box 2. Research funded through the FP7 WISER project is reported in Hering et al. (2010). They concluded that the WFD timescales to obtain good ecological status in all surface waters have been overambitious (the deadlines being for 2015 bar exemptions, and by 2027 in all cases). They warn that restoring water quality and habitats does not automatically mean that sensitive species will reappear and that these outcomes depend upon source populations, colonization paths and sufficient time for recovery. The importance of efforts to prioritise measures according to recolonisation potential are thus highlighted (further information on biodiversity and habitat enhancement relating to aquatic and riparian ecosystems can be found in Wild et al. (2020).

The 2019 Fitness Check follows an earlier 'Water Blueprint' review of the EU's freshwater policy (EC, 2012). A critical discussion in the lead-up to the Blueprint review was around the possibilities and models for public participation in WFD River Basin Management Planning (RBMPs) and appropriate scales for, and means of, engagement. Article 14 of the WFD makes provisions for public participation, following the Aarhus Convention (UNECE, 1998). However, as for the European Landscape Convention (e.g. Jones et al., 2007; Conrad et al., 2011) there has been much debate about real or perceived gaps between rhetoric, practice and reporting.

Box 3. Verwiej et al. (2016) describe tools developed in FP7 projects OpenNESS and ROBIN, to support quick, participatory methods to identify problems and scope WFD policy processes. Using the tool in different workshop situations, they report that participants were able to process knowledge usually provided in briefs and reports, to develop a joint understanding of the main interactions and impacts and to develop problem statements and solution spaces in a reduced lead time. However, the paper also notes that the method relied heavily on the availability and quality of spatial data ("If the data is of poor quality you will also get poor results"), a problem not unique to this setting, highlighting questions of inequity in the voice and power given to different stakeholders through the use of advanced mapping tools and via access to spatial data. Oppla summarises an applied case using the tools to develop an adaptive management plan for the lower Danube River, Romania.

Partly in answer to critiques that WFD strategic planning processes can be remote or overly bureaucratic, some countries have tried to develop more direct ways to involve people in water management decision-making at the local- to catchment- levels (e.g. Catchment-Based Approach - Defra, 2013; Contratti di Fiume - Gusmaroli et al., 2008). The success of such approaches can be usefully questioned as regards the depth of engagement of 'ordinary' i.e. layperson citizens in water management issues (e.g. see Westling et al., 2014).

Furthermore, the fragmentation or 'dis-integration' (Ashley, 2015) of responsibilities for water management, citizen engagement, spatial planning (Rijke et al., 2012) and particularly maintenance has led to missed opportunities for win-wins in terms of the regeneration of river corridors (Wild et al., 2008) in cities. Melbourne provides an interesting case where holistic attempts have been taken to transition to a water sensitive city, in part stimulated in the 1990s by diffuse pollution control measures that changed community attitudes towards urban amenity and ecological health (Brown et al., 2013), and where this transition is accelerating but incomplete (Ferguson et al., 2013). Other important examples where urban water management has been integrated with urban regeneration and wider spatial planning issues include Zurich (Wild et al., 2011; Broadhead et al., 2013) and the Sponge Cities Programme in Chinese cities such as Changzhou (Li et al., 2018; Chan et al.; 2018).

Box 4. The Interreg IVC ERCIP project on European River Corridor Improvement Plans developed shared understanding of different engagement models, allowing regional agencies with environmental protection duties to work in partnership with local authorities with their emphasis on the social and economic wellbeing. Further guidance on how to promote public participation in WFD implementation via the cooperation of various institutions and organisations was provided by Interreg RhineNet and through the large-scale river restoration delivered by LIFE+ 'My Favourite River' on the River Neckar, Stuttgart.

The recent Assessment Report on the implementation of the WFD and the Floods Directive Management Plans (EC, 2019c) emphasises the strategic issues of national-scale governance, the characterisation of river basin districts, and the monitoring and assessment of water bodies. It also provides an overview of progress to achieve environmental objectives and exemptions, implementation via the 'Programmes of Measures' (PoMs) and the designation of HMWBs and definition of Good Ecological Potential. The primary focus on procedural rather than (locally) substantive issues reflects the principle of subsidiarity, in that RBMPs are developed by Member States, which are not instructed by the EC on content.

The 2019 Assessment notes "the path towards full compliance with the WFD's objectives by 2027, after which exemption possibilities are limited, seems at this stage very challenging"; it highlights that in most Member States, reference conditions have not been established for all waterbody types (rivers, lakes, transitional and coastal) and for all quality elements and for all quality elements (EC, 2019c). This challenge, and calls to establish an EU-wide monitoring network of reference sites, had already been highlighted 10 years ago (Hering et al., 2010).

This lack of progress perhaps reflects a wider concern that although 'natural' or 'pristine' reference conditions for water bodies may be a desirable notion, in reality this quest for characterisations of waterbodies unaffected by anthropological impacts is fraught with difficulty and might even be unachievable. The ways in which human beings have altered water cycles and waterbodies are complex and manifold, having taken place over millennia, in almost endless layers of change.

Nesshöver et al. (2017) previously highlighted this central challenge around "where to draw the line as to what is considered as 'nature' or 'natural' ". Concepts from the NBS literature may therefore prove increasingly helpful to the future development of the WFD and associated water policy (e.g. Eggermont et al.'s (2015) framing of restoration as a continuum of actions that seek to habitats and a range of ecosystems functions, rather than recreating 'pristine' original conditions).

Box 5. In H2020 AMBER Jones et al. (2019) established that only 3% of the total river network of Great Britain is fully connected. Only 1% of the rivers in England, Scotland and Wales are free of artificial barriers. These findings show that most catchments in Great Britain are heavily fragmented, providing a much-needed critical starting point to assess the impacts of waterbody modification across ecologically relevant spatial scales.

Reporting compliance at the highest level, the 2019 Assessment identifies where the EC has pursued targeted legal action to enforce WFD implementation. These fall into broad classes of (1) Enforcement of the deadlines; and (2) Correct transposition – i.e. non-conformity of the national legislation transposing WFD requirements (EC, 2019a).

The latter category is further broken down into (a) Bad application cases, (b) failure to meet reporting requirements, (c) Targeted follow-up to the assessment of RBMPs, and (d) Cases arising from complaints (including those linked with public participation in line with the Aarhus Convention as described above). Case law from the Court of Justice of the European Union (ECJ) highlights that throughout Europe, injunctions have been taken that relate to several underpinning aspects that are fundamental to the WFD.

Overall, around 40% of the surface water bodies are in good or better ecological status, while 60% did not achieve these classes. The ecological status of natural water bodies is generally better than the ecological potential of heavily modified and artificial water bodies, particularly rivers and transitional waters (EC, 2019a). EU Member States are permitted exemptions to WFD Article 4, where reasons for derogations are given (according to specific sub-articles[1]).

Box 6. The H2020 Phusicos team reported on an 11-year participatory process leading to successful delivery of the River 'Isar Plan' in Munich, Germany. Budgeting €35 million to restore 8 km of river, the project reached goals to improve flood protection, ecological status and water quality. By applying a Living Lab approach, the recreational potential of the riverine area was increased, and the alpine river character re-established. The Isar Plan is also reported via the LIFE+ Restore river wiki here.

The 2019 Assessment highlights that WFD Article 4 exemptions are still being used extensively, with around half of Europe's water bodies currently under an exemption, and with certain exemptions being applied more often in the second cycle of river basin management planning than in the first in several Member States. Many of these Article 4(5) derogations involve HMWBs. Less stringent objectives under Article 4(5) can be applied to specific water bodies when they are so affected by human activity or their natural condition is such that the achievement of good status would be infeasible or disproportionately expensive (CIRCABC, 2017).

Box 7. FP7 OpenNESS investigated river basin management planning in five member states across differing institutional and governance arrangements. Grizzetti et al. (2016) studied ecosystem service concepts, highlighting benefits of intersectoral integration, synergetic uses of waterbodies, multi-functionality of measures, biodiversity conservation support and a need for more comprehensive economic valuation methods. They stressed that high expectations placed on water management authorities were accompanied by a lack of practical guidance to support the application of ecosystem service concepts.

The 2019 Assessment notes that good progress has been made since the first RBMPs in the establishment of reference conditions. However, gaps still remain, since in most Member States reference conditions have not been established for all water body types. Notably, the quality elements whose type specific reference conditions showed the most significant gaps for

[1] e.g. Articles: 4.4 - the extension of the deadline (good status must be achieved by 2021 or 2027); 4.5 - the achievement of less stringent objectives under certain conditions; 4.6 - the temporary deterioration of the status in case of natural causes or "force majeure" i.e. severe floods, prolonged droughts, accidents; 4.7 - new projects or modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or failure to prevent status deterioration of a body of surface water.

surface water body types were found to be the hydro-morphological ones. This is particularly problematic, because derogations under Article 4(5) are often based on hydro-morphological modifications. This may allow for circular arguments to delay the implementation of measures to restore ecological potential, particularly in urban watercourses. In the current work programming round of the Common Implementation Strategy[2] it will therefore be important to consider HMWBs issues from the viewpoint of scaling up practical actions, and sharing information about successful implementation of schemes that have succeeded in generating multiple values and co-benefits for Member States, beyond WFD outcomes.

The CIS was tasked with work to investigate the financing of measures and producing a report on good practices for the identification of investment needs and financing sources for the WFD Programmes of Measures or PoMs (CIS, 2018). Furthermore, its Working Groups were required to exchange information and good practices on PoMs, including a library of measures for achieving good status. The Flooding working group refers specifically to the use of NBS in this regard.



[2] The 2019-2021 Common Implementation Strategy (CIS) Work Programme, drafted at the time of the water legislation Fitness Check (EC, 2019b) and the WFD assessment report (EC 2019c) reconvenes several working groups (CIRCABC, 2018), including the ECOSTAT group which is responsible for providing technical guidance on issues including hydro-morpology.

4. HOW NBS PROJECTS ADDRESS WATER POLICIES AND SUPPORT IMPLEMENTATION

The Fitness Check (EC, 2019b) notes that success with next round of PoMs will be critical to the achievement of environmental objectives by the 2027 deadline. It stresses that the EC needs to work with Member States and help them to improve implementation at the lowest possible cost, e.g. by "sharing best practices on green infrastructure and cost reduction of pollutants at source". The ECJ injunctions relating to the fundamentals of WFD implementation also serve to highlight that awareness-raising actions, and the sharing of good practices, remain extremely relevant and their importance should not be neglected.

The 2019 Assessment Report (EC, 2019a) stresses the importance of efforts that have "facilitated the development of networks composed of key stakeholders in order to increase public awareness of water issues and thus lead to better implementation on the ground". The present report therefore summarises evidence of collaborative work to improve the characterisation of WFD issues and to better understand water-related problems, alongside what might be considered 'hard' evidence on the performance of novel NBS or more advanced policy developments.

This conclusion underlines a key issue regarding how the successful implementation of international water policy requires efforts to integrate action across governance scales. Source control and other NBS interventions touch on the lives of citizens very directly, and can do so in both positive and negative ways depending on how these measures are implemented or funded. A particular concern therefore is how to bring together strategic top-down priorities for water management with bottom-up, participatory actions. Broad-scale strategies can deliver direct benefits to local communities most effectively (gaining and maintaining support) where those agendas engage with practical actions that people can see, touch and feel. This is an area in which H2020 NBS demonstrator projects bring new dimensions to water policy development. Online resources can usefully complement these local, physical demonstrators. To this end the EC's web-based service Communication and Information Resource Centre for Administrations, Businesses and Citizens (CIRCABC) seeks to support the joint implementation of the Water Framework Directive (WFD) by improving the information exchange at the local to transnational level. Similarly, online NBS platforms like Oppla have a key role to play.

The WFD requires that for each river basin district, reporting by Member States of PoMs must accord to 25 predefined 'Key Types of Measures' or KTMs (CIS, 2016) covering a range of social, environmental and economic controls and activities. The WFD further specifies that PoMs shall include as a minimum 'Basic Measures' (and 'Supplementary Measures' where needed). Strong complementarity and clear read-across exists between

these requirements and a wide range of NBS responses, e.g. as elaborated in the EC's 2015 Expert Group report (EC, 2015a).

Basic Measures must as a minimum comprise measures to: (a) implement existing water legislation and other environmental legislation; (b) implement Article 9 (cost recovery); (c) promote efficient and sustainable water use; (d) protect drinking water quality and reduce level of treatment required; (e) control abstraction from surface and groundwater; (f) control recharging of groundwater; (g) control point source discharges; (h) prevent or control inputs of diffuse pollutants; (i) address any other significant impacts on status, in particular hydro-morphological condition; (j) prohibit direct discharges to groundwater; (k) eliminate or reduce pollution by Priority Substances; and (l) prevent accidental pollution (CIS, 2016).

Many H2020 NBS innovations, as well as those developed through other EU projects, can also be considered under the main (broad) categories of pressures on water bodies to be addressed by Programmes of Measures (EC, 2019a) reported as: (A) abstractions and water scarcity; (B) pollution from agriculture; (C) pollution from non-agricultural sectors (including nutrients, organic matter and chemicals); (D) hydro-morphological alterations; and (E) Cross-cutting measures. Notably, pollution from non-agricultural sectors includes a vast array of point-sources of wastewater and urban diffuse sources of pollution. It is noteworthy that many exemptions for waterbodies' chemical status relate to diffuse pollution pressures.

Bearing in mind the current state of implementation of the WFD and other water policies, the subsequent part of the report highlights areas where and how NBS can contribute to solving water-related societal challenges. In particular, this concerns how NBS can address: (i) Point sources of pollution, including combined sewer overflows; (ii) Urban drainage and stormwater quality – including urban diffuse pollution control; (iii) Agricultural pollution, land drainage and soil erosion in rural catchments; (iv) Hydro-morphology and the restoration of modified waterbodies; and (v) Wider relationships with cohesion, regeneration, health and wellbeing.

5. THE EVIDENCE BASE ON NBS AND THEIR RELATIVE COST-EFFECTIVENESS

5.1 POINT SOURCES OF POLLUTION INCLUDING COMBINED SEWER OVERFLOWS

As regards the treatment of foul sewage and effluent, NBS such as constructed wetlands were traditionally viewed as providing the greatest contribution to waste water treatment at the tertiary or effluent 'polishing' stage, following physical removal of major solids, sedimentation digestion, and biochemical treatment. However, interest is also increasing in the use of NBS as source control measures either to prevent contaminants from entering water streams or to reduce flows of water and pollutants into the sewer system.

The EC evaluation of the Urban Waste Water Treatment Directive (UWWTD) concluded that overall it has been effective, that the reduction of organic matter and other pollution in treated waste water has improved water quality, and that although implementation has been expensive, the benefits clearly outweigh costs (EC, 2019d). It also notes that with more heavy rainfall events expected due to climate change, storm water overflows (including combined sewer overflows, CSOs) will be an increasingly important source of pollution and pressure on surface water bodies. The evaluation also notes that urban runoff, which is only covered by the UWWTD in connection with combined sewage, is an increasingly important source of pollution including heavy metals and micro/plastics. The evaluation also notes that the UWWTD is too old to deal adequately with new concerns, such as the pollution of water bodies by pharmaceutical residues and micro plastics in waste water systems.

Montalto et al. (2007) found that low impact development (LID) employing NBS such as sustainable drainage can usefully complement to traditional stormwater management in dense, urban areas served by combined sewers. Under a range of cost and performance assumptions they show that systems integrating NBS-type interventions such as green roofs can achieve cost effective reductions in CSO spills, outperforming hard infrastructure storage tanks on cost grounds, whilst improving urban environmental quality. Engstrom et al. (2018) also report that green roof systems can deliver cost savings due to reduced stormwater flows and decreased CSO volumes and events, in turn decreasing nutrient and chemical pollution levels.

Davis and Naumann (2017) make the case for the use of sustainable drainage to address flooding and to reduce the impacts of CSO spills, drawing on the work of the FP7 RECREATE project, and quoting the comparative economic assessment of drainage options (sustainable drainage or SUDS, vs. conventional drainage) using the B£ST tool

as reported in CIRIA (2015). Keeler et al. (2019) note that in cities with combined sewer infrastructure, bioswales, street trees and rain gardens can intercept, evaporate and infiltrate stormwater before it reaches sewer systems, decreasing the volume of water needing treated.

Figures 1 a-c. Daylighting may solve combined sewer floods due to full/blocked culverts. Images: Tom Wild







Referring to studies of stormwater removal from combined sewers pertaining to the Thames Tideway Sewer Tunnel, Ashley et al. (2011) highlight the need to consider the wider multi-value benefits of green-infrastructure based SUDS. The City of Zurich is estimated to have reduced waste water treatment costs by removing stream flows from sewer networks, such that each litre per second of river flows diverted saved around 5,000 CHF per year in treatment costs (Wild et al., 2011). Broadhead et al. (2013) note that in the same case, 'captured' stream flows in sewers contributed 7-16% of the baseflow reaching wastewater treatment works. Eckart et al. (2017) report that the Philadelphia Water Department's 'Triple Bottom Line' study assessed CSO control options for a 40 year period, determining that the city-wide total present value benefits of using GI ranged from USD1.9 billion - USD4.5 billion depending on the extent used (25% to 100% respectively) in removing stormwater from the combined sewerage system.

Box 8. FP7 DESSIN's case study of the Aarhus River daylighting reports that enabling infrastructure including real-time control systems cost ~€47 million with operating costs of ~€600k/year. The benefits of opening the river and resulting water quality improvements were calculated at €120 million. However, this valuation is limited to the benefit of opening the river in the central city, and does not include the social benefits of water quality improvements to the lake, harbour and upper river between the lake and city centre (see also Jensen et al.'s (2014) report from the FP7 PREPARED project).

The above cases relate to the integration of NBS with wider water infrastructure. However, the UWWTD evaluation (EC, 2019d) concludes that individual and other appropriate systems may be substituted for centralised collection systems. It highlights that such 'off-grid' systems can become a problem if badly managed and unmonitored, but that they may sometimes offer a useful cost-effective alternative.

Masi et al. (2017) suggest that 'on-site' treatment by constructed wetlands allows continuous treatment and therefore higher pollutant mass removal compared to conventional (hard/concrete) storage tanks, without presenting negative side effects in operation or social acceptance. They stress the need for statistical analysis of hydraulic and pollutants loading rates and that new designs should be supported by detailed understanding of mass removal rates and effluent concentrations linked to specific event volumes and pollutant loading. Similarly, Garfí et al.'s (2017) life-cycle assessment of constructed wetlands and high-rate algal pond systems concluded that these are less expensive alternatives to conventional wastewater treatment systems, which require high electricity and chemicals consumption.

Box 9. Liquete et al. (2016) report that NBS for water pollution control at Gorla Maggiore, Italy performed equal or better than the alternative grey infrastructure for water purification and flood protection. Having a similar cost, the 'end of pipe' constructed wetlands to treat waste water from combined sewer overflows, together with the surrounding park - provide additional benefits including wildlife habitat and recreational opportunities (integrated valuation and multi-criteria analysis undertaken in FP7 OpenNESS with EC Joint Research Centre).

Figures 2 a-r. NBS for urban water: sustainable drainage (SUDS) & blue-green infrastructure



Biofilter, Rotterdam. NAIAD Project.
Image: Field Factors



Streetside rain garden, Eindhoven. UNaLab project.
Image: L. Postmes



Rain garden - detention, Sheffield.
Image: Tom Wild



Green roofs, Malmo Biodivercity. Naturvation Project



Green roof, Paris. REGREEN Project.
Image: ARB idF



Green roof, Valladolid. URBAN GreenUP project.
Image: Jesus Gomez Perez



Detention – brownfield site Zurich.
Image: Tom Wild



Retention basins, Eindhoven.
UNaLab project.
Image: L. Postmes



'Alluvial meadow' constructed wetland, Tampere. UNaLab project.
Image: Salla Leppänen







Green Walls, Bogota, São Paulo and Sheffield.
Images: Tom Wild, CONEXUS Project



Green Wall
Image: Tom Wild,
CONEXUS Project



Zurich's Bachekoncept: city river daylighting. Image: Tom Wild



Detention wetland: former steel works. Image: Tom Wild,
VALUE project



Detention wetland: former steel works. Image: Tom Wild,
VALUE project



Urban river deculverting.
Image: Tom Wild,
SEEDS project



Urban river deculverting.
Image: Tom Wild,
SEEDS project

5.2.URBAN DRAINAGE, STORMWATER QUALITY AND URBAN DIFFUSE POLLUTION CONTROL

The EEA State of Water Report (2018) provides an overview of the identification of significant pressures and impacts at EU level, and gives an indication of the relative importance of diffuse pollution, where known. It shows that diffuse source pollution affects 38% of all surface water bodies (c.f. point source pollution which accounts for 18% of degraded waters) in Europe. Most countries report diffuse sources of pollution as being a pressure for groundwater (24 out of 25 Member States). Diffuse pollution impacts may also be linked with waters in unknown condition: according to the EC (2019a), although the percentage of water bodies that are of unknown chemical status has decreased since the first RBMPs (from 39% of all surface water bodies to only 16%), some Member States have more than 60% of water bodies of unknown status (Bulgaria, Denmark, Estonia, Latvia, Portugal).

Generally, greater progress has been made to address point-sources problems than diffuse sources of pollution in Europe, yet measures to prevent or control inputs of diffuse pollutants are to be classed as 'basic' measures in WFD PoMs. Progress to address diffuse sources of pollution remains slow and patchy geographically. Historically, diffuse pollution in European and other countries has been vastly underreported, poorly understood, under-estimated as a challenge, and masked by other pressures, both in urban and rural catchments (Novotny & Olem, 1994; D'Arcy et al., 2000; Wild et al., 2003; Ellis & Mitchell, 2006). A particular issue around road drainage is that many Priority Substances are not removed from stormwater using conventional drainage structures or via settlement e.g. using gully pots.

To tackle diffuse pollution, the WFD requires the implementation of basic measures under Article 11(3)(h) to prevent or control the input of pollutants from agriculture at source. Such basic measures are reported for all assessed Member States but not for all river basin districts, and not for all diffuse pollutants (sediments, phosphorus, pesticides, nitrates, microbiological/bacteriological and other pollutants). Non-agricultural sectors contributing to pollution include atmospheric deposition, storm overflows and urban run-off, among others. Key types of measures to address these problems are required to include: (i) Measures to reduce sediment from soil erosion and surface run-off (KTM17); and (ii) Measures to prevent or control the input of pollution from urban areas, transport and built infrastructure (KTM21). Slow progress is being made across Europe to implement and especially to retrofit such measures. Thus, urban diffuse pollution impacts can be expected to become an increasingly important consideration as will be the potential role of NBS in taking forward Zero Pollution Europe, in freshwater, estuarial and marine environments (and thus the Oceans Protection elements of the Green Deal).

Box 10. The EC recently opened a Call for Proposals on NBS for water security and ecological quality in cities. The H2020 'strengthening international collaboration' Call SC5-27-2020 launched in November 2019 will fund projects starting after 2020. It notes that "Surface and groundwater in cities and downstream urban areas may suffer serious pollution from point and diffuse sources from upstream and in-catchment which might have a negative impact on the ecology, quality of life and land values in the city. Furthermore, urban runoff, storm water and wastewater represents a threat to water quality because of the pollutant load it conveys. Enhanced nature-based treatment solutions (such as artificial wetlands and lakes, bio-filtration, etc.) have the potential to remove pollutants from water (e.g. storm water, urban runoff, river water, wastewater) leading to improved water quality and water use efficiency."

Pollution from urban non-point sources is one of the main reasons for failure to reach WFD water quality objectives set for waterbodies, but NBS in the form of sustainable drainage (SUDS) are available to reduce diffuse pollution (Mitchell, 2005). Pollutant loads in urban stormwater have long been studied (e.g. Marsalek, 1991) and urban diffuse pollution problems have been well quantified (e.g. Novotny & Olem, 1994). Effective treatment of urban stormwater runoff can be achieved using specific SUDS-type NBS in combinations set out in the stormwater management train (CIRIA, 2000; 2001; 2015). Specific percentages of nutrient removal can be predicted (Clary et al., 2017a) along with associated performance (Wong, 2006) in improving receiving water quality.

Box 11. OPPLA describes an ambitious SUDS scheme at Southmead Hospital Brunel Building in Bristol, England. NBS constructed include six sedum green roofs and rain gardens, created to slow down rainwater collected from roofs and used for grounds maintenance and irrigation. Car park runoff is cleaned by 444 m of swales, prior to discharge via four attenuation ponds providing excellent invertebrate biodiversity. The scheme, recognised as an NHS Forest site, includes >700 trees and shrubs in small coppices and orchards. The NBS are reported to reduce surface water runoff by almost 40% and water consumption by 25%, leading to an annual saving of ca. £130,000.

Green roofs can deliver significant improvements in water quality (Berndtsson, 2010). SUDS such as bioswales and bioretention perform effectively in filtering pollutants out of stormwater flows further improving water quality downstream (Davis et al., 2001; Everett et al., 2015). Chan et al. (2018), quoting Qin et al. (2013), highlight that NBS such as bio-swales, rain gardens, pervious pavements and green roofs can mimic natural hydrological response and absorb urban stormwater through soil infiltration, stormwater retention, storage, purification, recharge groundwater and improving water quality of the runoff.

Box 12. The ERDF projects Grey to Green & Grey to Green II in Sheffield, England benefited from synergetic funding streams enabled by the Sustainable Urban Development instrument (ERDF Article 7) to implement NBS within a wider Strategy supporting green and inclusive development. In this example of innovative integration, local priorities to promote brownfield regeneration were linked with ESIF Priority Axes 4 and 5, generating investment worth >£7.5m. The scheme involved creating attractive GI assets combining NBS together with harder 'grey' investments such as cycling routes. According to H2020 Naturvation, this represents the UK's largest retrofit SUDS project.

Figures 3 a-e. ERDF Grey to Green project, Sheffield, England. Photos: Sheffield City Council



2014



2015



2016



2014



2016

Clary et al. (2017a) report that most SUDS-type NBS are effective in removing metals such as total copper, and in reducing concentrations of total suspended solids and oils, but a more mixed picture emerges for the removal of bacteria, nutrients and some metals such as dissolved lead and arsenic. SUDS implementation is becoming widespread in many EU countries, but their effective combination within an integrated chain or hierarchy of 'source controls, site controls and regional facilities' remains rare, a phenomenon which has been known about for many years (see Wild et al., 2002), yet the uptake of the stormwater management train approach remains limited and challenging in many settings.

Box 13. H2020 POWER: Mukhtarov et al. (2019) concluded that collaborative learning, while essential for legitimacy of a policy innovation, is not sufficient for policy change and a national legal and institutional framework is required to incentivise SUDS practices.

[3] ESIF Priority Axis 4: Supporting the shift towards a low carbon economy; Priority Axis 5: Promoting climate change adaptation, risk prevention and management.

Particular barriers purported to limit the scope for using NBS to control urban sources of water pollution relate to the costs of land-take and the issue of adoption and maintenance. However, many studies do not properly consider the wider co-benefits of NBS for urban water management, or their integration within wider GI networks (Ashley et al., 2011). The economic benefits of SUDS and other blue-green infrastructure (BGI) may include increases in house prices (Netusil et al., 2014; Zhou et al., 2014). Apostolaki et al. (2005) used social research methods to understand the wider implications for local communities of stormwater management practices. Public sector investments in urban water NBS such as SUDS and deculverting projects can deliver social, environmental economic and benefits, including in weak or failing urban property markets where such interventions may increase overall development viability (Wild et al., 2011; 2017).

Box 14. The H2020 Nature4Cities project uses 'dynamic assessment methodology' to evaluate NBS impacts at different spatial scales across an entire project lifecycle, by generating surrogate data. The simplified urban assessment tool is used to integrate hydrological and diffuse pollution data with other environmental outcome indicators.

An area where research evidence is lacking relates to performance and characteristics of plants and soils for pollution control and water storage in different contexts under different maintenance regimes, and the impact of climate change on those qualities, choices and supply chains. This links closely with the EC's Circular Economy ambitions. A particular knowledge gap exists around the relationship between the use of plants and landscapes for water management as compared with biodiversity and with their aesthetic qualities in different contexts (e.g. Kabisch et al., 2016b; Fernandes & Guiomar, 2018; Hoyle et al., 2017). A further knowledge gap concerns the relationships between perceptions and measurement of water quality, access to water, aesthetics and classifications schemes. The links between people's support for water quality improvements, and the inclusion or exclusion of aesthetic measures of the quality of water bodies is an area that has not been properly addressed through policy-relevant research and innovation projects.

Box 15. In FP6 ScorePP, Scholes et al. (2008) investigated the control of PHS such as arsenic, cyanides and herbicides in surface water runoff. Rainwater GI interventions consistently outperformed conventional grey infrastructures in removing PHS. Their work showed that NBS such as SUDS and constructed wetlands are effective in removing contaminants of emerging concern (CECs) discharged in effluents of wastewater treatment systems - vegetation in these NBS can directly uptake and translocate CEC, which, can be transformed to less toxic compounds during metabolisation in plants.

Few studies have addressed the control of priority hazardous substances (PHS) in surface water runoff using NBS. Waste water treatment works (WWTWs) are not specifically designed to remove contaminants of emerging concern (CECs), which pose serious hazards to human health and ecosystems (Krzeminski et al., 2019).

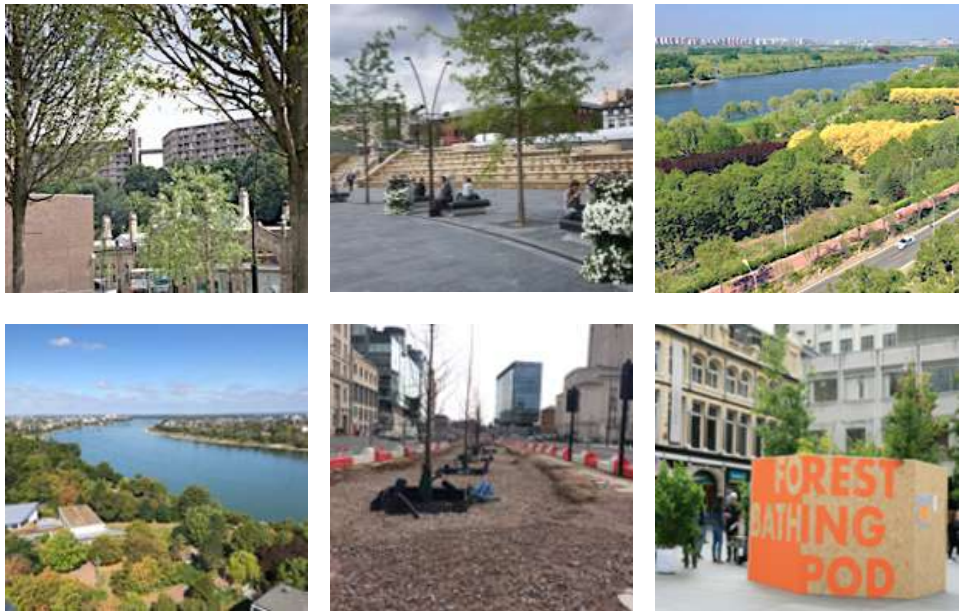
TABLE 1. The Water JPI (Joint Programming Initiative) is supporting many projects delivering innovative and transnational research covering a range of issues in managing water with NBS:
ATENAS, allying technology, nature and society for integrated urban water management.
RAINSOLUTION, improving city climate change resilience whilst avoiding material depletion.
DESCIPHER, on the integration of NBS within airshed and river basin management, to address urbanisation, climate change, air, soil and water quality, and ecosystem services.
FLOODCITISENSE, FLOODLABEL and GREEN BLUE CITIES, addressing the topic of urban flooding in different dimensions including early warning, multifunctionality and smart tools.
IFWEN, assessing changes in the food-water-energy nexus using urban BGI management.

Unknowns remain as regards the performance of NBS in treating/removing sewage-derived and waterborne bacteria, micropollutants, viruses and plastics (e.g. Clary et al. (2017a); Gorito et al. (2017); Krzeminski et al. (2019)). Oral et al. (2020) emphasise that plant-associated NBS play a crucial role in removing different CECs, with the key removal pathways being the uptake by plants, microbial degradation, adsorption and sedimentation. Notably, the Joint Programming Initiatives (JPIs) on Water, Oceans and Antimicrobial Resistance (AMR) recently announced a joint transnational call for projects in the area of pollutants and pathogens present in water resources.

The WFD objective to achieve good surface water chemical status means that concentrations of pollutants cannot exceed standards established in the EQSD within water environments. The significant decrease in water bodies that are of unknown chemical status (from 39% to 16%; EC, 2019a) does indicate that the monitoring (spatially, substances and frequency) and status assessment methods have improved overall. However, 16% still represents significant non-compliance, meaning that much remains to be done to improve both the uptake and development of monitoring protocols. It is also possible that PHS and other contaminants in stormwater and diffuse pollution sources are responsible as causes of downgrading in water bodies where point sources of pollution have been addressed, yet environmental outcomes remain poor. An important gap exists between and actual implementation of pilots and mainstreamed strategies across EU Member Sates. This is an area for policy development requiring careful consideration of the relationships between strands of research, practice and policy. Living labs approach pursued through the H2020 NBS projects could usefully be applied to hasten progress towards the Zero Pollution ambition for toxin-free environments.

Box 16. In H2020 CLEARING HOUSE, benefits of urban forest solutions, including stormwater management improvements, are being explored jointly between cities in EU and China. The opportunities presented by urban woodlands and forestry are summarised in Salbitano et al. (2016). The potential of 'massive tree planting' (Bastin et al., 2019) has received much attention. As well as providing useful options for sustainable drainage (see H2020 Urban GreenUp), urban forests contribute to climate change mitigation through carbon sequestration and storage. Pérez-Soba et al. (2016) describe methods for establishing carbon sequestration, and the capacity of forests to remove carbon from the atmosphere (stored in live and dead biomass and in soils). Urban forestry offers many advantages, not least in offering alternatives to using agricultural land for non-food producing purposes, which may be problematic in low and middle income countries (see Pritchard & Brockington, 2019).

Figure 4 a-f. 'Tree SUDS' & urban forest NBS. Images: a&b, Tom Wild; c&d Clearing House, Clive Davies; e&f: UrbanGreenUP, Tim Jervis.



5.3. AGRICULTURAL POLLUTION, DRAINAGE AND SOIL EROSION IN RURAL CATCHMENTS

The EEA State of Water Report 2018 notes that agricultural production is also a major source of diffuse pollution. Although average levels of orthophosphates and nitrates concentrations declined significantly in European rivers between 1992 and 2015, it highlights that in the 2nd RBMPs Member States identified that diffuse pollution affects 38% of surface water bodies. Agriculture is the main pressure causing failure to achieve good chemical status in groundwater, due to nitrates and pesticides pollution: diffuse pollution sources affect 35% of groundwater bodies by area, and diffuse pollution from agriculture is the major pressure causing poor chemical status, affecting 29% of groundwater bodies by area (EEA, 2018). Nitrogen pollution is particularly important for water quality (Mateo-Sagasta et al., 2017). As highlighted in WEF (2020), five direct drivers of nature loss have accelerated since 1970 - globally, around 115 million tonnes of mineral nitrogen fertilizers are applied to croplands each year; a fifth of these nitrogen inputs accumulate in soils and biomass, while 35% enter the oceans (Mateo-Sagasta et al., 2017). Nitrates affect over 18 % of the area of groundwater bodies (EEA, 2018).

Box 17. Oppla provides a synopsis of long-term research, including work funded through FP7 OpenNESS undertaken by CEH at Loch Leven in Scotland (May & Spears, 2012), exploring practical management options to enhance freshwater ecology, including the use of buffer strips and other catchment-based approaches to reduce erosion and to prevent diffuse pollution. “The enormous improvement in water quality at Loch Leven over the last 25 years, and the associated improvements in food and habitat for wildlife, provide a world leading example of what can be achieved when scientific evidence is used to underpin restoration and management activities." Dr Linda May, CEH.

The scale of the diffuse pollution problem was comprehensively explained in Campbell et al. (2005); its relative importance has increased over time as point-source problems have been removed. Source control measures employing NBS such as rural Best Management Practices (BMPs) depend on sustainable and economically viable approaches to agricultural land management. Diffuse pollution from agricultural sources is also closely linked with erosion and soil quality, and progress has been limited since the May 2014 decision to withdraw the proposal for a European Soil Framework Directive. Soil erosion and diffuse pollution exert wide and adverse social and economic impacts well beyond local environmental degradation, for instance through the costly siltation of reservoirs (Kovacs, 2012) and resulting requirements for additional treatment of drinking water. According to Natural England, between 2004 and 2009, water companies in England spent £189 million removing nitrates and £92 million removing pesticides from water supplies in order to meet drinking water standards (National Audit Office, 2010).

Box 18. In H2020 AquaNES, Zawadzka et al. (2019) found that members of the public welcomed combined natural and engineered water systems including riverbank filtration, constructed wetlands and soil-based managed aquifer recharge, as compared with their engineered equivalents. They assessed a range of ecosystem services and report that the interventions performed favourably in terms of carbon storage, pollination, water retention, sediment retention, nutrient retention and habitat connectivity for biodiversity.

Furthermore, modifications to hydro-morphology are a significant issue in rural as well as urban areas. The main drivers of the physical alterations reported for water bodies in the second RBMPs are flood protection and agriculture (EEA, 2018). For almost 60% of the waterbodies affected by hydro-morphological pressures, these are caused by physical alterations in the channel, bed, riparian zone or shore. Earlier, only 10% of the supplementary measures for diffuse pollution sources and hydro-morphology had been completed by 2012 - 75% were ongoing and 15% had not yet started (EC, 2015b). There are many ways that NBS can be used to mitigate more harmful water quality impacts of agricultural activity, across the whole cause-effect spectrum of drivers, pressures, states, impacts and responses. From a strategic, EU-wide perspective, key drivers can be considered as a function of the trends in land use and associated ecosystem services (Maes et al., 2015).

Box 19. H2020 Naturvation: NBS can range from measures to prevent flooding (e.g. NWRM, dyke relocation, re-naturing rivers, buffering areas, restoration of wetlands, woodlands, floodplain, remeandering, de-poldering, set back of estuarine defences, maintaining dunes, beaches and salt marshes) to responding to droughts and erosion in rural areas using sustainable agricultural practices and irrigation systems, reforestation, rainfall water management, torrents and river management (Bulkeley, 2017).

Quoting Newell-Price et al. (2011), McGonigle et al. (2012) noted that "there is a growing body of evidence on the cost-effectiveness of measures to tackle diffuse water pollution". Vinten et al. (2004) appraised rural best management practices (BMPs) in Scotland including NBS for diffuse pollution control and biodiversity enhancement. They conclude that effective measures include nutrient budgeting, retention of winter stubble, headland subsoiling, use of buffer strips, restricting livestock access to water and constructed wetlands. Frost et al. (2004) identified both diffuse pollution risks and options for habitat conservation and enhancement; financial data were also gathered to determine the current sources of farm income, which was used to devise a possible agri-environment grant scheme to aid the implementation of the whole farm plans. Cuttle et al. (2007) reviewed a range of similar measures to reduce diffuse water pollution from agriculture, describing in detail the costs and technical effectiveness of each measure. Clary et al.'s (2017b) review of the performance of 26 types of BMPs concludes that these interventions provide significant reductions in pollutant loading from agricultural land.

Box 20. Funded by LIFE+ EKOROB Izydorczyk et al. (2019) report on the impacts of diffuse pollution reduction programmes in the Pilica catchment and Sulejów Reservoir in Poland. Cooperation between water managers, interdisciplinary researchers and stakeholders catalysed capacity-building and public participation. Spatially-targeted mitigation measures were identified, based on the modelling results and following discussion of the measures by stakeholders. They concluded that eco-hydrological NBS should be used complementarily to good agricultural practices, which in this case has contributed to a faster achievement of good ecological status of water bodies.

The EEA's (2018) European Waters Assessment highlighted that "During the implementation of the first RBMPs, there were several examples of Member States strengthening action to reduce nutrient pollution from agriculture". Member States are implementing different kinds of measures, e.g. using farm-level nutrient planning, setting fertiliser standards (e.g. timing), using appropriate tillage, using nitrogen-fixing and catch crops, setting aside buffer strips and using crop rotation.

Box 21. H2020 NAIAD is developing methods for the monetary valuation of water regulating services. Hérivaux et al. (2019) note that econometric approaches can be applied to assess water quality benefits provided by forests using water bills data. They highlight Fiquepron et al.'s (2013) findings that on average, 1 ha of afforestation would generate a saving for French domestic water users of ca. 22€/user/year (2004 prices) due to improved water quality, and Abildtrup et al.'s (2013) reports of household water bills reductions ranging from 99 to 138 €/ha/year (2008 values) of newly created forest.

In terms of forestry and woodland, measures to meet WFD objectives can be integrated with adaptation strategies and measures to promote climate change mitigation, using NBS such as catchment restoration measures (Nisbet et al., 2011) and floodplain forests (Dixon et al., 2016). Nagabhatla et al. (2018) provide an overview of the role of forests as NBS for ensuring water security. Rural NBS schemes that are less dependent upon regulations and publicly funded policy measures are reviewed by Knickel & Marechal (2018) alongside the agri-environment schemes under the Common Agricultural Policy (CAP) Pillar 2. Together these funds and initiatives provide financial incentives to farmers to adopt more sustainable practices and maintain agro-ecosystems that might otherwise be lost.

Box 22. H2020 PEGASUS investigates environmental and economic impacts of organic farming, e.g. reporting on the 'Skylark' organic farmers cooperative's work in the Dommel area of Midden Brabant in the Netherlands (Westerllink & van Doorn, 2016). This brings together stakeholders including food processing industries, the public, and the Water Board, to address intractable challenges – such as water quality problems that have been hard to resolve through normal policy measures. The region faces some of the most intensive agriculture in Europe, exerting significant pressures on natural resources. Environmental regulation and agri-environmental schemes were deemed insufficient to

resolve these problems. Plans for exchanging water quality measures with land leases are being used to develop riparian buffer strips and reed fields in lower areas to improve water quality, in return for land elsewhere instead of through financial subsidies (the Water Board owns 180 ha of land in the region).

The EU Water Regulation Fitness Check (EC, 2019b) emphasises the importance of the issue of cross-compliance between WFD outcomes and the two Pillars of the CAP. As regards the first pillar, which includes payments for environmentally friendly farming and mechanisms to stabilise farm revenues, by delivering public goods not normally paid for by the markets - instruments have been put in place to ensure coherence of the CAP's payments with environmental legislation. Several of these cross-compliance requirements have direct and indirect impacts on water quality and water quantity protection. However, it is also noted that a 2016 European Court Auditors report shows that the effects of cross compliance are also limited by the fact that not all farmers supported by the CAP have to comply with cross-compliance (approximately 68% have to comply; some e.g. organic farmers are not required to meet these requirements). The rate of non-compliance for the statutory management requirement stemming from the Nitrates Directive is 10%.

Box 23. H2020 NAIAD features a case study of the Moors for the Future project in the Peak District, UK. Its LIFE+ MoorLIFE scheme restored 893 ha of damaged peatland to self-sustaining, active blanket bog. NAIAD researchers reported improved water quality and flood risk management delivered through (1) recovery of the natural vegetation, creation of erosion detention barriers and tree planting; 2) changes in agricultural practices; and (3) changes in land use and infrastructure to reduce diffuse pollution.

Martin-Ortega et al. (2014) review the evidence on relationships between peatland degradation and poor water quality. They report that while it is difficult to establish cause-and-effect relationships between peat restoration and WFD outcomes, in river catchments with significant peat degradation there is evidence of poor water quality leading to failure to achieve good ecological status. Bonn et al. (2016) provide an overview of valuation studies of peatland restoration. Glenk et al. (2018) report that benefits exceed cost in appraisals of previous and future public investments in peatland restoration. ONS (2019) investigated values for the restoration of 100% of UK's peatlands, with costs estimated at between £8 billion and £22 billion, yet with the benefits (including carbon sequestration) of having 55% of peatland in good status being ~ £45 billion to £51 billion over a 100 year-period. Mitsch & Gosselink (2000) highlight a 'trap' of assigning economic value to natural ecosystems such as wetlands (and, by extension, NBS) in that if short-term economic analyses are made it will always be possible to find more profitable (e.g. commercial) land-uses. They highlight that: wetlands are multiple-value systems; relationships with marginal value are complex; and their most valuable 'products' are public amenities.

Box 24. H2020 PHUSICOS investigates the use of NBS to reduce hydro-meteorological risks in rural and mountainous regions. The project will deliver a 'receded green barrier' on the River Gausa, at Jorekstad near Lillehammer, Norway. Built using only natural and local materials, the barrier will contribute to water quality improvements to meet WFD objectives (Oen et al., 2019). Due to diffuse pollution impacts from agricultural land runoff, the river has only moderate ecological status as regards total phosphorous, and a poor state in terms of total nitrogen. By creating a wetland and setting back the flood barrier the scheme is intended to prevent plastics and other substances from entering the river, as well as reducing nitrogen and phosphorous runoff, and mitigating against the loss of fish habitat and spawning areas.

The literature on natural water retention measures (NWRM) and natural flood-risk management (NFM) is growing rapidly. Ngai et al. (2017) provide a comprehensive review of relevant evidence provided through the UK Environment Agency's 'Working With Natural Processes' project on flood and coastal erosion management. This provides compelling evidence for the benefits and co-benefits of NBS covering river and floodplain management, woodland management, runoff management, and coastal and estuary management. It also highlights important research needs, including: knowledge on 'leaky barriers' and catchment restoration improvement measures; monitoring of the geomorphic, hydraulic and ecological effects of river restoration (such as daylighting culverted rivers); and better understanding of the functioning of floodplains during extreme events. Despite this evidence on the impacts and co-benefits of NBS, action to implement and upscale ecosystem-based approaches in rural catchments has been pitifully slow throughout most of Europe. This points to the need for a different approach, and the co-production methods trialled in H2020 offer significant scope to be adapted in rural environments.

Figures 5 a-e. Rural and peri-urban NBS including catchment management and rural BMPs



Catchment restoration measures, Gudbrandsdalen, Norway (PHUSICOS)



Constructed wetlands (OPERANDUM)



Peatland grip-blocking & buffer strips, Peak District UK, MoorLIFE / SEEDS © Tom Wild

Box 25. NBS investments can yield considerable economic returns at both regional and local scales, and a key challenge is to understand how government organisations can best target the location of green investments to maximise socio-economic benefits (after Gellinck, 2013). This applies to networked infrastructures such as green cycling routes as well as NBS for water management at the catchment scale. In H2020 NAIAD economic valuations of flood storage and ecosystem services are being undertaken for NBS in Romania as part of Lower Danube Green Corridor scheme, addressing wetlands, canopy cover, floodplains, waterbodies and soil. The results show that "the impact of individual small wetlands can be lost in the noise and uncertainty of data and processes associated with catchment modelling" (Burke et al., 2018).

A new model Eco:actuary for insurance industry valuation is being piloted by NAIAD, coupling elements of WaterWorld and Co$tingNature (Mulligan et al., 2019; see also OPPLA). This entails mapping absolute insurable asset value per pixel in GIS-based tools, which provide an interface for experts in economic valuation to enter economic and insurance values, and can be used to map economic asset values of (collective) NBS investments. The NAIAD project team stresses the following key issues: the location of NBS interventions within catchments is critical; these NBS interventions should not be considered in isolation from each other; and the sum of all interventions upstream of assets is critically important (Burke et al., 2020).

5.4. HYDRO-MORPHOLOGY AND THE RESTORATION OF MODIFIED WATERBODIES

According to Albert et al. (2019), many of the ecosystem services lost through river straightening, bank modification and agricultural intensification can probably be brought back through river restoration, and thus river landscapes provide a particularly useful setting to make use of NBS. The EEA State of Water Report 2018 highlights that river and floodplain restoration measures involving NBS may be used to address hydro-morphological pressures, which have the most widespread impacts on surface water bodies (40% of all surface water bodies affected). Fish populations are particularly susceptible to such pressures via the impacts of interruptions in longitudinal continuity, riverbank constructions, large flow fluctuations, and water abstraction (EEA, 2018). Hydro-morphological changes also exert other important adverse impacts on flood risk management, erosion, nutrient pollution and amenity.

The WFD requires the assessment of waterbody status and prospects for achieving 'Good Ecological Potential' (GEP) of HMWBs resulting from physical alterations by human activity, which substantially change hydro-geomorphological character (Borja & Elliot, 2007). In 2006, Hanley & Black noted that “the WFD recognizes the need to accommodate social and economic considerations, so HMWBs may be designated where achievement of the Directive's objectives may result in disproportionate costs”, and that “significantly, the HMWB designations themselves are uncertain, because the ecological status assessments on which they depend are not certain”. They conclude that for Scotland as a whole, implementation of the WFD is predicted to result in positive net benefits.

Box 26. In FP7 WISER Verdonschot et al. (2013) assessed restoration measures comparatively across the four major categories of rivers, lakes, transitional and coastal waters. Also analysing WISER data, Borja et al. (2013) provided assessments for the biological quality elements (phytoplankton, macroalgae-seagrasses, macro-invertebrates and fish) requiring evaluation, validating existing indicators and developing new indices. They report that indices respond differently to specific pressures, and each comes with challenges in defining reference conditions against which future changes may be judged.

Heavily modified river systems and their multiple human impacts pose considerable challenges for assessment of their ecological status (de Leeuw et al., 2007). The ‘one-out-all-out’ approach means that many nations are far from achieving good status even though almost all member states accomplished WFD formal implementation of PoMs: in Germany, 82% of all surface water bodies were exempted from good ecological status requirements under Article 4 of the WFD

(Richter et al., 2013). Although the development of HMWB assessment methods has been a transparent process and has resulted in improved and more standardised tools, the process has been more time consuming, and methods are more complex, than originally expected (Hering et al., 2010).

Box 27. H2020 NAIAD researchers report that Spain's National Strategy on River Restoration draws from the WFD and Floods Directive and has the objective to implement a series of actions meant to initiate a 'process of change in the management of river systems', which will lead to an enhancement of the ecological status of rivers, while gradually increasing the involvement of the public (Rica et al., 2017). H2020 AMBER provides international guidance on adaptive management of the operation of dams and barriers in European rivers to achieve more efficient restoration of stream connectivity and to address river fragmentation impacts.

The modification of river bank structures, reconnection of backwaters or floodplains, and restoration of wetlands are among the most common NBS measures applied to achieve hydro-morphological improvements (EEA, 2018), incorporating specific techniques such as removal of bank fixation, re-meandering or widening, tree planting and preserving riparian zones. It can also include the re-introduction of animals, that can modify the environment in ways that suit human beings as well as improving their own habitat - for instance, in rural environments Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands (Puttock et al., 2017).

Box 28. The H2020 URBINAT project includes cases of several sustainable drainage demonstrator projects including the daylighting and restoration of culverted watercourses. In 2015 at the Asprela-Quinta de Lamas Park, a brook was deculverted and restored, creating opportunities for active recreation, making connections between different social groups, and building a closer relationship between the University and watercourse (Farinha-Marques & Lameira, 2017). The scheme retains large volumes of runoff from the watershed, with rain water falling in the park being managed on site through infiltration and storage using a system of retention basis, prior to discharge to the deculverted watercourse. The watercourse section was designed to retain water volumes from a 1 in 50 year recurrence storm event.

Other river restoration measures including daylighting (deculverting), which entails opening up piped and buried rivers and restoring them to more natural conditions (Wild et al., 2011) to deliver a wide range of social, economic and environmental benefits. Daylighting has been called the most 'radical' expression of river restoration (Pinkham, 2000) and is primarily, though not exclusively, an urban endeavour or intervention (Wild et al., 2019).

Box 29. Wild et al. (2019) report on two daylighting case studies in Sheffield, UK, funded by Interreg IVB SEEDS, the Environment Agency and Sheffield City Council (one city-centre project, one rural headwaters scheme). Costs data were synthesised and analysed, using information from an international database of self-reported cases. Urban deculverting schemes cost USD 21k on average compared with USD 6k for suburban and rural sites (2017 prices); daylighting yielded differing, valuable benefits in each setting.

Figures 6 a-d. Porter Brook daylighting Peak District, Sheffield, UK. Images: Tom Wild



2011



2012



2013



2020

Kail & Wolter (2011) note a lack of knowledge on the effect of restoration measures and a specific gap around how to enhance the ecological state of HMWBs. Post-project evaluation and outcome reporting of river restoration projects remains rare (Bernhardt et al., 2005) and thus it is often unclear whether the goals of restoration schemes are achieved (Palmer et al., 2010). In contrast to the degradation effects, biotic responses to restoration are less well-known and not easily predicted (Hering et al., 2010). Surrogates such as riparian tree cover, woody debris

presence and sediment transport are thus increasingly used, often at catchment scales by employing technological advances e.g. remote sensing data (see Bizzi et al., 2016).

Box 30. FP7 REFORM developed a hierarchical framework of river behaviour (RHF) to support water management. It provided a methodology to complement official WFD guidelines for hydro-morphological surveys (CEN2004) addressing process-form interactions over spatial scales from catchments down to sub-reach levels - e.g. geomorphic and hydraulic units (Gurnell et al., 2015). Bizzi et al. (2016) showed that many of the proposed RHF assessment indicators can be derived using remote surveying sources and existing methods, and that Member States already have sufficient data to begin incorporating them into WFD assessments and monitoring of hydro-morphology.

According to Palmer et al. (2014) "ecosystem restoration was originally founded upon recovering ecosystems using wildlands as a reference state… more recently there has been interest in shifting to restoring… the benefits that natural systems can provide to humans". Piégay et al. (2020) go further in suggesting that fluvial systems are now 'socio-ecological hybrids' and that human (river) constructions can be perceived as potentially valuable novel ecosystems.

Box 31. The H2020 RECONECT project will make available water quality and quantity data on the performance of the Niederneunforn river restoration project in the Thur River Basin, Switzerland (completed in 2002 through the RECORD project). The Thur River in NE Switzerland was channelised in the 1890s. Since 1993, several river sections were widened to allow the formation of alternating gravel bars colonised by pioneer vegetation and to increase hydrological connectivity between the main channel and floodplain. Habitat enhancement created by the restoration has provided a broader range of ecological niches and improved aquatic and riparian biodiversity - however, more erosion has taken place leading to lost riparian forest; strategic balancing between erosion control and rehabilitation is needed (Schirmer et al., 2014).

Figures 7 a & b, Niederneunforn River. Photos: BHAteam, Frauenfeld





Bledsoe et al. (2016) provides a useful summary of research and development needs relating to river restoration techniques including (1) bed and bank stabilisation; (2) riparian buffers; (3) in-stream enhancement; (4) floodplain reconnection and (5) other restoration practices including dam removal and land-use management. This review provides specific areas for future investigation to better understand the performance or river restoration techniques for the removal and retention of nutrients, sediments and catchment management of stormwater.

Box 32. FP7 DESSIN researchers report that large-scale river restoration "pays off" (Gerner et al., 2018). In this ecosystem service valuation case, a wide range of benefits delivered by the €5.3 billion Emscher river restoration programme were analysed. Market values of the restoration schemes were calculated totalling €21 million every year along with non-market values of €109 million per year. Benefits analysed included: self-purification and retention of N, P and C; maintenance of nursery populations and habitats; alignment with other infrastructures; reduced risk of flooding; opportunities for biking and recreational boating; appreciation of restored stream sections; and opportunities for understanding, communication and education.

5.5. WIDER RELATIONSHIPS WITH COHESION, REGENERATION, HEALTH AND WELLBEING

Quoting de Vries et al. (2003), Faivre et al. (2017) note that access to natural recreational areas may help prevent socio-economic inequality from leading to health inequality. Van den Bosch & Ode Sang's (2017) systematic review of reviews addresses pathways and services, as well as defined health outcome benefits of NBS, including stress reduction, heat reduction, increased physical activity, noise reduction and decreased obesity (however this did not cover air pollution). Drawing on a range of studies, Kabisch et al. (2016a) report that urban blue spaces can also help to reduce air pollution levels and heat (depending on their context, management and planning), as well as protecting individuals from diseases related to harmful environmental exposures e.g. reduced infections from contaminated drinking water. Their findings support a beneficial impact of the use of green and blue spaces and residential surrounding greenness on behavioural development and ADHD in children, in line with Amoly et al.'s (2014) evidence of beneficial associations between use of blue spaces and wellbeing outcomes. Similarly, Twohig-Bennett & Jones (2018) meta-analysis of health outcomes of greenspace exposure showed statistically significant reductions in blood pressure, salivary cortisol, heart rate, diabetes, cardiovascular mortality. They conclude that although systematic review results were limited by poor study quality and high levels of heterogeneity, greenspace and street greenery may form part of a multi-faceted approach to improve a wide range of health outcomes.

Box 33. In FP7 Green Surge Kabisch et al. (2016a) found that a lower percentage of natural area cover was correlated with deficits in children's viso-motoric development, and that areas with lower natural area per capita had significantly higher values of childhood obesity. They note that while resources are limited and may prohibit extensive re-greening, 'upstream' prevention of health problems may still be achieved using innovative solutions e.g. opening currently private spaces or refurbishing less well maintained urban greyfields, whilst being mindful to mitigate against eco-gentrification.

Following work on the FP7 PHENOTYPE project, Lawrence et al. (2019) stress that much research relating to health benefits of outdoor natural environments have followed oversimplified linear cause–effect models, whilst neglecting interaction between key variables and feedback loops between different components. Ossola et al. (2018) also highlight that many projects fail to capture the complexity of service provision mediated by interactions between people and ecological structures. These results point to important areas for future research and innovation.

Zhou et al. (2014) estimate the marginal willingness to pay for proximity to urban blue-green spaces of various types. They evaluated the performance of the four strategies (laissez-faire, pipe enlargement, local infiltration, open urban drainage systems). All adaption strategies investigated were found to be economically beneficial relative to the laissez-faire alternative. The largest gain was found for the open SUDS solutions, with a considerable increase in estimated net present value, when taking into account the additional environmental amenity benefits. They conclude that a budget-oriented cost-benefit analysis approach alone is insufficient to support through decision-making, as it will miss the potential additional non-market services (negative and positive) achievable using urban water NBS.

Box 34. H2020 CONEXUS includes pilot interventions with local schools and NGOs to investigate the health, wellbeing and educational opportunities of urban NBS, such as constructing green walls to mitigate air pollution impacts of traffic congestion (in Buenos Aires). Contributions of and benefits to young people of NBS represent important opportunities for implementation of the UN Sustainable Development Goals. In particular, challenges should be stressed around youth unemployment in market failure areas. According to the World Bank/ILO (2015) ~1/2 of all young people in the world are unemployed or underemployed, and this situation is likely to get worse (BA, 2019). However, surprisingly little evidence exists about young people's perspectives of global challenges and solutions, and the potential responses that can be pursued using NBS.

Incorporating attractive NBS can play a significant role in encouraging regeneration in locations where a surfeit of empty properties or stalled development mean that the private sector may be unlikely to take the lead in implementing NBS to deliver ecosystem services (Wild et al., 2017). Since such schemes can deliver multiple co-benefits for a

wide range of citizens and users, investment in NBS by governments at the national and local level is justifiable as an effective way to stimulate inclusive regeneration. These findings build on the results of earlier EU projects investigating the economic impacts of landscape quality improvements within regeneration programmes such as in the Ruhr, Germany (Mielke, 2008). Similarly, Netusil et al. (2014) report property sale price increases with tree canopy coverage; they suggest that the value of street trees outweigh their maintenance costs, and can help overcome the market failure identified in Donovan & Butry (2010).

Figures 8 a & b. Blue green infrastructure: NBS for urban river corridor regeneration



'Streets' and 'Parks' redevelopment options
(images: URSULA project team)

NBS have the potential to increase the connectivity between existing, modified and new ecosystems, as well as offering important opportunities for social innovation to restore and rehabilitate ecosystems within cities and at the urban-rural interface. Examples of interventions that can deliver such win-wins include healthy green corridors, providing both routes to employment centres for rural communities, and greater more inclusive access to the countryside for urban populations.

Box 35. H2020 URBINAT is co-creating 'healthy green corridor NBS' with citizens in seven EU cities. At Porto in Portugal, this process includes the active participation of parish organizations and initiatives to involve local actors, resources and talents in designing and creating interventions. Also in Portugal, a €75m national programme has been commissioned to restore 5,000 km of freshwater streams, using NBS to help prevent forest fires, soil erosion, droughts and flooding, and to improve biodiversity and water quality. Within this programme, 1,000km length of rivers have already been restored (costing €11.5m) and a further 5,000km are targeted for restoration (at a cost of €75m). The Minister of the Environment has highlighted that such NBS are part of the national effort to reduce emissions and mitigate against climate change, and that NBS living-labs in 16 different municipalities helped bring together civil engineers, local authorities, the forestry sector and other businesses. Riverside 'parkways' connecting urban and rural communities represent important opportunities to achieve synergies between ecosystem restoration and social integration.

While the H2020 cross-cutting sustainable cities initiatives made real inroads to low carbon development for motorised forms of transport, arguably, much less attention was placed on the potential to increase walking and cycling. By combining urban mobility plans with BGI interventions, significant potential exists to integrate NBS within healthy blue-green 'parkways'. These river corridor regeneration approaches represent important opportunities for Just Transitions, facilitating both ecosystem restoration and social integration. Non-motorised transport options offer two-way benefits for productivity of reduced congestion on the one hand and increased activity and wellbeing on the other, both contributing to GVA (multi-modal mobility e.g. https://www.interregeurope.eu/match-up).

6. BUSINESS MODELS AND FINANCING OF NBS FOR WATER MANAGEMENT

NBS-type interventions for urban water quality management, such as green roofs, can achieve cost savings due to reduced stormwater flows and CSO spills, outperforming hard infrastructure storage tanks on cost grounds, whilst improving urban environmental quality and other valuable co-benefits (Montalto et al., 2007; Engstrom et al., 2018; Davis & Naumann, 2017; CIRIA, 2015). Similarly, in rural communities, integrated valuations of NBS for water purification and flood protection show they can outperform grey infrastructure alternatives, at a similar cost, whilst providing additional benefits such as wildlife habitat and recreational opportunities (Liquette et al., 2016).

The economic benefits of SUDS and other NBS may include increases in property values, or willingness to pay for housing and NBS maintenance costs, attributable to views and access to these green assets (Mell et al., 2013; Netusil et al., 2014; Zhou et al., 2014). Public sector investments in urban water NBS can deliver significant benefits in weak or failing urban property markets where such interventions may increase overall development viability (Wild et al., 2017), in line with the results of earlier EU projects investigating the economic benefits of GI (e.g. Mielke, 2008).

The daylighting or deculverting of underground, piped rivers can also deliver significant economic outcomes (Wild et al., 2011) - the City of Zurich is estimated to have significantly reduced WWTW costs by removing stream flows from the sewer network, such that each litre per second of river flows diverted from the sewer saved the city around 5000 Swiss Francs per year in treatment costs. Using this source data, Broadhead et al. (2013) estimate that for a typical WWTW (Esholt, Bradford), removing the 16% of baseflow from captured streams and springs would deliver a cost saving of between £2 million to £7 million. Wild et al. (2019) reported that urban deculverting schemes cost USD 21k on average, compared with USD 6k for rural and suburban schemes. Based on multilevel hedonic pricing models, Kang & Cervero (2009) concluded that daylighting of the Cheong Gye Cheon in Seoul, Korea delivered net benefits to both residential and non-residential land markets.

The FP7 DESSIN case study of the Aarhus River reported that the benefits of opening the river and the associated water quality improvements are estimated to be €120 million, while the costs of enabling infrastructure including real-time control systems was ~€47 million, with an operating cost ~€600k/year. This valuation is limited to the benefit of opening the river in city centre, and does not include the social benefits of water quality improvements to the lake, the harbour and the upper river section between the lake and the central city (Jensen et al., 2014).

At the macro-scale, Hanley & Black (2006) concluded that implementing the WFD in Scotland was likely to generate benefits in excess of costs, with a central benefit to cost ratio of 1.69:1. Noting that the "benefits are likely to be considerably greater than those identified in their study, because many gaps in the benefit assessment exist", they relate this to the option to designate water bodies as HMWB and associated exemptions from the requirement for good ecological status. Whilst this may reduce WFD implementation costs for some EU Member States, it also has significant implications for social and environmental justice (Fairburn et al., 2005; 2009) and eco-gentrification (Haase, 2017; Kabisch et al., 2016a), about which important questions remain.

Box 36. ONS (2019) investigated values for the restoration of 100% of the UK's peatlands, with costs estimated at between £8 billion and £22 billion, yet with the benefits (including carbon sequestration) of having 55% of peatland in good status being between £45 billion and £51 billion over a 100 year-period.

Figure 9. VALUE project - river restoration and riverside cycle path, Stuttgart. Image: Tom Wild



7. INNOVATIVE GOVERNANCE OF NBS FOR WATER MANAGEMENT

Hindering factors to successful implementation of the WFD include national (and local) governance frameworks (EC, 2019c), and the possibilities and models for public participation in the WFD River Basin Management Plans (RBMPs). Appropriate scales for, and means of, engagement in water management (in line with Article 14) remain an important area for innovation. H2020 NBS projects are exploring and demonstrating innovative ways to bring together strategic priorities such as biodiversity and climate change resilience with participatory actions to promote sustainable water management in rural and urban environments. The living lab model of NBS demonstrators can add significant value and bring a new dimension to the development of more nuanced water policy in Europe. Online resources usefully complement and scale-up the impact of these local demonstration projects. At a strategic level this includes the resources available via CIRCABC, as well as platforms such as OPPLA that promote wider access to NBS evidence.

Box 37. OPPLA reports that H2020 AQUACROSS governance innovations linked with policy-making and implementation were used to better understand the interactions and feedback processes between society and ecosystems that influence long-term restoration outcomes. The Lake Ringsjön Rönne å Catchment case in Kattegat, Sweden provides insights into how collaborations can be achieved across different water governance levels, sectors and geographical regions, to improve catchment management outcomes. Similarly H2020 PEGASUS case studies on cross-compliance in agriculture, demonstrate how WFD implementation may be integrated with other EU legislative requirements.

URBACT, the European Territorial Cooperation programme that aims to foster sustainable integrated urban development in cities across Europe, also serves to promote innovative water management and governance models. Its good practices resource showcases around 100 cases from 25 countries, documenting efforts to achieve more sustainable urban development. An easy-to-search database provides city practitioners with a snapshot of the practice, why it works, the context, and who to contact for more details. An example promoting better WFD and climate change resilience outcomes is the urban waterways strategy and action plan reported here, providing practicable information on how cities can use collaborative planning and partnership approaches to integrate bottom-up local citizens' engagement with strategic water priorities. Similarly, the FP7 PREPARED project provides important lessons on reflexive adaptation for resilient water services (Westling et al., 2019).

These examples play an important role to meet the recommendations of the EC's water management Fitness Check (EC, 2019b), to promote programmes of measures

that will help to achieve the WFD 2027 environmental objectives. They show how the EC is working with Member States to improve implementation at the lowest possible cost, e.g. by sharing best practices on GI and cost reduction of pollutants at source. However, collaborative learning and participation alone are in themselves insufficient to improve waterbody conditions and to meet current sustainable water management challenges, including diffuse pollution and hydro-morphological impacts. For instance, Mukhtarov et al. (2019) draw on their work in the H2020 POWER project to show how collaborative learning, while essential for legitimacy of a policy innovation, is not sufficient for policy change and a national legal and institutional framework is required to incentivise SUDS uptake.

Furthermore, EU NBS projects help to address a specific challenge in the successful implementation of water legislation, around retrofitting to solve existing problems. Achieving good waterbody status depends not only on mitigating new and emerging pressures, but also requires faster progress to retrofit appropriate measures to solve issues such as diffuse pollution and hydro-morphological impacts (EC, 2019b). Inspiring and engaging examples include Urban GreenUp's pop-up forest, GrowGreen's vertical gardens in Valencia schools, the UrbanbyNature global programme for urban nature pioneers, and Naturvation's Innovation Pathways. H2020 NBS projects are grappling with global societal issues, and working collaboratively across sectors and regions to find innovative solutions, covering a wide spectrum of social, technical, economic, environmental and political measures.

8. POLICY RECOMMENDATIONS AND KNOWLEDGE GAPS

8.1. RECOMMENDATIONS AND GAPS SPECIFIC TO NBS FOR WATER MANAGEMENT

Several H2020 projects are investigating the water management benefits of NBS as regards pollution control and reduced flashiness of stormwater flows in urban and rural areas. Very few tend to incorporate integrated monitoring or modelling of both outcomes, however, and this may prove to be problematic since the two challenges are strongly linked. Important knowledge gaps exist in terms of water quality impacts of catchment-scale habitat degradation and, conversely, WFD benefits of implementing NBS such as peatland restoration (Martin-Ortega et al., 2014). Understanding the impacts of rainfall-runoff from both water quality and quantity perspectives requires investigation of data for specific storms, using methods such as analysis of event mean concentrations to study pollution control benefits of NBS.

Similarly, cooperation on comprehensive catchment flood modelling and monitoring runoff for more frequent heavy storms (expected in many parts of Europe due to climate change) requires new ways to understand how multiple often individually small NBS can combine to deliver collectively significant natural flood management strategies. Integrating these approaches with knowledge coproduction methods in both urban and rural communities would be beneficial. Similarly, international-scale cooperation on data-sharing towards the development of open platforms (e.g. comparable with the US BMP databases) would facilitate more rapid progress.

A topic requiring further investigation that is of particular relevance to water-management NBS, but also of wider interest, involves the performance and characteristics of plants and soils for pollution control and water storage in different contexts under different maintenance regimes. This requires fundamental science and wider academic input on: (a) the impact of climate change on those qualities; (b) the supply chain of materials including plants, soils and substrates; and (c) choices as to what vegetation to plant where, considering relationships between the use of plants and landscapes for water management c.f. aesthetics, c.f. biodiversity (e.g. Kabisch et al., 2016b; Fernandes & Guiomar, 2018; Hoyle et al., 2017).

Another area where wider expertise would be beneficial involves the activities of the WFD CIS working groups, and in particular the ECOSTAT teams working on hydro-morphology and diffuse pollution. Progress has been made to develop internationally comparable monitoring regimes and scientific underpinnings relating to good ecological status and potential, but a broader range of perspectives beyond the purely technical will be required to shift - from

understanding waterbodies - towards facilitating rapid and widespread action to implement measures for achieving good status. Doing so needs insights from social researchers and political sciences as well as those with biological and technical backgrounds. In particular, input may be required from those with expertise in monetary valuation of NBS, to understand data on primarily the economic values- side, but also on the prices- side of NBS cost-benefit analyses, enabling more realistic comparisons with hard-engineered approaches especially at finer scales and in specific development contexts (e.g. Wild et al., 2017; Keeler et al., 2019; Albert et al., 2019). The challenges and opportunities therein are also linked with earlier decisions not to include aesthetics as a WFD indicator for waterbody status, in contrast with other (predecessor) classification schemes (e.g. see SEPA, 2004).

Box 38. Policy recommendation: broadening the expertise of WFD working groups

The 2019-2021 Work Programme of the Common Implementation Strategy (CIS), drafted at the time of the water legislation Fitness Check (EC, 2019b) and the WFD assessment report (EC, 2019c) reconvenes several working groups (CIRCABC, 2018). The CIS was tasked with work to investigate the financing of measures and producing a report on good practices for the identification of investment needs and financing sources for the WFD PoMs (CIS, 2018). Furthermore, its Working Groups were required to exchange information and good practices on PoMs, including a library of measures that can be used towards reaching good status. The working group on Flooding refers specifically to the use of NBS in this regard.

The working group ECOSTAT is producing technical guidance, sharing best practices and promoting exchanges of experiences on hydro-morphology. This group has undertaken substantial tasks during previous work programmes (e.g. publishing guidance documents and a mitigation measures library) and new actions have started in the context of the current work programme. This includes further comparison of methods to set Good Ecological Potential, development of a technical document on sediment management, exchange of information and sharing of best practice on methodologies to assess hydro-morphological conditions.

However a broader range of perspectives beyond the purely technical will now be required to shift from understanding waterbodies towards stimulating rapid action to achieve good status. This work would benefit from the input of social and economic research and insights from other fields (e.g. political sciences) as well as biologists and technical experts. In particular, input may be required from those with expertise in understanding the cost effectiveness and public support for ecosystem restoration, and related fields such as monetary valuation of NBS. This additional expertise will be needed if the work programme is to meet its overall aim to improve the implementation and effectiveness of measures to reach good status.

8.2. BROADER NBS POLICY RECOMMENDATIONS AND KNOWLEDGE GAPS

Calls for proposals on NBS have been extremely popular with city and regional governments, which raises some important questions as well as being a success to celebrate. Funding for Innovation Actions around climate and water resilience have been particularly popular and oversubscribed. It is important to consider the reasons why local government authorities would seek to participate in H2020, beyond the obvious benefits of innovating together with partners in strategic international networks. The funding made available by Europe is urgently required to implement NBS in cities. However, EU project funding is not exactly the easiest to administrate, and if local governments are using this income to replace statutory measures or supplement mainstream budgets, then perhaps this indicates that all is not well.

Austerity, in the form of reduced taxes to pay for public goods such as water management services, can be seen as limiting the wide uptake of NBS - even if there is an ambition and capability to use these interventions to deliver a wide range of ecosystem services in cost effective ways. The current (fashionable) focus on blended finance models and investment vehicles (e.g. recycling loans via the private sector to pay for ecosystem services) may need rethinking, particularly in locations where markets are weak or failing (Wild & Henneberry, 2020).

Other useful models to consider might entail longer-term public sector investment employing NBS at appropriately wide scales, to stimulate regeneration and promote wellbeing. Similarly, spatial planning, regulation, land value capture and tax incentives may prove to be more successful in stimulating more rapid uptake of NBS than relying solely on private sector investment. Nevertheless the market has a key role to play. Europe currently has a genuine advantage in growing knowledge economy around NBS but will not retain this lead for long without further investment, refinement and harvesting of cooperation potentials. H2020 NBS programmes would benefit from further development of knowledge exchange and 'impact-accelerator' type approaches involving the private sector. This could entail using new methods of co-production, bringing experts and research users together with stakeholders and knowledge brokers. For instance, international cooperation on SME development in NBS could be enabled through the targeted use of exchanges, secondments and placements, facilitated by more flexible project structures and financing mechanisms. Doing so could support trade within and beyond the EU in line with the original vision for the NBS 'Reference Framework', which seems to have rather dropped off the agenda.

However, as yet the underpinnings for these kinds of impacts are not fully in place. At present, the generation of programme-level data on NBS communities of practice remains underdeveloped, and this is an important gap that should be addressed. Projects may be required to collate and report data about participation of different sectors in

events, training and continual professional development activity. This would support strategic understanding and development of capacity in the emerging professional field of NBS implementation.

Such capacity-building intelligence and activity needs facilitating at both the EC-level and at the scale of individual projects. This strategic goal of professionalisation could also be supported through a tailored programme of complementary activities, for instance by developing specific strands in awards programmes and skills development initiatives (e.g. Eurostars, Marie Skłodowska-Curie Actions and Innovative Training Networks), and through the use of structured thematic calls.

A particular area of concern linked with skills and professional training relates to youth unemployment, made worse by the recent economic shocks linked with COVID-19. The lack of opportunities for young people was already a systemic problem and a significant threat to cohesion in Europe prior to the pandemic, with around half of all young people in the world unemployed or underemployed and the situation "likely to get worse" (British Academy, 2019).

In the coming years, all sectors of society will need to do much more to create a wider range of chances for skills development and professional advancement. Doing so will require patience and time due to the inevitable impacts in education and personal development associated with such a huge disruption, and its adverse effects on mental health and wellbeing. It is estimated that one billion young people will enter the labour market between 2015 and 2025, and that only 400 million of these young people will be likely to find jobs in the formal economy (World Bank, 2015). Careful consideration is required in the conception, framing and development of programmes that can bring in perspectives of young people to global sustainable development challenges. This should involve people from a wide range of socio-economic backgrounds, directly including youth themselves, to shape programmes for NBS skills development using this particular lens on societal challenges.

9. REFERENCES

Albert, C. et al. (2019). Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute? Landscape and Urban Planning, 182: 12-21.

Alterra (2012). Mitigation options for nutrient reduction in surface water and groundwaters. European Cost Action 869: www.cost869.alterra.nl.

Amoly, E. et al. (2014). Green and blue spaces and behavioral development in Barcelona schoolchildren: the Breathe project. Environmental Health Perspectives 122(12): 1351-1358.

Apostolaki, S., Jefferies, C. & Wild, T. (2005). The social impacts of stormwater management techniques. 10th international conference of urban drainage, Copenhagen, Denmark.

Ashley, R. et al. (2011). A Review of Current Knowledge Surface Water Management and Urban Green Infrastructure A review of potential benefits and UK and international practices. FR/R0014. Foundation for Water Research, Marlow, England.

Ashley, R. (2015). Synchronicity: Multiple Benefits from Green Infrastructure (Looking at SUDS from both sides now). Green Infrastructure: a growing need. 6th & 7th October 2015. Scottish Green Infrastructure Forum, Glasgow.

Bastin, J.F. et al. (2019). The global tree restoration potential. Science; 365 (6448): 76.

Bernhardt, E.S. et al. (2005). Synthesizing U.S. river restoration efforts. Science, 308(5722): 636-637.

Berndtsson, J.C. (2010). Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering 36(4): 351-360.

Bizzi, S. et al. (2016). The use of remote sensing to characterise hydromorphological properties of European rivers. Aquatic Sciences, 78(1): 57-70.

Bledsoe, B.P. et al. (2016). Stream restoration as a BMP. Report prepared for the Water Environment & Reuse Foundation (WE&RF), Alexandria, Vancouver.

Bonn, A. et al. (2016) Eds. Peatland restoration and ecosystem services: science, policy and practice. Cambridge, Cambridge University Press.

Borja, A. & Elliott, M. (2007). What does 'good ecological potential' mean, within the European Water Framework Directive? Marine Pollution Bulletin 54(10): 1559-1564.

Borja, A. et al. (2013). Transitional and coastal waters ecological status assessment: Advances and challenges resulting from implementing the European Water Framework Directive. Hydrobiologia, 704(1): 213-229.

British Academy (2019). https://www.thebritishacademy.ac.uk/programmes/youth-futures (accessed 26 November 2019).

Broadhead, A.T., Horn, R. & Lerner, D.N. (2013). Captured streams and springs in combined sewers: A review of the evidence, consequences and opportunities. Water Research 47(13): 4752-4766.

Brown, R.R., Farrelly, M.A. & Loorbach, D.A. (2013). Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. Global Environmental Change 23(4): 701-718.

Bulkeley, H. (2017). State of the Art Review: Overview. Naturvation project Deliverable 1.3. Durham University.

Burke, S. et al. (2018). Lower Danube (Romania). In: P. Van der Keur et al. (Eds.): From hazard to risk: models for the Demonstrators. H2020 NAIAD Project Deliverable D6.2.

Burke, S. et al. (2020). Innovating to understand investments in nature-based solutions for flood mitigation from the point to the Danube scale. https://platform.think-nature.eu/system/files/s8_swinkels.pdf (accessed 12 March 2020).

Campbell, N. et al. (2005). Diffuse Pollution: An Introduction to the Problems and Solutions. IWA Publishing, London.

Carvalho, L. et al. (2019). Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. Science of The Total Environment, 658: 1228-1238.

Chan, F.K.S. et al. (2018). "Sponge City" in China—a breakthrough of planning and flood risk management in the urban context. Land Use Policy, 76: 772-778.

CIRCABC (2017). Common Implementation Strategy for the Water Framework Directive and the Floods Directive: Natural Conditions in relation to WFD Exemptions. EU Water Directors, Tallinn, December 2017.

CIRCABC (2018). Common Implementation Strategy for the Water Framework Directive and the Floods Directive: Work Programme 2019-2021. EU Water Directors, Vienna, November 2018.

CIRIA (2000). Sustainable urban drainage systems - design manual for Scotland and Northern Ireland. CIRIA Report C521. Construction Industry Research and Information Association, Dundee.

CIRIA (2001). Sustainable urban drainage systems - best practice manual for England, Scotland, Wales and Northern Ireland. CIRIA Report CR086A. Construction Industry Research and Information Association, London.

CIRIA (2015). The SUDS Manual. CIRIA Report C697. Construction Industry Research and Information Association, London.

CIS (2016). WFD Reporting Guidance 2016 Final – Version 6.0.6. Common Implementation Strategy for the Water Framework Directive and the Floods Directive. EU Water Directors Meeting, Heraklion.

Clary, J. et al. (2017a). International Stormwater BMP Database 2016 summary statistics. Water Environment & Reuse Foundation. Alexandria, Virginia.

Clary, J. et al. (2017b). Agricultural BMP Database Project Summary 2017. Water Environment & Reuse Foundation. Alexandria, Virginia.

Conrad, E. et al. (2011). Rhetoric and Reporting of Public Participation in Landscape Policy, Journal of Environmental Policy & Planning, 13(1): 23-47.

Cuttle, S.P. et al. (2007). An inventory of methods to control diffuse water pollution from agriculture. DEFRA Project ES0303.

D'Arcy, B.J. et al. (2000). Diffuse pollution impacts: the environmental and economic impacts of diffuse pollution in the UK. Terence Dalton Publishers, Lavenham, Suffolk, UK. ISBN 1870752465.

Davis, A.P. et al. (2001). Laboratory study of biological retention for urban stormwater management. Water Environment Research, 73(1): 5–14.

Davis, M. & Naumann, S. (2017). Making the case for sustainable urban drainage systems as a nature-based solution to urban flooding. In: N. Kabisch et al. (Eds.) Nature-Based Solutions to Climate Change Adaptation in Urban Areas (pp 123-137). Springer, Cham.

Defra (2013). Catchment Based Approach: Improving the quality of our water environment https://www.gov.uk/government/publications/catchment-based-approach-improving-the-quality-of-our-water-environment (accessed 21 February 2020).

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: 997 - 1008.

Donovan, G.H. & Butry, D.T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. Landscape and Urban Planning. 94(2): 77-83.

EC (2012). A Blueprint to Safeguard Europe's Water Resources. COM/2012/0673. https://ec.europa.eu/environment/water/blueprint/index_en.htm (Accessed April 2020). Brussels, European Commission.

EC (2015a). Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'. European Commission, Brussels.

EC (2015b). The fourth implementation report: Assessment of the Water Framework Directive Programmes of Measures and the Flood Directive, Communication and Staff Working Documents (http://ec.europa.eu/environment/water/water-framework/impl_reports.htm#fourth).

EC (2019a). European Overview - River Basin Management Plans: accompanying the document implementation of the Water Framework Directive and the Floods Directive (Report from EC to European Parliament and Council). SWD(2019)30 final. European Commission, Brussels.

EC (2019b). Fitness Check of the Water Framework Directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive. SWD(2019)439 final. European Commission, Brussels.

EC (2019c). Report from the EC to the EU Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC): 2nd River Basin Management Plans; 1st Flood Risk Management Plans. COM(2019) 95 final. European Commission, Brussels.

EC (2019d). Evaluation of the Urban Waste Water Treatment Directive. SWD(2019)700 final. European Commission, Brussels.

Eckart, K., McPhee, Z. & Bolisetti,T. (2017). Performance and implementation of low impact development - A review. Science of the Total Environment, 607: 413-432.

EEA (2018). European Waters – Assessment of status and pressures 2018, EEA Report No 7/2018, ISSN-1977-8449. European Environment Agency, Copenhagen.

Ellis, J.B. & Mitchell, G. (2006). Urban diffuse pollution: key data information approaches for the Water Framework Directive. Water and Environment Journal, 20(1): 19-26.

Eggermont, H. et al. (2015). Nature-Based Solutions: New influence for environmental management and research in Europe. Gaia, 24(4): 243-248.

Engstrom, R. et al. (2018). Multi-functionality of nature-based and other urban sustainability solutions: New York City study. Land Degradation and Development, 29: 3653 - 3662.

Everett, G., Lawson, E. & Lamond, J. (2015). Green infrastructure and urban water management. In: D.Sinnett et al. (Eds.) Handbook on Green Infrastructure: 50-66. Edward Elgar Publishing.

Fairburn, J. & Smith, G. (2009). Environmental justice in South Yorkshire: locating social deprivation and poor environments using multiple indicators. Local Environment, 14: 139-54.

Fairburn, J., Walker, G. & Smith, G. (2005). Investigating Environmental Justice in Scotland - Links Between Measures of Environmental Quality and Social Deprivation. Report UE4(03)01. Edinburgh, SNIFFER.

Faivre, N. et al. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. Environmental Research, 159: 509-518.

Farinha-Marques, P. & Lameiras, J.L. (2017). Eastern and West-Central Asprela Parks, Porto, Portugal: a new green infrastructure to mitigate climate change in the urban context. CITTA 10th Annual Conference on Planning Research. Planning for Climate Change: Political Climate and Policy Changes. 12th May 2017 AESOP, Porto.

Ferguson, B.C., Frantzeskaki, N. & Brown, R.R. (2013). A strategic program for transitioning to a Water Sensitive City. Landscape and Urban Planning, 117: 32-45.

Fernandes, J.P. & Guiomar, N. (2018). Nature-based solutions: The need to increase the knowledge on their potentialities and limits. Land Degradation and Development 29(6): 1925-1939.

Forestry Commission (2016). Our vision for a resilient urban forest. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700389/urban-forest-final-v4.pdf

Garfí, M., Flores, F. & Ferrer, I. (2017). Life cycle assessment of wastewater treatment systems for small communities: activated sludge, constructed wetlands and high rate algal ponds. Journal of Cleaner Production, 16: 211-219.

Gellinck, L. (2013). VALUE: Valuing Attractive Landscapes in Urban Economy (project summary). In: 2013: een Plattelandsodyssee – 25 jaar VLM. https://www.vlm.be/nl/SiteCollectionDocuments/Forms/AllItems.aspx (accessed 12 March 2020).

Gerner, N.V. et al. (2018). Large-scale river restoration pays off: A case study of ecosystem service valuation for the Emscher restoration generation project. Ecosystem Services, 30: 327-338.

Glenk, K. et al. (2018). The economics of peatland restoration. Journal of Environmental Economics and Policy, 7(4): 345-362.

Gorito, A.M. et al. (2017). A review on the application of constructed wetlands for the removal of priority substances and contaminants of emerging concern listed in recently launched EU legislation. Environmental Pollution, 227: 428-443.

Green, S. et al. (2018). Methane and carbon dioxide fluxes from open and blocked ditches in a blanket bog. Plant and Soil, 424(1-2): 619-638.

Grizzetti, B. et al. (2016). Ecosystem services for water policy: Insights across Europe. Environmental Science and Policy, 66: 179-190.

Gurnell, A. et al. (2015). A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. Aquatic Sciences, 78(1): 1-6.

Gusmaroli, G. et al. (2008). Contrat de Rivière as participative decision making tool to implement River Restoration. State of art in Italy and Agogna stream case study. In 4th ECRR International Conference on River Restoration, Venice, Italy.

Haase, A. (2017). The contribution of nature-based solutions to socially inclusive urban development–some reflections from a social-environmental perspective. In: Kabisch, N. (ed.) Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Springer, Cham: 221-236.

Hanley, N. & Black, A.R. (2006). Cost-benefit analysis and the Water Framework Directive in Scotland. International Environmental Assessment and Management 2(2): 156-165.

Hart, K. et al. (2017). Case study reports Developing innovative and participatory approaches for PG/ESS delivery. PEGASUS Project Deliverable 4.3.

Hering, D. et al. (2010). The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. Science of the Total Environment, 408. 4007-4019.

Hérivaux, C., Le Coent, P. & Gnonlonfin, A. (2019). Natural capital and ecosystem services to valuate cobenefits of NBS in water related risk management. NAIAD Project Deliverable 4.4. http://naiad2020.eu/wp-content/uploads/2019/09/D4_4_FINAL_Edited.pdf

Hoyle, H., Hitchmough, J. & Jorgensen, A. (2017). Attractive, climate-adapted and sustainable? Public perception of non-native planting in the designed urban landscape. Landscape and Urban Planning, 164: 49-63.

Izydorczyk, K. et al. (2019). The ecohydrological approach, SWAT modelling, and multi-stakeholder engagement–A system solution to diffuse pollution in the Pilica basin, Poland. Journal of Environmental Management, 248: 109329.

Jensen, I.H. et al. (2014). Demonstration of integrated real time control of sanitation systems incl. early warning for WQ in receiving waters in Aarhus. PREPARED Project Report 2014.047, Deliverable D1.3.4.

Jones, J. et al. (2019). A comprehensive assessment of stream fragmentation in Great Britain. Science of the Total Environment, 673: 756-762.

Kabsich, N. et al. (2016a). Adding natural areas to social indicators of intra-urban health inequalities among children: a case study from Berlin, Germany. International Journal of Environmental Research & Public Health 13(8): 783.

Kabisch, N. et al. (2016b). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society 21(2): 39.

Kail, J. & Wolter, C. (2011). Analysis and evaluation of large-scale river restoration planning in Germany to better link river research and management. River Research & Applications 27(8): 985-999.

Kang, C.D. & Cervero, R. (2009). From Elevated Freeway to Urban Greenway: Land Value Impacts of the CGC Project in Seoul, Korea. Urban Studies, 46: 2771–2794.

Kay, P. et al. (2012). The effectiveness of agricultural stewardship for improving water quality at the catchment scale: experiences from an NVZ and ECSFDI watershed. Journal of Hydrology, 422-423: 10-16.

Kazmierczak, A. & Carter, J. (2010). Adaptation to climate change using green and blue infrastructure. A database of case studies. Interreg IVC GraBS project. University of Manchester, England.

Keeler, B.L. et al. (2019). Social-ecological and technological factors moderate the value of urban nature. Nature Sustainability, 2(1): 29-38.

Knickel, K. & Maréchal, A. (2018). Stimulating the social and environmental benefits of agriculture and forestry: An EU-based comparative analysis. Land Use Policy, 73: 320-330.

Kovacs, A.S., Fulop, B. & Honti, M. (2012). Detection of Hot Spots of Soil Erosion and Reservoir Siltation in Ungauged Mediterranean Catchments, Energy Procedia, 18: 934-943.

Krzeminski, P. et al. (2019). Performance of secondary wastewater treatment methods for the removal of contaminants of emerging concern implicated in crop uptake and antibiotic resistance spread: A review. Science of the Total Environment 648: 1052-1081.

Lawrence, R. et al. (2019). Rethinking conceptual frameworks and models of health and natural environments. Health, 23(2): 158-79.

Li, Z. et al. (2018). Objectives and indexes for implementation of sponge cities-A case study of Changzhou City, China. Water (Switzerland), 10(5): 623.

de Leeuw J.J. et al. (2007). Challenges in developing fish-based ecological assessment methods for large floodplain rivers. Fisheries Management & Ecology 14(6): 483-494.

Liquete C. et al. (2016). Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. Ecosystem Services, 22: 392-401.

Maes, J. et al. (2015). ESS trends 2000-2012. Mapping and Assessment of Ecosystems and their Services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. Report EU 27143 EN.

Marsalek, J. (1991). Pollutant loads in urban stormwater: review of methods for planning level estimates. Water Resources Bulletin, 27(2): 283–291.

Martin-Ortega, J. et al. (2014). Valuing water quality improvements from peatland restoration: Evidence and challenges. Ecosystem Services, 9: 34-43.

Masi, F. et al. (2017). Constructed wetlands for combined sewer overflow treatment: Ecosystem services at Gorla Maggiore, Italy. Ecological Engineering, 98: 427-438.

Mateo-Sagasta, J. et al. (2017). Water pollution from agriculture: a global review. International Water Management Institute / Food and Agriculture Organisation of the UN (FAO), Rome.

May, L. & Spears, B.M. (2012). Loch Leven: 40 years of scientific research. Understanding the links between pollution, climate change and ecological response. Developments in Hydrobiology, 218: 130.

McGonigle, D.F. et al. (2012). Towards a more strategic approach to research to support catchment-based policy approaches to mitigate agricultural water pollution: A UK case-study, Environmental Science and Policy, 24: 4-14.

Mell, I.C. et al. (2013). Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry and Urban Greening, 12(3): 296-306.

Mielke, B. (2008). The costs and benefits of landscape quality enhancements on brownfield sites. In: CSI, 2008. Creating a Setting for Investment Project Report: 38-42. SYFP, Sheffield.

Mitchell, G. (2005). Mapping hazard from urban non-point pollution: a screening model to support sustainable urban drainage planning. Journal of Environmental Management, 74(1): 1-9.

Mitsch, W.J. & Gosselink, J.G. (2000). The value of wetlands: importance of scale and landscape setting. Ecological Economics, 35(1): 25-33.

Montalto, F. et al. (2007). Rapid assessment of the cost-effectiveness of low impact development for CSO control. Landscape and Urban Planning, 82(3): 117-131.

Mukhtarov, F. et al. (2019). Collaborative learning for policy innovations: sustainable urban drainage systems in Leicester, England. Journal of Environmental Policy and Planning, 21(3): 288-301.

Mulligan, M. et al. (2019). Guidelines on the Eco:Actuary Policy Support System for understanding the role of Natural Flood Management (NFM) in flood mitigation. NAIAD Project Deliverable 2.5.

Nagabhatla, N., Springgay, E. & Dudley, N. (2018). Forests as nature-based solutions for ensuring urban water security. Unasylva, 69(250): 43-52.

National Audit Office. 2010. Tackling diffuse water pollution in England. Report by the Comptroller and Auditor General. London, National Audit Office. HC 188 Session 2010-2011.

Nesshöver, C. et al. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of the Total Environment, 579: 1215-1227.

Netusil, N.R. et al. (2014). Valuing green infrastructure in Portland, Oregon, Landscape and Urban Planning, (124), 14-21. ISSN 0169-2046.

Newell-Price, J.P. et al. (2011). An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture. Defra Project WQ0106: http://randd.defra.gov.uk

Netusil, N.R. et al. (2014). Valuing green infrastructure in Portland, Oregon. Landscape and Urban Planning, 124: 14-21.

Ngai, R. et al. (2017). Working with Natural Processes – Evidence Directory. Appendix 2. Literature review. Project SC150005. Environment Agency, Bristol.

Nisbet, T. et al. (2011) Woodland for Water: Woodland measures for meeting Water Framework Directive objectives. Forest Research Monograph, 4: 156, Forest Research, Surrey.

Novotny, V. & Olem, H. (1994). Water Quality: Prevention and Management of Diffuse Pollution. Van Nostrand-Reinhold, New York. ISBN 978-0442005597.

Oen, A.M.P. et al. (2019). PHUSICOS Work Package 1 Report. 776681_D1.4: 77.

ONS (2019). UK natural capital: peatlands. Office for National Statistics, Fareham. https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapitalforpeatlands/naturalcapitalaccounts#executive-summary (accessed 12 March 2020).

Oral, H.V. et al. (2020). A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature. Blue-Green Systems, 2(1): 112-136.

Ossola, A. et al. (2018). The provision of urban ecosystem services throughout the private-social-public domain: a conceptual framework. Cities and the Environment 11(1):1.

Palmer, M.A., Filoso, S. & Fanelli, R.M. (2014). From ecosystems to ecosystem services: Stream restoration as ecological engineering. Ecological Engineering, 65: 62-70.

Palmer, M.A., Menninger, H.L. & Bernhardt, E. (2010). River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? Freshwater Biology, 55(1): 205-222.

Pérez-Soba, M. et al. (2016). Review of approaches and datasets to categorise and map Public Goods and Ecosystem Services at EU level. PEGASUS Project Deliverable 2.1.

Piégay, H. et al. (2020). Remotely sensed rivers in the Anthropocene: state of the art and prospects. Earth Surface Processes and Landforms 45(1): 157-188.

Pinkham, R. (2000). Daylighting: New Life for Buried Streams. Old Snowmass, Colorado, Rocky Mountain Institute.

Pritchard, R. & Brockington, D. (2019). Forests: regrow with locals' participation. Nature, 569 (7758): 630.

Puttock, A. et al. (2017). Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands. Science of the Total Environment, 576: 430-443.

Qin, H.P., Li, Z.X. & Fu, G. (2013). The effects of low impact development on urban flooding under different rainfall characteristics. Journal of Environmental Management, 15(129): 577-85.

Rica, M. et al. (2017). Institutional analysis report: baseline analysis and policy recommendations. NAIAD Project Deliverable 3.2.

Richter, S. et al. (2013). The Water Framework Directive as an approach for Integrated Water Resources Management: Results from the experiences in Germany on implementation, and future perspectives. Environmental Earth Sciences, 69(2): 719-728.

Rijke, J. et al. (2012) Room for the River: delivering integrated river basin management in the Netherlands, International Journal of River Basin Management, 10(4): 369-382.

Salbitano, F. et al. (2016). FAO Guidelines on urban and peri-urban forestry. Food & Agriculture Organization of the UN, Rome. http://www.fao.org/3/a-i6210e.pdf.

Schirmer, M. et al. (2014). Morphological, hydrological, biogeochemical and ecological changes and challenges in river restoration – the Thur River case study. Hydrology and Earth Systems Sciences, 18: 2449–2462.

Schleyer, C. et al. (2015). Policy analysis of key regulatory frameworks within Europe. OpenNESS Project Deliverable 2.1.

Scholes, L., Revitt, D.M. & Ellis, J.B. (2008). A systematic approach for the comparative assessment of stormwater pollutant removal potentials. Journal of Environmental Management, 88(3): 467-478.

SEPA (2004). National Water Classification 2004. https://www.sepa.org.uk/media/38540/water-quality-classification-2004.pdf. (accessed March 2020). Scottish Environment Protection Agency, Falkirk.

Steyaert, P. & Ollivier, G. (2007). The European Water Framework Directive: how ecological assumptions frame technical and social change. Ecology and Society 12(1): 25.

Trinomics & Wood (2019). Fitness Check Evaluation of the Water Framework Directive and the Floods Directive. Study contract for European Commission DG ENV.

Twohig-Bennett, C. & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environmental Research, 166: 628-37.

UNECE (1998). Aarhus Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters. UN Economic Commission for Europe, Aarhus, Denmark www.unece.org/env/pp/treatytext.htm.

van den Bosch, M., & Sang, Å.O. (2017). Urban natural environments as nature-based solutions for improved public health - A systematic review of reviews. Environmental Research, 158: 373-384.

Verdonschot, P.F.M. et al. (2013). A comparative review of recovery processes in rivers, lakes, estuarine and coastal waters. Hydrobiologia, 704(1): 453-474.

Verweij, P. et al. (2016). QUICKScan as a quick and participatory methodology for problem identification and scoping in policy processes. Environmental Science & Policy, 66: 47-61.

Vinten, A.J.A. et al. (2004). Appraisal of rural BMPs for controlling diffuse pollution and enhancing biodiversity. SNIFFER Project WFD13. Edinburgh, SNIFFER.

de Vries, S. et al. (2003). Natural environments—healthy environments? An exploratory analysis of the relationship between greenspace and health. Environment and Planning A, 35(10): 1717-1731.

Westling, E.L. et al. (2014). Developing adaptive capacity through reflexivity: lessons from collaborative research with a UK water utility. Critical Policy Studies, 8(4): 427-446.

Westling, E.L. et al. (2019). Reflexive adaptation for resilient water services: Lessons for theory and practice. Global Environmental Change, 57: 101937.

Westerlink, J. & van Doorn, A. (2016). Case study 'Skylark' (Netherlands). Pegasus project deliverable D4.1(23). http://pegasus.ieep.eu/case-studies/list-of-case-studies#netherlands

WEF (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. WEF, Geneva.

Wild, T.C., Dempsey, N. & Broadhead, A.T. (2019). Volunteered information on nature-based solutions Dredging for data on deculverting. Urban Forestry and Urban Greening, 40: 254-263.

Wild, T.C. et al. (2003). An Evaluation of SUDS and Urban Diffuse Pollution and Reference Material. Proceedings of the Second National Conference on Sustainable Drainage Coventry University.

Wild, T.C. et al. (2011). Deculverting: Reviewing the evidence on the 'daylighting' and restoration of culverted rivers. Water and Environment, 25(3): 412-421.

Wild, T.C., Freitas, T. & Vandewoestijne, S. (2020) Eds. Nature-based Solutions: State of the Art in EU-funded Projects. Luxembourg: Publications Office of the European Union. ISBN: 978-92-76-17334-2. doi: 10.2777/236007.

Wild, T.C. & Henneberry, J.M. (2020). Nature-based solutions and water challenges: financing an accelerated transition to more sustainable cities using NBS. In C.Herzog et al. (Eds.). EU-Brazil Sector Dialogue on Nature-Based Solutions. EC, Brussels. ISBN: 978-92-76-18445-4; doi:10.2777/95912

Wild, T.C., Henneberry, J.M. & Gill, L. (2017). Comprehending the multiple 'values' of green infrastructure - valuing nature-based solutions for urban water management, from multiple perspectives. Environmental Research, 158: 179–187.

Wild, T.C., Jefferies, C. & D'Arcy, B.J. (2002). SUDS in Scotland - the Scottish SUDS database. SNIFFER Final Report SR(02)09. Edinburgh, SNIFFER.

Wild, T.C., Ogden, S. & Lerner, D.N. (2008). An innovative partnership response to the management of urban river corridors - Sheffield's River Stewardship Company. 11th International Conference on Urban Drainage, Edinburgh. IAHR/IWA.

Winkler, K. & Schleyer, C. (2015). Policy Analysis: Water Framework Directive. http://www.openness-project.eu/sites/default/files/OpenNESS%20D2.1 %20Paper%20on%20the%20policy%20analysis%20WP2_ANNEXES.pdf.

Wong, T. (2006). Australian Runoff Quality: A Guide to Water Sensitive Urban Design. ISBN 0 85825 852 8, Engineers Australia, Canberra, Australia.

World Bank (2015). https://www.worldbank.org/en/news/press-release/2015/10/13/addressing-the-youth-employment-crisis-needs-urgent-global-action (accessed 25 March 2020).

Zawadzka, J. et al. (2019). Ecosystem services from combined natural and engineered water and wastewater treatment systems: Going beyond water quality enhancement. Ecological Engineering, X (2): 100006.

Zhou, Q. (2014). A Review of sustainable urban drainage systems considering the climate change and urbanization impacts. Water, 6: 976-992.

10. ANNEX 1. LIST OF REVIEWED PROJECTS

AMBER (Adaptive Management of Barriers in European Rivers). H2020, Jun 2016 – Sep 2020, EU contribution €6,020,172, project link

AQUACROSS (Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies), H2020, Jun 2015 – Nov 2018, EU contribution: €6,343,614, project link

AQUANES (Demonstrating synergies in combined natural and engineered processes for water treatment systems), H2020, Jun 2016 – May 2019, EU contribution: €7,837,292, project link

AQUAVAL (Sustainable Urban Water Management Plans, promoting SUDS and considering Climate Change, in the Province of Valencia), LIFE, Jan 2010 – Sep 2013, EU contribution: €499,458, project link

CLEARING HOUSE (Collaborative Learning in Research, Information-sharing and Governance on How Urban tree-based solutions support Sino-European urban futures), H2020, Sep 2019 – Aug 2023, EU contribution: €4,986,464, project link

CLEVER CITIES (Co-designing Locally tailored Ecological solutions for Value added, socially inclusivE Regeneration in Cities), H2020, Jun 2018 – May 2023, EU contribution: €14,214,661, project link

CONEXUS (CO-producing Nature-based solutions and restored Ecosystems: transdisciplinary neXus for Urban Sustainability), H2020, Sep 2020 – Aug 2024, EU contribution: €4,999,940, project link

CONNECTING (Connecting Nature), H2020, Jun 2017 – May 2022, EU contribution: €11,394,282, project link

DESSIN (Demonstrate Ecosystem Services Enabling Innovation in the Water Sector), FP7, Jan 2014 – Dec 2017, EU contribution €5,980,942, project link

ECOADAPT (Ecosystem-based strategies and innovations in water governance networks for adaptation to climate change in Latin American Landscapes), FP7, Jan 2012 – Jan 2016, EU contribution: €1,899,000, project link

EKLIPSE (Establishing a European Knowledge and Learning Mechanism to Improve the Policy-Science-Society Interface on Biodiversity and Ecosystem Services), H2020, Feb 2016 – Jul 2020, EU contribution: €2,997,272, project link

EKOROB (ECOtones for Reducing Diffusion Pollution), LIFE+, Jan 2010 - Sep 2015, EU contribution: €624,368, project link

GREEN SURGE (Biocultural diversity, green infrastructure and ecosystem services), FP7, Nov 2013 – Oct 2017, EU contribution: €5,701,837, project link

GROW GREEN (Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments), H2020, Jun 2017 - May 2020, EU contribution: €11,224,058, project link

MARS (Managing Aquatic ecosystems and water Resources under multiple Stress), FP7, Feb 2014 – Jan 2018, EU contribution: €8,996,782, project link

MOORLIFE (Moor Life 2020), LIFE+, Oct 2015 – Feb 2021, EU contribution: €11,984,887, project link

NAIAD (Nature Insurance Value: Assessment & Demonstration), H2020, Dec 2016 – May 2020, EU contribution: €4,994,370, project link

NATURAL COURSE (Integrated water management approach to delivery of the North West England River basin management plan). LIFE-IP, Jan 2015 – Dec 2019, EU contribution: €11,988,811, project link

NATURE4CITIES (Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models). H2020, Nov 2016 – Oct 2020, EU contribution: €7,499,981, project link

NATURVATION (NATure-based URban innoVATION), H2020, Nov 2016 – Oct 2020, EU contribution: €7,797,878, project link

OPENNESS (Operationalization of natural capital and ecosystem services), H2020, Dec 2012 – May 2017, EU contribution: €8,999,193, project link

OPERANDUM (OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risks), H2020, Jul 2018 – Jun 2022, EU contribution: €12,257,343, project link

OPERAS (Operational Potential of Ecosystem Research Applications), FP7, Dec 2012 – Nov 2017, EU contribution: €8,997 910, project link

OPTWET (Finding optimal size and location for wetland restoration sites for best nutrient removal performance using spatial analysis and modelling), H2020, Apr 2015 – Mar 2018, EU contribution: €240,507, project link

PEGASUS (Stimulating long-lasting improvements in the delivery of social, economic and environmental benefits from PEARL agricultural and forest land), H2020, Mar 2015 – Feb 2018, EU contribution: €2,977,525, project link

PHENOTYPE (Positive health effects of natural outdoor environments in typical populations in different regions in Europe), FP7, Jan 2012 – Dec 2015, EU contribution: €3,499,403, project link

PHUSICOS ("According to nature": Solutions to reduce risk in mountain landscapes), H2020, May 2018 - Apr 2022, EU contribution: €9,472,200, project link

POWER (Political and sOcial awareness on Water EnviRonmental challenges), H2020, Dec 2015 – Nov 2019, EU contribution: €3,747,938, project link

PREPARED (Prepared Enabling Change). FP7, Feb 2010 – Jan 2014, EU contribution €6,993,815, project link

PROGIREG (productive GI for post-industrial urban regeneration: nature for renewal), H2020, Jun 2018 – May 2023, EU contribution: €10,432,512, project link

RAMSES (Reconciling Adaptation, Mitigation and Sustainable Development for Cities), FP7, Oct 2012 – Sep 2017, EU contribution: €5,200,000, project link

RECONECT (Regenerating ECOsystems with Nature-based solutions for hydro-meteorological risk rEduCTion), H2020, Sep 2018 – Aug 2023, EU contribution: €13,520,690, project link

RECREATE (REsearch network for forward looking activities and assessment of research & innovation prospects in the fields of Climate, Resource Efficiency & raw mATErials), H2020 Jul 2013 – Jun 2018, EU contribution: €2,996,868, project link

REFORM (Restoring rivers for effective catchment management), FP7, Nov 2011 – Oct 2015, EU contribution: €6,997,603, project link

RESIN (Climate Resilient Cities and Infrastructures), H2020, May 2015 – Oct 2018, EU Contribution: €7,466,004, project link

ROBIN (Role Of Biodiversity In climate change mitigatioN), FP7, Nov 2011 – Oct 2015, EU contribution: €6,985,678, project link

TURAS (Transitioning towards Urban Resilience and Sustainability), FP7, Oct 2011 – Sep 2016, EU contribution: € 6,813,819, project link

UNALAB (Urban Nature Labs), H2020, Jun 2017 – May 2020, EU contribution: €12,768,932, project link

URBAN GREENUP (New Strategy for Re-Naturing Cities through Nature-Based Solutions), H2020, Jun 2017 – May 2020, EU contribution: €13,970,642, project link

URBINAT (Healthy corridors as drivers of social housing neighbourhoods for the co-creation of social, environmental and marketable NBS), H2020, Jun 2018 – May 2023, EU contribution: €13,019,300, project link

WISER (Water bodies in Europe: Integrative Systems to assess Ecological status and Recovery), FP7, Mar 2009 – Feb 2012, EU contribution: €6,984,092, project link

11. ANNEX 2. ABBREVIATIONS AND ACRONYMS

ADHD	Attention Deficit Hyperactivity Disorder
AMR	Antimicrobial Resistance
BGI	Blue-Green Infrastructure
BMPs	Best Management Practices
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CEC	Contaminants of Emerging Concern
CIS	Common Implementation Strategy (Water Framework Directive)
COST	Cooperation in Science and Technology Programme
CO2	Carbon Dioxide
CSO	Combined Sewer Overflow
EASME	Executive Agency for Small and Medium-sized Enterprises
EBA	Ecosystem-based Adaptation
EBM	Ecosystem-based Management
EC	European Commission
ECJ	Court of Justice of the European Union
Eco-DRR	Ecosystem-based Disaster Risk Reduction
ECOSTAT	Ecological Status Working Group (Water Framework Directive)
EEA	European Environment Agency
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
EU	European Union
FD	Floods Directive
FP6	6th Framework Programme
FP7	7th Framework Programme
GEP	Good Ecological Potential
GHG	Greenhouse Gases
GI	Green Infrastructure
GIS	Geographical Information Systems
GVA	Gross Value-Added
GWD	Groundwater Directive
H2020	Horizon 2020 EU Framework Programme for Research & Innovation
HMWB	Heavily Modified Water Bodies
IPBES	Intergovernmental Platform on Biodiversity & Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JPI	Joint Programming Initiative
KTM	Key Types of Measures
LID	Low Impact Development
MAES	Mapping and Assessment of Ecosystems and their Services
MS	Member States of the EU

NBS	Nature-Based Solutions
NCFF	Natural Capital Financing Facility
NCP	Nature's Contributions to People
NFM	Natural Flood-risk Management
NGO	Non-Governmental Organisation
NWRM	Natural Water Retention Measures
PoM	Programme of Measures
RBMP	River Basin Management Plan
SDG	Sustainable Development Goals
SME	Small and Medium Sized Enterprises
SUDS	Sustainable Urban Drainage Systems
UN	United Nations
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WHO	World Health Organisation
WSUD	Water Sensitive Urban Design
WTP	Willingness-To-Pay
WWTW	Waste Water Treatment Works

Image credits:
Cover: © Visual Generation, #338248360; ©Visual Generation, #348620988, 2020. Source: stock.adobe.com
Page 13: © Tom Wild. Page 17, Figure 1a-c, © Tom Wild. Page 18: Figure 2a, NAIAD Project, © Field Factors. Page 18: 2b, UNALAB Project, © L. Postmes. Page 18: Figure 2c, © Tom Wild. Page 18: Figure 2d, © Naturvation Project. Page 18: Figure 2e, Regreen Project, © ARB iDF. Page 18: Figure 2f, Urban GreenUp Project, © Jesus Gomez Perez. Page 19: Figure 2g, © Tom Wild. Page 19: Figure 2h, UNALAB Project, © L Postmes. Page 19: Figure 2i, UNALAB Project, © Salla Leppänen. Page 19: Figure 2j-m, CONEXUS Project, © Tom Wild. Page 19: Figure 2n, © Tom Wild. Page 19, Figure 2o-p, VALUE Project, © Tom Wild. Page 19: Figure 2p, VALUE Project, © Tom Wild. Page 19: Figure 2q, SEEDS Project, VALUE Project, © Tom Wild. Page 19:. Figure 2r, © Tom Wild. Page 22: Figure 3a-e, © Sheffield City Council. Page 25: Figure 4a-b, © Tom Wild. Page 25: Figure 4c-d, Clearing House Project, © Clive Davies. Page 25: Figure 4e-f, Urban GreenUp Project, © Tim Jervis. Page 30: Figure 5a, © PHUSICOS Project. Page 30: Figure 5b, © OPERANDUM Project. Page 31: Figure 5c, © Tom Wild. Page 31: Figure 5d, SEEDS Project, © Tom Wild. Page 34: Figure 6a-d, SEEDS Project, © Tom Wild. Page 35: Figure 7a-b, © BHA Team, Frauenfield. Page 38: Figure 8a-b, © URSULA Project Team. Page 41: Figure 9, © Tom Wild.

Getting in touch with the EU

IN PERSON

All over the European Union there are hundreds of Europe Direct information centres.
You can find the address of the centre nearest you at:
https://europa.eu/european-union/contact_en

ON THE PHONE OR BY EMAIL

Europe Direct is a service that answers your questions about the European Union.
You can contact this service:

– by freephone: **00 800 6 7 8 9 10 11** (certain operators may charge for these calls),

– at the following standard number: **+32 22999696**, or

– by email via: **https://europa.eu/european-union/contact_en**

Finding information about the EU

ONLINE

Information about the European Union in all the official languages of the EU is available on the Europa website at: **https://europa.eu/european-union/index_en**

EU PUBLICATIONS

You can download or order free and priced EU publications from:
https://op.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see **https://europa.eu/european-union/contact_en**)

EU LAW AND RELATED DOCUMENTS

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: **http://eur-lex.europa.eu**

OPEN DATA FROM THE EU

The EU Open Data Portal (**http://data.europa.eu/euodp/en**) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

This document summarises outcomes relating to water quality and waterbody conditions from the report 'Nature-based Solutions: State of the Art in EU-funded Projects' (Wild et al. (Eds.) 2020) prepared through the EC's Valorisation of NBS Projects Initiative. EU research and innovation projects were scanned for results pertaining to key areas such as Water Framework Directive implementation, cross-compliance with the Common Agricultural Policy, catchment management, diffuse pollution and waterbodies. Evidence from the reviewed projects (and the EC's NBS policy topic area) is framed within knowledge from the literature in the realm of water policy, to give as full a picture as possible about the state of the art with relevant NBS. Contextualised information is provided on policy developments, research results and key lessons. The resulting evidence base includes figures and monetary values showing the relative cost-effectiveness of NBS, and exploring how they support water policy implementation. Policy recommendations and knowledge gaps are also highlighted to support the strengthening of strategies and practical action for the uptake of NBS, to deliver targeted and efficient interventions to help solve societal challenges in Europe and beyond.

Studies and reports

Publications Office
of the European Union