Naturally Resilient

Final Draft report

Wildlife and Countryside Link

Project number: 60608287

03 July 2020

Quality information

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Revision History

Revision	Revision date	Details	Authorised	Name	Position
1	06/03/2020	Draft Report	06/03/2020	Katie Pearson	Project Manager
2	24/05/2020	Final Draft Report	24/05/2020	Katie Pearson	Project Manager

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Table of Contents

Executive summary 5
1. Introduction 10
2. Overview of approach 13
3. Interdependencies between the water sector and the natural water environment 18
4. Definition, principles and metrics for resilience 22
5. Legislation, regulatory frameworks, policies and incentives to enhance resilience 35
6. Key stakeholders 53
7. Current and future risks to resilience 61
8. Managing risks to resilience through collaboration 71
9. Summary of key findings 93
10. Recommendations 98
Glossary 103
Bibliography 104
Appendix A – Online survey questionnaire 107
Appendix B – Case studies 114
Appendix C – Defining resilience: Supporting information 136
Appendix D – Key stakeholders: Supporting information 154
Appendix E – Interdependencies between sectors: Supporting information 170
Appendix F – Current and future risks to resilience: Supporting information 188
Appendix G – Managing risks to resilience through collaboration: Supporting information 205

Figures

Figure 3-1: Interdependencies between the water sector and the natural water environment 21
Figure 4-1: Key Considerations for Delivery of Resilience 24
Figure 8-1: Summary of management opportunities identified by survey respondents 72
Figure 8-2 Perceived 'blockers' of collaboration between the water sector and the natural environment to enhance resilience (online survey; n=16) 89
Figure 10-1: Flow Chart for Resilience Projects Involving the Water Industry and Natural Water Environment 99

Tables

Table 2-1: Selected case studies 15
Table 4-1: Common themes across definitions of resilience in the literature 23
Table 4-2: Recommended Resilience Metrics for Environmental Systems 29
Table 4-3: Recommended Resilience Metrics for Water Companies 30
Table 4-4: Use of Resilience Metrics in Case Studies 32
Table 5-1: Legislation, regulatory frameworks, policies and incentives for enhanced resilience 35
Table 5-2: Review of Impacts of Legislation on Case Studies 51
Table 6-1: Sectoral overview of key stakeholders with respect to enhancing resilience (in alphabetical order) 53
Table 6-2: Key stakeholders with respect to enhancing resilience (in alphabetical order) 53
Table 6-3: UKWIR's Big Questions 55
Table 6-4: Sectoral mapping of key stakeholders against UKWIR priorities (in alphabetical order) 56
Table 6-5: Mapping of key stakeholders against UKWIR priorities (in alphabetical order) 58
Table 7-1: Risks themes for the water sector and the natural environment 61
Table 7-2: Survey respondents' views on top risks to resilience 66
Table 7-3: Survey respondents' top five current and future risks to resilience (n=16) 67

Table 7-4: Effects on people due to potential for risk to materialise 69
Table 8-1: Management Measures for Risks Themes 73
Table 8-2: Effect of joint risks to resilience on interdependencies within the water environment 78
Table 8-3: Summary of Stakeholder Collaboration in Resilience Case Studies 80
Table 8-4: Mapping of key stakeholders against risk management measures (in alphabetical order) . 83
Table 8-5: Sectoral mapping of key stakeholders against risk management measures 86
Table 9-1: Sectoral overview of key stakeholders with respect to enhancing resilience (in alphabetical order) 95
Table 9-2: Survey respondents' top five current and future risks to resilience (n=16) 96

Executive summary

Project Background & Aims

AECOM were commissioned by Wildlife and Countryside Link on behalf of a partnership of water companies and environmental NGOs entitled *Naturally Resilient.* The steering group formed from this partnership to lead the project consisted of representatives from Wildlife and Countryside Link, Thames Water. The overarching aim of the project is to explore the interplay between resilience in the water sector and resilience of the natural environment.

The water sector is critically dependent on the resilience of the natural environment, in particular the water environment (e.g. rivers, lakes, groundwaters, etc.). Similarly, the resilience of the water environment depends on sustainable and managed abstraction and discharges by water-dependent sectors including water companies. This interdependency between sectors has become increasingly evident in recent years, particularly given the growing recognition that we are in a climate and biodiversity emergency.

The observation that improving the resilience of the natural environment enhances the sustainability and resilience of water companies is complemented by Ofwat's recommendation that water companies should achieve 'resilience in the round' (Ofwat, 2017b).

In 2018, Defra's *National Policy Statement for Water Resources Infrastructure* required Ofwat to further the resilience of ecosystems by encouraging the sustainable use of "natural capital" in water company plans (Defra, 2018c). Most recently, the currently proposed Environment Bill[1] recognises resilience in the context of the water environment (HM Government, 2020) and includes measures to help secure long-term, resilient water and wastewater services and solutions to drought and flooding.

In future, therefore, the water sector needs to move away from simply managing disruption, and toward building a capacity to withstand disruption. The report examines how a 'naturally resilient' approach can assist water companies in managing future challenges and pressures.

The overarching aim of this project was to explore the interplay between resilience in the water sector and resilience of the natural environment, as well as how investments in one of the sectors can benefit both.

The specific objectives of the project were to:

1. Explore the definitions, principles and metrics in both sectors around resilience and how they could be used to prioritise action and gauge progress;
2. Identify the interdependencies between ecosystem resilience and water sector resilience using examples across the water cycle;
3. Set out areas of current and future risk to resilience for both sectors due to factors such as climate change, increased water demand and changing societal behaviours;
4. Describe opportunities for the two sectors to work together to improve resilience alongside the regulatory frameworks/incentives that would encourage it;
5. Identify the key stakeholders beyond the two sectors, especially those with wider responsibilities for improving water environment resilience and those who depend on it; and
6. Identify important gaps in knowledge and develop recommendations for any future work.

[1] At the time of finalising this report (May 2020), the passage of the Environment Bill was delayed during consideration by the Public Bill Committee by circumstances associated with the Covid-19 pandemic (https://services.parliament.uk/bills/2019-21/environment.html)

Method

The project focused on the water environment in England and developed a body of evidence to support the uptake of more naturally resilient approaches to water resource management and the natural environment. The project was undertaken following a task based approach with the deliverable at the end of each task reviewed and approved by the Steering Group before progress on to the next task.

The evidence body identified through this project and presented in this report was developed through an:

- Iterative literature review covering definition, principles and metrics for resilience and legislation, regulatory frameworks and policies;
- Online stakeholder survey on the perceived current and future risks to resilience; and
- Use of case studies to demonstrate where and how the environmental and water sectors have collaborated to enhance resilience.

Findings & Recommendations

The top current and future risks to resilience in both the water industry and the natural water environment identified through this project are:

a. Environmental degradation;
b. Climate change;
c. Natural hazards;
d. Political or regulatory frameworks, and;
e. Socio-economic factors such as population growth.

Each of these risks impact on the key interdependent ecosystems services which are important for the resilience of both the water industry and the natural water environment, as follows:

f. Water quality regulation;
g. Soil quality regulation;
h. Wild species diversity;
i. Disease and pest control;
j. Water supply;
k. Global climate regulation;
l. Hazard regulation, and;
m. Recreation.

The management measures that can help address these risks include managing catchments and land, managing housing developments and managing water supply and demand and will require multiple stakeholder input. These stakeholders' remits include delivery of actions which will impact on, and could assist, water company actions to deliver industry resilience as set out in UKWIR's 12 'Big Questions.'

This study emphasises the complexity of resilience in terms of the water environment, with many inter-related factors and numerous affected stakeholders. This complexity makes it difficult to give specific recommendations which will address the resilience of the system as a whole. Instead, work to address resilience should begin with identifying a specific problem and relating that problems to the natural water environment or water industry actions. This gives a clear objective to be addressed by any proposed actions and assists with identifying and communicating with stakeholders. Actions to address the problem through improved environmental resilience should be related to delivery of multiple benefits. A key consideration is to record all outcomes from all projects, regardless of success or failure, in order to build up the evidence base and inform the design of future projects.

The nature of environmental resilience means that a combination of localised and more generalised, national measures will be necessary in the long term and this may require proactive lobbying of government departments to strengthen policy and legislative direction. Four key recommendations for large sale, long term measures are set out below.

Recommendation 1

Develop an online repository of case studies

Overview

Resilience project case studies need to be collated in an online, searchable database which is maintained and easy to contribute to. This will help build the evidence base to show the value of improved resilience, provide examples of good practice and set out lessons learnt. It could refer to, or expand on, the CaBA website which already has a series of readily available examples to draw from. Alternatively, this recommendation could be delivered through UKWIR in order to capture more industry-centric projects such as work to manage new technology and address security risks, although this may risk excluding projects which do not include a water industry stakeholder.

Recommendation 2

Develop agreed metrics for resilience

Overview

Section 4 reported that there is currently no published set of metrics for resilience across the water sector and the natural environment which consistent, comparable and centralised. There are a range of sources with potentially relevant metrics including:

- The metrics used to monitor water companies' performance commitments (including on Discover Water[2]).
- The metrics from Wildlife Countryside Link's Blueprint for Water (WCL, 2017).
- The metrics used by the Natural Capital Committee in its State of Natural Capital Reports.[3]
- Natural England's natural capital indicators.[4]

Drawing on the case studies in the online database, as well as their own specialist knowledge, water companies and other stakeholders should come together to advise regulators on an appropriate list of metrics to:

- establish a baseline so that environmental resilience can be monitored in future;
- justify future investments in resilience by the water industry;
- secure stakeholder support and partnership in future projects, and;
- communicate with customers to demonstrate how their actions help enhance environmental resilience and the resilience of their water and wastewater services.

The initial stage of this work would include workshops with representatives from the water industry, regulators and stakeholders in the environmental sector to discuss and agree a priority list of metrics. This may include, or lead onto, a discussion of what type of metrics, indicators and criteria might be needed to justify investment in environmental resilience within PR24 business plans.

Recommendation 3

Work to improve and rationalise the legislative and policy framework for environmental resilience.

Overview

[2] See https://discoverwater.co.uk/
[3] See https://www.gov.uk/government/groups/natural-capital-committee
[4] See http://publications.naturalengland.org.uk/publication/6742480364240896

This is a long-term recommendation as it is recognised that legislation needs to balance the needs of multiple interests and the evidence base for many aspects of resilience is not sufficient to form the basis for legislative change. However, the water industry and other stakeholders working to improve the natural water environment could collaborate on shared statements emphasising the interconnectedness of the water environment and recommending specific regulation changes to improve resilience. The case studies in the database (Recommendation 1) should also note where legislation has previously been a blocker to resilience as this will provide the evidence base which justifies legislative change.

The currently proposed Environment Bill provides an opportunity to develop a national environmental resilience policy. The Bill sets out targets, plans and policies for improving the natural environment, including the water environment, but still relies on underlying or secondary legislation which may change as a result of Brexit. There will be future opportunities to influence legislation and guidance as laws change following Brexit and in future iterations of the water industry price review process.

Improvements to the legislation and policy instruments affecting resilience should aim to:

- Address the lack of clarity identified in this project around national priorities and incentives regarding resilience.
- Mitigate the potential risks associated with changes in legislation following the Brexit transition period. EU Directives have been a major driving force for the protection and enhancement of environmental resilience in the UK and there is therefore a need for a national policy framework to anchor and drive actions to maintain and enhance resilience over time.
- Complement the Environment Bill by setting out the pathway for the water sector to manage its resilience as it impacts and depends on environmental resilience;
- Tie together the different legislation, regulatory frameworks, policies and incentives that currently exist, and;
- Provide policy incentives for stakeholders to collaborate.

Given the volume and complexity of the legislation and policy affecting the water industry and natural water environment (Section 5), it is recommended that a specific, detailed review of legislation is undertaken as a first stage. This should include a combination of desk-based research and workshops with representatives from the water sector and other sectors including land managers and the housing sector. The review should analyse how the different pieces of legislation impact on each other, on resilience case studies and on environmental and water industry resilience, including direct and indirect links, and should also consider the history of the legislation and the way it seeks to balance competing interests. The review would them identify opportunities and priorities for legislative reform.

Recommendation 4

Work with land managers and the housing sector to specify measures to improve environmental resilience

Overview

The water industry and stakeholders working to improve the natural water environment should work with selected stakeholders to identify opportunities to co-design management measures to improve environmental resilience while benefitting both parties. This requires identifying where improving the resilience of the water environment through partnership working can benefit land managers and the housing sector. For example:

- Habitat improvements and river and floodplain hydromorphological improvements could be provided as part of urban regeneration schemes. This could be incorporated into proposals for blue-green corridors, SuDS and natural flood alleviation measures, and may also deliver improvements in river quality and ecological value.
- Management of land to maximise its carbon sequestration potential could assist with meeting the UK's net zero carbon emissions target by 2050. One option is tree planting and a woodland creation project would be additional under the Woodland Carbon Code and could generate verified credits that could be sold to partners within the project or other parties to generate an income stream for the landowner. An alternative income stream could be the Peatland Carbon Code which applies to peatland restoration projects.;
- Delivering other environmental benefits besides carbon sequestration, for example biodiversity or recreational benefits, could increase land value, particularly if land is designated which may restrict alternative land management options. This could include creating priority habitats to generate biodiversity credits through the delivery of biodiversity net gain.

- Parties could enter into Conservation Covenants, assuming that they are brought into effect once the Environment Bill is enacted.

An initial stage of this work would be to identify and prioritise potential locations where partnership working with land managers or the housing sector might be viable, as well as determining appropriate management measures. This would be achieved by:

- Identifying priority stakeholders to approach in terms of specific land managers and organisations in the housing sector;
- Discussing each party's respective goals and objectives when it comes to environmental resilience in order to identify overlaps where partnership working may be viable;
- Identifying locations for partnership projects to take place, either on land currently owned by either party or on land to be acquired; and
- Co-designing management measures to balance the objectives of enhancing the resilience of both parties while enhancing environmental resilience.

Note that successful delivery of this recommendation will require a strong evidence base. The use of results from previous projects, as set out in the case study database, will be vital to secure buy-in to the broader principles of improving resilience.

1. Introduction

This is the report for the project commissioned by Wildlife and Countryside Link on behalf of a partnership of water companies and environmental NGOs entitled *Naturally Resilient.* The steering group formed from this partnership to lead the project consisted of representatives from Wildlife and Countryside Link, Thames Water. The overarching aim of the project is to explore the interplay between resilience in the water sector and resilience of the natural environment.

1.1 Background and purpose

The water sector is critically dependent on the resilience of the natural environment, in particular the water environment (e.g. rivers, lakes, groundwaters, etc.). Similarly, the resilience of the water environment depends on sustainable and managed abstraction and discharges by water-dependent sectors including water companies. This interdependency between sectors has become increasingly evident in recent years, particularly given the growing recognition that we are in a climate and biodiversity emergency and was recognised in Wildlife and Countryside Link's (WCL) blueprint for the water sector's Price Review for 2019 (PR19) and Blueprint for Water initiative (WCL, 2017a).

The observation that improving the resilience of the natural environment enhances the sustainability and resilience of water companies is complemented by Ofwat's recommendation that water companies should achieve 'resilience in the round' (Ofwat, 2017b). Ofwat's final methodology for PR19 also acknowledged the natural environment as essential for delivery of water and wastewater services (Ofwat, 2017a) and the Environment Agency and Natural England have also recognised this in their document *Water Industry Strategic Environmental Requirements* (WISER, 20017).

In 2018, Defra's *National Policy Statement for Water Resources Infrastructure* required Ofwat to further the resilience of ecosystems by encouraging the sustainable use of "natural capital" in water company plans (Defra, 2018c). Most recently, the currently proposed Environment Bill[5] recognises resilience in the context of the water environment (HM Government, 2020) and includes measures to help secure long-term, resilient water and wastewater services and solutions to drought and flooding.

In future, therefore, the water sector needs to move away from simply managing disruption, and toward building a capacity to withstand disruption. The report examines how a 'naturally resilient' approach can assist water companies in managing future challenges and pressures.

1.2 Project aims and objectives

The overarching aim of this project was to explore the interplay between resilience in the water sector and resilience of the natural environment, as well as how investments in one of the sectors can benefit both.

The project focused on the water environment in England and develops a body of evidence to support the uptake of more naturally resilient approaches to water resource management and the natural environment. The specific objectives of the project were to:

7. Explore the definitions, principles and metrics in both sectors around resilience and how they could be used to prioritise action and gauge progress. This includes making recommendations for the definitions that should be adopted with respect to both the water sector and the environment, in the context of this project;

[5] At the time of finalising this report (May 2020), the passage of the Environment Bill was delayed during consideration by the Public Bill Committee by circumstances associated with the Covid-19 pandemic (https://services.parliament.uk/bills/2019-21/environment.html)

8. Identify the interdependencies between ecosystem resilience and water sector resilience using examples across the water cycle; representing different pressures (e.g. pressures on quality, availability) and from both rural and urban environments;
9. Set out areas of current and future risk to resilience for both sectors due to factors such as climate change, increased water demand and changing societal behaviours. This includes highlighting those risks that are particularly fundamental for both sectors;
10. Describe opportunities for the two sectors to work together to improve resilience alongside the regulatory frameworks/incentives that would encourage it. This includes illustrating those opportunities with case study examples, such as projects within water companies' PR19 submissions. The case studies also identify 'blockers' (perceived and otherwise) that may prevent opportunities from being delivered and what might be done to mitigate these blockers;
11. Identify the key stakeholders beyond the two sectors, especially those with wider responsibilities for improving water environment resilience and those who depend on it. The key stakeholders are also considered alongside the various priorities set out by UKWIR (UK Water Industry Research) for the water industry; and
12. Identify important gaps in knowledge and develop recommendations for any future work.

1.3 Report structure

The project has been delivered following a staged approach. On completion of each stage a note or report was provided to the steering group for review and approval. These interim deliverables have been collated together into this final report. The remainder of this report is structured as follows:

- Section 2 provides an overview of the project methodology;
- Section 3 explores the interdependencies between the water industry and the natural water environment;
- Section 4 defines resilience including its underlying themes, principles and metrics;
- Section 5 outlines the legislation, regulatory frameworks, policies and incentives that affect resilience;
- Section 6 identifies the key stakeholders with respect to resilience in the water sector and the natural environment and how their responsibilities are linked to UKWIR's priorities;
- Section 7 explores the current and future risks to resilience;
- Section 8 outlines measures to manage risks to resilience, as well as the opportunities for collaboration between sectors with respect to resilience and the associated benefits, blockers and mitigation measures;
- Section 9 provides a summary of the findings from the project; and
- Section 10 provide recommendations for future actions and research following this project.

The report is supported by the following appendices:

- Appendix A presents the online survey questionnaire used to collect stakeholders' views about resilience and its associated risks;
- Appendix B presents the case studies developed to demonstrate examples of collaboration between stakeholders with respect to resilience;
- Appendix C provides information from the literature review to support the definitions, principles and metrics of resilience in Section 4;

- Appendix D provides information to support the identification of key stakeholders with respect to resilience in Section 5;
- Appendix E sets out information to support the analysis of interdependencies between sectors in Section 3;
- Appendix F presents information to support the analysis of current and future risks to resilience in Section 7; and
- Appendix G presents information to support the identification of measures to manage risks to resilience, opportunities for collaboration and the associated benefits, blockers and mitigation measures in Section 8.

2. Overview of approach

This section provides an overview of the approach to the project which consists of the following activities.

2.1 Iterative literature review

An iterative literature review was undertaken which initially identified legislation, regulatory frameworks, policies and incentives which could facilitate enhanced resilience in the natural water environment and the water industry. Ofwat issued guidance on assessing any likely improvements in resilience arising from PR19 water industry investment, both as part of the price review consultation process (Ofwat, 2016a), and in Ofwat's *Resilience Task and Finish Group Final Report* (Ofwat 2016b). These documents identified further sources which have been reviewed and summarised in this report, augmented by discussions with the project Steering Group as well as responses to the online survey (see Section 2.2) and the development of case studies (see Section 2.3).

The literature review also helped identify the definitions, principles and metrics that exist across both the water sector and natural environment relating to resilience, with more than 30 sources reviewed. This process fed into the findings in Section 4. To allow for a consistent and comprehensive approach, a database was developed to capture the following information for each source:

- Definition of resilience provided;
- Rationale for definition/additional information;
- Relevant sectors (water sector/natural environment);
- Relevant capitals including human, manufactured, financial, natural, social, and intellectual capital;
- Resilience principle(s) provided;
- Supporting information for resilience principle(s);
- Metric(s) defined;
- Supporting information for metric(s);
- Hazards/pressures associated with metric(s);
- Benefits and limitations of metric(s);
- Whether the metric(s) cut across multiple aspects of resilience; and
- Whether the resource identifies current or future risks to resilience

A high-level literature review was also undertaken to identify current and future risks to resilience across both sectors. It considered documents such as the Global Risk Report (2019), the Government's 25 Year Environment Plan, UKWIR's (UK Water Industry Research) Big Questions, and strategic water company documents such as Water Resource Management Plans (WRMPs). Where examples are provided for particular water companies, this does not indicate that the named water company is the only organisation that is relevant to that specific example.

2.2 Online survey

The project also involved an online survey which gathered stakeholders' views on the current and future risks to resilience using a combination of single choice, multiple choice and open-ended questions. The

survey was administered via Smart Survey[6] and also identified stakeholders that were interested in developing case studies (see Section 2.3) which provide examples of collaboration between the two sectors to improve resilience. The full online survey questionnaire is provided in Appendix A.

Sixteen survey responses were received from water companies, environmental NGOs and regulators. The sample comprised Steering Group members, with the survey also being distributed amongst Water UK members. Upon dissemination of the survey, participants were encouraged to share the survey more widely. As a result, the exact sample is challenging to determine.

2.3 Identification of case studies

The project also included the identification of case studies to demonstrate where and how the environmental and water sectors have collaborated to enhance resilience. Case studies related to:

1. Water quality regulation (environment not drinking water);
2. Soil quality regulation;
3. Wild species diversity;
4. Disease and pest control;
5. Water supply (including drinking water);
6. Global climate regulation;
7. Hazard regulation; and
8. Recreation.

The case studies were identified based on suggested examples provided in the online survey. A total of seventeen case studies were initially proposed, each with varying levels of information and relevance. A case study selection template was provided to all stakeholders who proposed case studies in the survey to collate the following information which was required for inclusion of the case study in this project:

- Their type of organisation e.g. public, private, third sector;
- The location of the case study;
- Whether the initiative was a strategic approach or more targeted;
- The type of habitat(s) that the case study affects e.g. rivers, farmland, etc.;
- The types of interdependencies along the water cycle that the case study relates to;
- The risks to resilience that the case study highlights;
- The type of collaboration that took place as part of the case study; and
- A qualitative assessment of the data available to develop the case study.

Sufficient information was available for five case studies, summarised in Table 2-1 below. The case studies cover the public, private and third sector and a reasonable geographical coverage is achieved across England. The case studies also cover a range of habitat types and interventions. Appendix B provides the full details for each case study, while the key findings are reported in subsequent sections of the main report.

[6] https://www.smartsurvey.co.uk/

Table 2-1: Selected case studies

no.	Organisation	Sector	Location	Short description	Relevant interdependencies	Status
CS1	British Canoeing	Third (NGO)	National	**Invasive species programme** The initiative aimed to promote awareness and behaviours among canoers via social media, signage, and partnership working to help manage invasive non-native species in waterways. Partners include various NGOs, water companies and public sector bodies based in the UK.	Water quality regulation ☒ Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☒ Water supply ☐ Global climate regulation ☐ Hazard regulation ☐ Recreation ☒	Commenced and on-going
CS2	Environment Agency	Public	Cumbria	**Water abstraction** The project aimed to change two United Utilities abstraction licences to protect flows in the rivers Dunsop, Brennand and Whitendale, whilst still providing enough water for United Utilities' customers. It was part of the Environment Agency's Restoring Sustainable Abstraction programme. Partners include a UK water company.	Water quality regulation ☒ Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☐ Water supply ☒ Global climate regulation ☐ Hazard regulation ☐ Recreation ☒	Completed
CS3	South East Water	Private	South East	**PROWATER-Interreg project** The project aims to build resilience within catchments against droughts and extreme rainfall events through landscape-scale change. The overarching objective of the work is to examine how land use can be changed to help with infiltration and ground water resources. Partners include various NGOs, water companies and public sector bodies based in the UK and EU.	Water quality regulation ☒ Soil quality regulation ☒ Wild species diversity ☒ Disease and pest control ☐ Water supply ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☐	Commenced and on-going
CS4	Southern Water	Private	South	**Instream catchment resilience scheme**	Water quality regulation ☒	Planned but not commenced

no.	Organisation	Sector	Location	Short description	Relevant interdependencies	Status
				This project aims to explore future investment in catchment resilience in order to maintain resilient water supply for customers, identify sustainable levels of abstraction, and deliver a range of wider environmental benefits. Partners include various NGOs and water companies based in the UK.	Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☐ Water supply ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☐	
CS5	Thames Water	Private	South East	**Thames Water – Walthamstow wetlands project** The main objectives of the project were to provide the local community with free access to green space, communicate important water efficiency messages to visitors, and engage people with the rich industrial heritage of the area. The Walthamstow wetlands deliver important benefits in terms of biodiversity, drinking water, and recreation. A balanced approach to consider these different benefits and associated pressures was therefore required. Partners include various NGOs and public sector bodies alongside Thames Water.	Water quality regulation ☒ Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☐ Water supply ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☒	Commenced and on-going

To develop the case studies, telephone interviews were conducted with each stakeholder to characterise their case study in terms of:

- The types of partners involved in the case study;
- The overall objectives of the case study;
- The regulatory and other drivers of the intervention;
- The approach followed as part of the intervention;
- The broad outcomes as a result of the intervention;
- The trade-offs and blockers experienced throughout the lifetime of intervention; and

- The lessons learnt from the intervention.

This information was recorded in a standardised proforma for each case study, presented in Appendix B. Throughout the development of the case studies, the management opportunities to address risks to resilience, identified in Section 7.2, were sense-checked with stakeholders to check their practicability and the added value to both sectors from their implementation.

3. Interdependencies between the water sector and the natural water environment

This section sets out the interdependencies between the water sector and the natural environment within the water cycle. It is supported by Appendix E.

Figure 3-1 illustrates impacts and interdependencies in the water sector and natural environment. Impacts and interdependencies between both sectors (natural environment and the water sector) were identified through consideration of the water cycle and an ecosystems approach.

Where possible, impacts (both beneficial and adverse) and interdependencies have been distinguished in Figure 3-1. However, it should be noted that the complexity of the natural water ecosystems and the links between each component are too complex to be easily represented in any simple diagram. Interdependencies exist between all areas of the system; therefore, key links are focused on and are highlighted in Figure 3-1, including:

- feedback loops for water resources and climate;
- feedback loops whereby more extensive urbanisation can exacerbate flooding impacts;
- links between environmental water quality and water for drinking;
- links between environmental water quality and biodiversity, and;
- links between water resources and biodiversity.

In view of the complexity of the system, consideration of how the water sector impacts on, and is impacted by, natural resilience needs to begin with identifying specific problem areas. This allows for more focused and targeted improvements and management of operations, including works to minimise impacts as part of a partnership approaches, e.g such as via catchment management initiatives. This may yield significant ecosystem service benefits through links with other aspects of the water environment. Specific problems and risks for resilience are discussed in more details in Section 7.

Based on an assessment of the interdependencies of the water sector and natural environment across the water cycle, the following ecosystem services have been identified as interdependencies. Most, although not all, of these links are illustrated in Figure 3-1, and the difficulty of fully accounting for all the links between different aspects of the water environment means that work to improve resilience in one area of the system may have unintended benefits or disbenefits in other areas.

- **Hazard regulation:** Hazard regulation requires elements such as soil stability, vegetation (inclusive of riparian buffers, for example), floodplains and resilient shorelines. Specifically, for hazard regulation in relation to drought, sufficient base flows, precipitation and temperature regulation are needed. In urban environments, point-source pollution may take the form of chloride from road de-icing salts, landfill leachates and/or industrial effluent. In rural environments, diffuse sources of pollution inclusive of inorganic fertilisers may be more common. Hazard regulation services may be more prominent in rural environments where natural capital assets (such as river channels and undeveloped floodplains) are less likely to have been altered and therefore could provide additional protection. In urban environments, hazard regulation services may be reduced and/or compromised as a function of development. Similarly, hazards such as flood risk may be increased in urban areas owing to increased areas of impermeable hard standing. Reinstatement of hazard regulation services can be challenging due to the densely populated nature of urban environments and limited room to re-naturalise watercourses and create habitats.
- **Water quality regulation:** Both sectors are fundamentally reliant upon water quality regulation. For water quality regulation, assets which filter water naturally are required. Initial water quality

(prior to filtering) should also be considered, with good raw water quality of importance. As identified within 'hazard regulation', rural and urban environments have different water quality challenges.

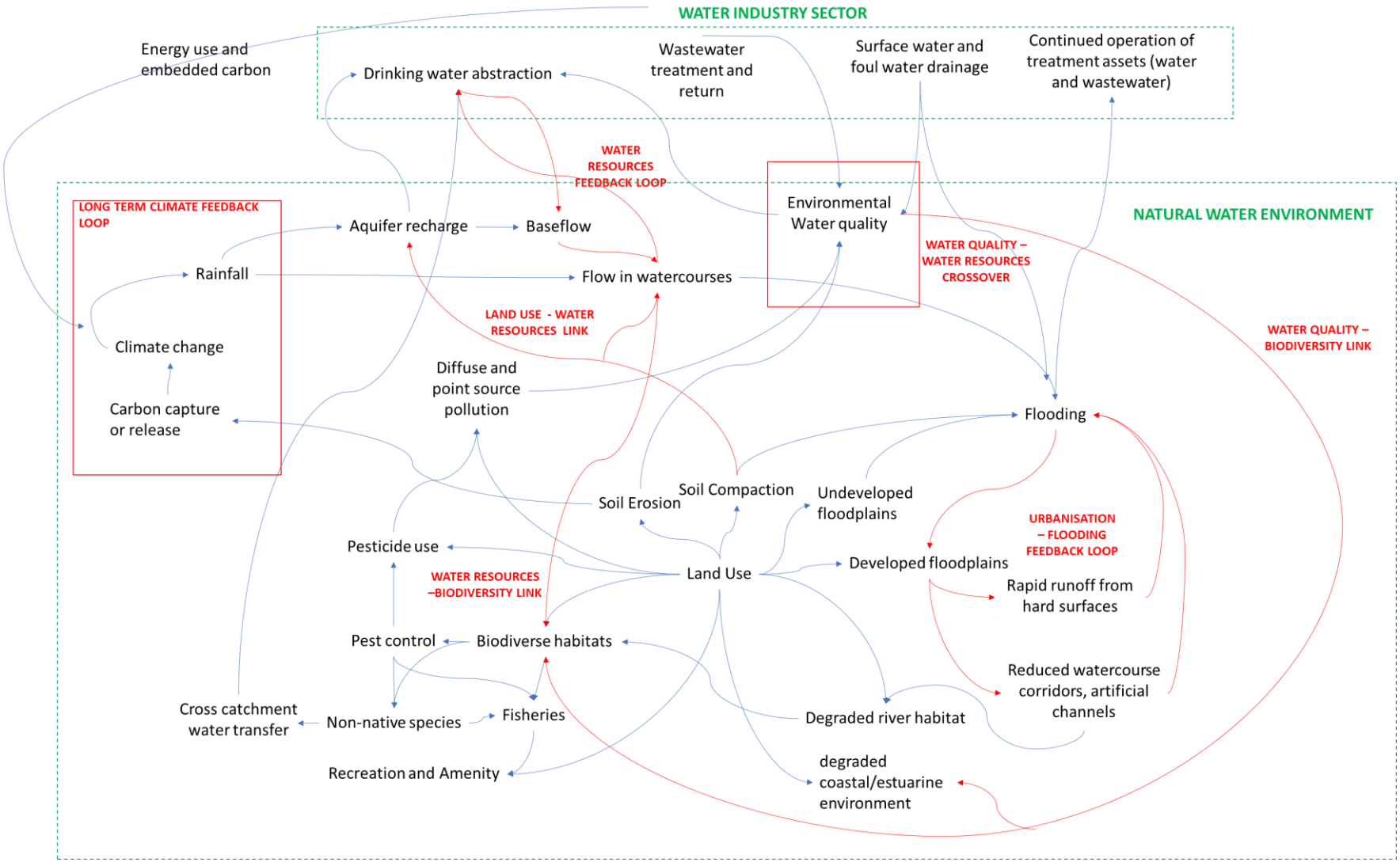
- **Soil quality regulation:** Soil quality regulation has a role to play in the delivery of a range of ecosystem services, including hazard regulation, disease and pest control, and water quality regulation. Soil quality is likely to differ across rural and urban environments. In rural environments, agriculture may result in soil degradation and chemical contamination. In urban environments, heavy metal pollution may be more common for example.
- **Wild species diversity**: The water sector has a direct link to water species diversity through land holdings as part of assets (and how the land is managed), but also where aquatic wild species diversity is directly impacted by operations including abstractions (affecting flow regimes, fish entrainment etc) and discharges of treated and untreated wastewater. Wild species diversity also has a key role to play in maintaining clean waters, which is critical to resilient water company operations.
- **Disease and pest control:** To facilitate effective disease and pest control, wild species diversity is required, comprising diverse resilient species. Management is also important with respect to accidental transportation and spread. Increasingly, water companies are being encouraged to consider strategic inter-basin water transfers as new sources of water supply, which could increase the risk of spreading invasive, non-native species. Disease and pest control allow for healthy ecosystems with continued wild species diversity. Where disease and pest control is compromised, wild species diversity can be undermined, with an increased abundance and distribution of invasive, non-native species.
- **Water supply (including drinking water):** Both the natural environment and the water sector rely on streams, rivers and aquifers to supply unpolluted water. Water companies directly influence the supply of water across ecosystems as a function of abstraction and the discharge of treated effluent.
- **Global climate regulation:** Whist the water sector may not actively impact ecosystems which deliver global climate regulation services, the relationships between the two sectors when considering global climate regulation and climate change are extremely interlinked. It is likely that rural environments will have the greatest stock of natural capital assets which have the potential to regulate global climate change (depending on their condition).
- **Recreation:** Both the natural environment and the water sector rely upon recreational activities being carried out in a responsible manner, to subsequently avoid adverse impacts/to promote protection and enhancement. The benefits of recreation are highly spatially dependent and tend to be greater in densely populated urban areas where population is greater, and proximity to recreational sites is less likely.

In addition to these interdependencies, the central importance of land use is clearly visible in Figure 3-1. Land use is controlled by a combination of many conflicting societal, environmental and economic pressures, but its central importance and the diversity of its impacts means that resilience measures affecting land use will inevitably impact on a very large array of diverse stakeholders. A list of 49 stakeholders identified in this report is discussed in Section 6. These have been limited to stakeholders with a direct interest in the water industry or water environment, and the list is not exhaustive.

The above interdependencies between the water industry and the natural water environment were identified in this report based upon professional judgement and consideration of the relationships between water ecosystem services. Most interdependencies relate to regulating ecosystem services (the benefits obtained from the regulation of ecosystem processes), showing the importance of the systems which regulate the natural environment.

Identifying interdependencies between sectors allows opportunities for co-benefits to be explored. A further area of work could be to explore each of the interdependencies in more detail, to identify opportunities for co-benefits including which parties and organisations would be involved, specific actions and associated timeframes and costs.

Figure 3-1: Interdependencies between the water sector and the natural water environment



4. Definition, principles and metrics for resilience

This section sets out the definition of resilience including its underlying themes, principles and metrics.

4.1 Definition of resilience

The literature review (Appendix C) set out to identify a shared definition of resilience which reflects the needs of the water sector and the environmental sector in the context of the interdependencies between the two sectors. The review showed that defining resilience is complex, particularly when considering the vast number of components that underpin it. This complexity may be one of the reasons that an agreed and accepted definition for resilience has not be developed to date. With these challenges in mind, Box 4.1 presents the definition of resilience that was identified and used within this project.

Box 4.1: Definition of resilience

Resilience is the extent to which a system can withstand stressors and continue to provide benefits in the long term.

Improving resilience requires taking into account the system dynamics and implementing effective measures to facilitate long-term flows of benefits, whilst protecting and enhancing society, the environment and the economy.

The underlying concepts of this definition are as follows:

- **Stressors**: *disruption, disturbances and changes*. This could include demographic change, customer behaviour, economic or political disruption, or climate change.
- **System dynamics**: *the relationships between the elements of a system*, specifically related to this study, the interdependencies between the water sector and the natural environment as well as dependencies and interdependencies with other systems.
- **Effective measures**: enhance a system's ability to withstand stressors.
- **Long-term perspective**: promotes a sustainable approach and impacts on future generations.
- **Flows of benefits**: the benefits obtained from ecosystems services and natural capital (e.g. water available for abstraction for drinking)
- **Society, the environment and the economy**: the three pillars of sustainability, with the economy including water company operational, corporate, financial and leadership assets and systems.

For the specific context of the study, a more accessible version of this definition was developed with the project Steering Group for the purposes of communicating with non-technical audiences, as follows:

- Resilience is the effective protection and enhancement of society, the environment and the economy, based on our understanding of the systems and environments which we all live and operate in.

4.2 Themes and Principles of Resilience

The literature review (Appendix C) has identified six common themes of resilience:

1. Components of resilience;
2. Receptors;
3. Services and Benefits;
4. Stressors;
5. Sustainability, and;

6. System-based approach.

Key terms used within the literature have been mapped to their corresponding theme in Table 4-1.

Table 4-1: Common themes across definitions of resilience in the literature

Theme	Key terms extracted from literature review	
Components of resilience	• Response • Adaptation • Ability • Robustness • Redundancy • Cope/Withstand • Maintain function • Capacity • Length of recovery period/Quick recovery	• Resistance • Retaining ability • Management • Anticipate • Absorb • Withstand problems • Working effectively • Mitigating impacts • Good communications
Receptors	• Habitats • Changing climate • Environment • Natural resources • Ecosystem function • Protection of the natural environment • Original state	• People • Customers • Economic losses • Operational • Corporate • Financial • Leadership
Services/outputs and benefits	• Protect • Resources • Services • Change in outputs • Levels of service • Failure • Outages	
Stressors	• Disruption • Events • Disturbance • Change • Risk and Opportunities • Interruptions • Issues • Threshold • Water supply shortages	• Severity • Flooding • Drought • Failure • Trends • Variability • Demographic change • Customer behaviour • Climate change and weather • Environmental pressures
Sustainability	• Longevity • Sustainability (present and future) • Scenarios	

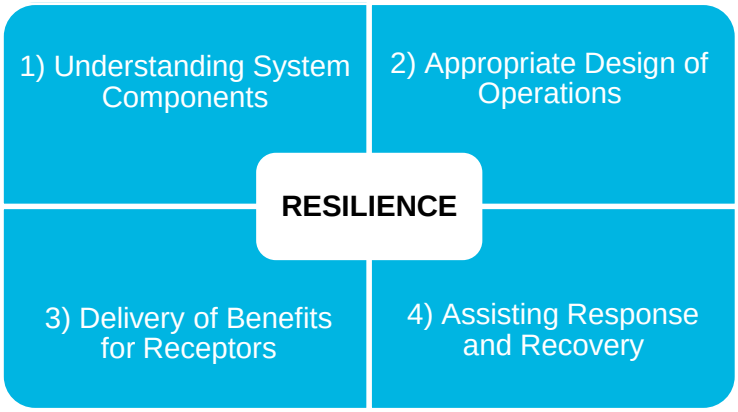
Theme	Key terms extracted from literature review
Systems	• Infrastructure (assets, networks, systems, processes) • Natural Systems • System Dynamics

The principles of resilience identified through the literature review are as follows:

- Transparency
- Response
- Recovery
- Resistance/providing protection
- Resourcefulness
- Reliability
- Thresholds
- Risk-based approach
- Redundancy
- Robustness
- Adaptability
- Diversity
- Condition
- Connectivity
- Extent
- Stakeholder-led
- Delivering multiple benefits
- Proactivity
- Informed approach
- Whole-life costing
- Efficiency
- Alignment
- Effectiveness

Examining the themes and principles outlined above, successful delivery of resilience in the environmental and water sectors requires four key considerations, as show in Figure 4-1.

Figure 4-1: Key Considerations for Delivery of Resilience



These key considerations are discussed in further detail below, pulling in the aforementioned principles and elements of resilience as they relate to these considerations. For clarity, and because an accurate understanding of any environmental system is essential to any effort to improve its resilience, they are discussed in the order set out in Figure 4-1. However, it should be understood that the considerations are interlinked, for example appropriately designed resilient operations will allow information sharing and improved understanding of systems, while all projects will have drivers which are focussed on delivery of benefits, often as part of a response to adverse events.

4.2.1 Understanding System Components

It is essential to understand how both environmental and the water sector's water management systems operate in order to plan for improving resilience. The following principles are particularly important:

- There should be an **understanding of asset robustness** (across both sectors) **and adaptability/adaptive capacity**, to inform approaches to enhancing resilience. Robustness can often be referred to as a systems ability to 'absorb' disruptive events. While it should be acknowledged that not all systems require adaptation to endure change, this may not be the case for environmental systems, given the poor status of many UK environments.
- **Diversity i**s a fundamental component of resilience, with increasingly diverse natural ecosystems often being more resilient than monocultural agricultural systems. Similar comparisons can be drawn across operations in the water sector, for example, having a diverse range of water supply options (sources and distribution networks) to Water Resource Zones is a key part of providing resilience by removing vulnerability to failure of single source assets.
- As with diversity**, ecosystem connectivity** is fundamental to ecosystem health and resilience.

As per the Cabinet Office (2011):

- The **resistance** element of resilience is focused on providing protection. Whilst this definition is more infrastructure focussed, for the purposes of the natural environment it can equally be considered as the need to protect the natural environment, natural resources and ecosystem function from the impact of stressors.
- The **reliability** component is concerned with ensuring that the infrastructure components are inherently designed to operate under a range of conditions and hence mitigate damage or loss from an event. Specifically, for the natural environment, the concept of ecological thresholds is important i.e. the point at which an external change or disturbance causes a rapid change in an ecosystem.
- The **redundancy** element is a key part of reliability. With respect to water sector operations, it is concerned with increasing the reliability of a system or network through duplication of critical components or functions of a system. For the purposes of the natural environment, it can take the form of functional redundancy, which is the notion of multiple species providing the same role in an ecosystem such that loss of one species does not cause the ecosystem to collapse.

4.2.2 Appropriate Design of Operations

For the consideration of 'Operational Approaches' the following principles and elements will be of importance:

- **Approaches to resilience should be proactive,** with the aim of minimising reactive and emergency responses. A proactive approach encourages building resilience through an active process.
- Resilience approaches should be **measured using appropriate, quantifiable metrics** to measure progress and effectiveness, which is often challenging.
- **Ownership of resilience approaches should be led and managed effectively**, with named parties responsible for specific activities and effective cascading of information through appropriate communication channels.
- All works undertaken with regards to resilience should be **transparent** and reported on appropriately.
- Resilience should be considered as a method of **delivering resource efficiencies**.
- An informed approach to resilience activities is required and facilitated through undertaking works to **understand system dynamics** (relationships, dependencies and interdependencies) and stressors and associated impacts on system thresholds. Further research and assessments may be required to understand inherent variability of systems and emerging and developing trends.

- Approaches to resilience should be **stakeholder-led**, considering the wants and needs of partners and local communities that are receptors.
- **Whole-life costing should be utilised**, and should consider different capitals (e.g. natural, social, human, etc.) where practicable, allowing for future resilience when assessing, comparing and designing new infrastructure schemes or projects.

4.2.3 Delivery of Benefits for Receptors

For the consideration of 'Benefits and Receptors' the following principles and elements will be of importance:

- Resilience efforts should **deliver multiple benefits**, with the concept of **additionality** being fundamental to achievement. This can be achieved through an informed, evidence led approach which identifies sector interdependencies and subsequent opportunities for co-benefits. This approach ultimately facilitates the opportunity to deliver more for less, particularly through partnership working.
- Effective resilience measures will allow for the continued **long-term flow of benefits** (inclusive of service delivery) in both the natural environment and water sector operation sectors.
- Protecting the natural environment, natural resources and ecosystem function is fundamental to long-term resilience in both sectors, with the requirement for the identification of opportunities for **environmental net gain**.
- **Social acceptability** is fundamental to resilience. Social value should be considered as a function of activities.
- Resilience should encompass **operational, corporate, financial and leadership requirements and aspirations** of water companies, with resilience approaches being considered as one of the 'tools' to deliver wider strategic objectives.

4.2.4 Assisting Response and Recovery

As per the Cabinet Office (2011), the response and recovery element aims to enable **a fast and effective response to and recovery from disruptive events**. These elements, particularly rapid recovery, are fundamental elements of resilience and should be a key consideration of resilience planning.

However, for the purposes of this project, less focus on these elements reflects the need to move towards a more proactive approach which inherently builds resilience and reduces the frequency and severity of disruptive events.

4.3 Metrics for resilience

Despite efforts to improve resilience in the water sector and resilience of the natural environment over recent years, there is currently no published record of progress. There is limited centralised reporting or systematic recording of the resilience of water company assets, networks or services and no agreed measure or record of the resilience of environmental systems. While some water companies have published their own internal measures (e.g. Thames Water), these are not necessarily comparable within or across the sectors. Some centralised or collated information is published, e.g. water industry information on the Discover Water website and the Environment Agency EPA report and there are elements within this reporting that provides measures of resilience. However, this project has identified significant challenges around the collation and publishing of resilience metrics, as described below.

The absence of suitable metrics to define and measure resilience is a barrier to progress (Environment Agency, 2015) and while there have been notable advances in models, tools and other resources to support resilience assessments, there are still fundamental gaps that need addressing (HM

Government, 2017). Ofwat (2015b) has identified the need to develop metrics for measuring and monitoring resilience in order to understand future challenges and inform adaptation priorities within the water sector, and the National Infrastructure Advisory Council (NIAC) Working Group recently identified assistance to enhance preparedness and resilience as one of the top priorities for the water sector (National Infrastructure Advisory Council, 2016).

One of the main challenges associated with defining metrics which measure resilience is its complexity. Due to the cross-cutting nature of resilience pressures, there is a need to look at the interconnections within and between sectors and systems, including links to components that are often seen as discrete (Ofwat, 2015b). Additionally, because of the uncertainty and long-term nature of future pressures, it is challenging to develop metrics that measure resilience against threats which are yet to be identified or experienced (Ofwat, 2017b). For metrics to be useful, accurate and comparable over time, it is important to consider these challenges and address uncertainties surrounding them.

The literature review identified an extensive list of metrics which are currently used to measure a range of resilience pressures and challenges within the water sector and the natural environment. The appropriateness of these measures was explored by identifying the benefits and limitations of their use and assessing their applicability to the cross-cutting nature of the approach with respect to interdependencies between the two sectors. An assessment was then made as to whether each metric could be recommended for future resilience assessments.

It should be noted that the Environment Agency are currently developing ‘Resilience Standards’ as part of the update of the National Flood and Coastal Erosion Risk Management Strategy. These standards may include additional relevant metrics but were not available for review for this study.

Measuring resilience is complex and it is challenging to reduce to a specific set of measurable variables. Rather, it requires a nuanced collection of quantitative and qualitative metrics. The literature includes examples of resilience metrics which are broad and operate across habitat types (e.g. Habitats Directive Article 17) or local and specific (e.g. Resilience framework for resilience and tree health). Metrics can also assess a range across different hazards and pressures, including flooding, drought, water supply, wastewater, asset health and the environment, with some measures focusing on one specific pressure and others being applied generally across several pressures.

Section 4.3.1 sets out some existing metrics and methods which are recommended as core indicators for measuring and assessing resilience within the water sector and the natural environment. They have been chosen based on the following criteria:

1) They are established, transparent and widely accepted;

2) Measurement requirements are understood and can be consistently applied across the UK;

3) Most metrics have a history of being widely used, so an appropriate baseline and previous variations should be available to judge the extent of change;

4) They cover a wide range of environmental conditions and targets for improved resilience, as well as water company operational resilience, allowing selection of suitable metrics on a project-by-project basis, with the understanding that not all metrics will be applicable to all projects.

5) They include both quantitative and qualitative metrics which can, in combination (or, more rarely and for smaller, focussed projects, in isolation) given an indication of changes in the resilience of the subject system.

4.3.1 Using Metrics to Measure Resilience

Table 4-2 below sets out recommended metrics for measuring the resilience of environmental systems, based on the criteria above. However, given the variability of environmental systems, other criteria may

be more appropriate for a given scenario, e.g. methodologies published by the Resilience Alliance such as Toolkit for the Indicators of Resilience in Socio-ecological Production Landscapes and Seascapes (SEPLS), or monitoring of weather and climate to define threshold events for monitoring of environmental systems response. For the purpose of measuring the impact of measures aimed at improving resilience, a suite of metrics should be selected which are **appropriate, specific, measurable, comparable over time and space, communicable and transparent.** Recognising the requirements for appropriate operations and the requirements of receptors, it is recommended that metrics should also be **agreed** with all relevant stakeholders (Section 6, 7 and 8), ideally prior to the start of implementation of measures.

Table 4-3 sets out metrics which could be used by the water industry specifically. These have the advantage of being highly measurable, often with an extensive and comparable baseline dataset from which to judge the effectiveness of any measure. However, they are limited to the operation of water industry assets, so this baseline will not, in many cases, extend beyond the 1980s, and will be affected by a complex history of changes in infrastructure and investment over time. In addition, while some metrics will give a direct measure in improvements in environmental resilience (e.g. abstraction records), others will need to be combined with metrics from Table 4-2 to give a complete assessment of the impact of any measures. As with environmental metrics, not all water company metrics will be appropriate for all projects, and other metrics not listed in Table 4-3 could be used instead, provided they comply with the criteria set out above for environmental metrics.

Table 4-2: Recommended Resilience Metrics for Environmental Systems

Source of Metric	Quantitative Measure	Qualitative Measure
Habitats Directive Article 17	Range of species/habitat, area and diversity of ecosystems, species populations	Structures and Function (condition and habitat pressures), future prospects (including threats)
SSSI Monitoring		Condition, pressures
Designations	Bathing Water standards compliance Shellfish water standards compliance	Information (including quality) on other environmental designations inclusive of heritage and landscape
Water Framework Directive	Water Quality, Abstraction Pressures, Current Ecological Status	Reasons for not achieving good status, Future target status
Surveillance and monitoring of invasive, non-native species	Distribution and number	
Soil quality indicators	Nutrient and carbon content, extent of erosion, soil structure, agricultural land grade	
Energy Usage	Extent of carbon emissions (tCO2e/yr) or reduction achieved, Energy mix from purchased renewable supply, or direct renewable energy from land holdings, Net reduction in grid energy use per year	
Land cover	% cover, or extent of change (e.g. removal of impermeable paving)	Land cover quality
River Flow	Water levels in groundwater, streams and rivers	Long-term flood risk (as per the Environment Agency mapping)

Table 4-3: Recommended Resilience Metrics for Water Companies

Metric	
Catchment Measures	Percentage of land holding in better stewardship and km of river length improved due to water company actions
	Percentage of drinking water safeguard zones where improvements in water quality are being seen
	Percentage of catchments with a long-term strategic wastewater plan and committed options for improvement delivery
Abstraction	Percentage of total abstraction from groundwater sources that are in poor quantitative status
	Percentage of total abstraction that is from surface water sources in waterbodies where recent actual flows are below the Environmental Flow Indicator[7] at high flows
Potable Water Use	Per capita consumption in litres/household/day – dry year annual average or peak day multiple
	Leakage per km of network (Ml/d/km)
	Proportion of metered/smart metered households (percentage of total households).
	Total water volume put into distribution (Ml/d)
	Water supply interruptions and the risk of severe water supply restrictions in a (1-in-200 year) drought
	Water quality compliance and the DWI's Compliance Risk Index (CRI)
Wastewater Management	Percentage of sewerage capacity incorporating greein infrastructure based SuDS
	Percentage of combined sewer system which has been separated[8]
	The percentage of the population at risk of sewer flooding in a severe (1-in-50 year) storm
	Volume of treatment sludge and other wastes
	Sewage treatment works discharge compliance
Customer Care	Percentage of households eligible for social tariff that actually receive one
	Percentage of households on a tariff or financial incentive scheme that rewards water saving
	Customer measure of experience (C-MeX)
	Number of hours of engagement in awareness raising and educational initiatives
Impact Management	Total number of pollution incidents in each category each year, and a trend to zero pollution incidents.
	Unplanned maintenance for infrastructure and non-infrastructure assets (water and wastewater)

[7] In some cases, river specific EFIs are being developed and should be used
[8] Will need to be measured from an agreed baseline year

4.3.2 Further Considerations for Resilience Metrics

One important consideration for use of metrics to measure resilience and evaluate the effectiveness of measures is whether to use forward-facing or backward-facing metrics. In the context of resilience, forward-facing metrics are essentially predictions of future trends (e.g. in ecosystem resilience or water supply requirements) or outcomes (e.g. a project will result in additional woodland habitat area or improved water quality). Backward facing metrics use information or observations collected in the past to describe actual trends in resilience, up to the time of assessment, or actual outcomes of actions which have affected the natural environment or water management systems. The metrics in Table 4-2 or Table 4-3 can be used as either forward or backward facing metrics.

At present, forward-facing metrics are most commonly used to assess resilience, as they can be applied consistently, are meaningful to customers and allow stakeholders to better understand the issues surrounding resilience. However, while using forward-facing metrics is essential to communicate the aspirations for a system or measure, it can cause problems if these aspirations are not delivered. Additionally, they are often at the early stages of development and the complex system dynamics makes predicting the outcome of measures very difficult. Forward-facing metrics can lack historical and comparative performance data so caution should be applied, particularly when relating them to companies' financial investments.

It is therefore important for these forward-facing metrics to be used in combination with traditional backward-looking performance metrics. This will allow clear comparisons to be made with past trends, actions and system status, and improved understanding of how resilience changes and systems interact. Use of backward facing metrics also permits a critical review of whether specific measures delivered the expected benefits, reasons for success or failure and whether any unexpected benefits were realised.

In addition to the resilience-focused metrics identified above, more general metrics such as customer satisfaction, value for money and key labour market trends may be important to consider as changes in social capital and labour capacity can result in resilience issues. However, these metrics may only give limited insight into long-term resilience issues if used independently. Overall, there is a vast number of potentially relevant metrics and the list above underestimates the importance of the interdependencies between the water sector and the natural environment, risks to resilience and the range of key stakeholders that operate in this space. Cross-sector teams (e.g. the Water and Wastewater Resilience Action group) are the most effective way to develop resilience metrics which cover the full range of challenges facing the sectors both directly and indirectly.

It is also important to note that while metrics are necessary to assess resilience, bespoke resilience performance commitments and real-life events (e.g. floods) can also be used to quantify and validate levels of resilience. Company culture and ethos are central to securing resilience within the water sector and the natural environment.

4.4 Use of Metrics in Case Studies

Practical examples of the use of metrics to assess resilience and the effectiveness of measures to improve resilience can be obtained from the case studies in Appendix B. Table 4-4 gives details of the ways that metrics have been used in each case study, the advantages and disadvantages and recommendations for using metrics in similar projects in future.

It is not possible to monitor all aspects of resilience for all water environment and management systems simultaneously; instead, when working to improve system resilience, the aim will be to agree and monitor the most cost effective metrics to determine efficacy of measures and change in resilience overall, recognising the criteria set out above. The metrics to be measured will need to be bespoke to each project, as illustrated by the range of different measures set out below, as well as reflecting the stage of any work.

Table 4-4: Use of Resilience Metrics in Case Studies

Project Aims	Metrics Used	Advantages and Disadvantages of Metrics Used	Metrics for Future Use
British Canoeing Invasive Species Programme **11 keys aims, summarised as:** • **develop a programme of invasive species promotion, education and control;** • **improve access to water for canoeing and promote environmental awareness;** • **Widely promote Check, Clean and Dry (CCD);** • **increase inclusion of environmental awareness in the coaching scheme and performance awards;** • **increase awareness of the impacts of invasive non-native species, and;** • **be actively involved in the control of certain species such as floating pennywort.**	Qualitative forward- facing metrics, outlining what the project hopes to achieve (see left). As a result of the work undertaken to date, the canoeing community is active and engaged on environmental matters, specifically invasive non-native species, which is demonstrated clearly by their readiness to undertake clean-ups on waterways across the country. British Canoeing have also developed various environmental modules in their coaching syllabus, with biosecurity being just one aspect. Consequently, paddlers are made aware of lots of different environmental issues and are changing their behaviour to protect species that are at risk.	This project aims to increase awareness and voluntary management of invasive species by individual. An advantage of this approach is that, if sufficient awareness is raised, political pressure may increase to address some of the challenges identified in this project, specifically lack of: • coordination at a national level; • clarity over prioritisation and responsibility; • easily accessible opportunities for volunteers; • capacity within governing bodies to dedicate resources to invasive species, and; • clear rules for access to waterways on private land which makes it difficult to undertake measures without land owner consent. However, it is currently not possible to judge the potential pressure which could be brought because there is no systematic collection of data on the number of people reached through this programme. A significant increase in government funding would be needed to address invasive species, but with no quantitative estimate of the impacts and effectiveness of British Canoeing's project, there is little evidence which could be used to support applications for further funds or government support for expanding this project.	British Canoeing has identified a need to quantify the impact of this project in managing invasive species. Potential metrics for this include: • Number of projects to clear invasive species (people involved, area or length of waterway cleared); • Cost of each clearance; • Comparison of cost between volunteers working and contractors working for local authorities; • Benefits of each project (e.g. change in WFD status, observation of native species population recovery, number of known sites of invasive species cleared). Some of this information may already exist, but other metrics will require improved monitoring of this project in future.
Environment Agency Project to reduce abstraction for drinking water and increase flows in the Rivers Dunsop, Brennand and Whitendale.	Quantitative and Qualitative backward-facing metrics: • River flow (increase achieved) • Ecosystem assemblage (improving) • Salmon and trout survival (improved) • WFD status (now at Good)	The initial metrics for this project were river flow, ecology and fish survival. The project also reports improvements in the amenity value and recreation value of the watercourses, communication and collaboration between stakeholder groups and water company reputation, relationships and trust. Continued monitoring of fish and macroinvertebrate populations is planned over the next ten years	Future projects of this type could include improvements in amenity value, relationships, communication, collaboration and trust as forward-facing metrics from the start. This project found that collaboration and communication were essential to successful delivery, while aiming for

Project Aims	Metrics Used	Advantages and Disadvantages of Metrics Used	Metrics for Future Use
	• Amenity value (improved)	which is essential to judge success and provides a robust basis for decision making but is also costly and time consuming.	improvements in amenity may be useful in gaining wider public support for the project.
South East Water PROWATER-Interreg project **Project aims:** • **Landscape change to improve catchment resilience against droughts and extreme rainfall** • **Examine how land use change can increase infiltration** • **Improve baseflow in chalk streams** • **Prevent flooding by slowing down flows** • **Improve water quality** • **Work with farmers** • **Recognising ecosystems service for retention of water sources**	The following are required outcomes for the project: • Explore what this sort of project might be able to achieve; • Review how the project outcomes can influence project partner policy; • GIS tool which shows where infiltration measures would be more or less successful; • Assess effectiveness of infiltration measures using before and after measures of river flows and groundwater flooding; • Assess impacts on ecosystems services and vegetation impacts on infiltration; • Assess different methods for reducing surface water flooding in clay catchments • Increasing communication with stakeholders.	A mixture of backward-facing metrics (groundwater levels, low flows) and forward-facing metrics (increased communication, understanding of water this type of project can achieve) are proposed. The project is still at the scoping stage so none of the backward-facing metrics have been achieved yet. However, success on forward-facing metrics (improved communication, development of the GIS tool) can already be reported.	This project shows the importance of forward-facing metrics as they can quickly be realised and reported. Backward-facing metrics are vital for judging the overall success of the project in terms of the resilience of the water environment, but often require extensive data analysis at the end of the project.
Southern Water Instream Catchment Resilience Scheme **Aims to:** • **Take a more holistic and integrated approach to catchment management;** • **Justify investment in more natural solutions;**	The project focusses on the Arun & Rother and Test & Itchen catchments. The required outcomes are: 1) evidence to inform the types of measures to be implemented; 2) Data to identify the current baseline (catchment-wide geomorphology, hydrology and land use); 3) Cost assessment for in-channel interventions.	At present, all metrics within this project are related to the forward-facing targets by which this project will be considered a success or failure. This sort of project will provide valuable information to enable future decisions to be made but will not currently improve the resilience of the actual water environment within the catchment. The next phase of the project, when the costed interventions will be implemented, will include backward-facing metrics (e.g. water quality sampling, hydro-ecology modelling) to determine success, however these	The future (implementation) stage of this project will need to include backward-facing measures to demonstrate success in terms of improved flow and sustainable abstraction. It could also include a range of forward-facing metrics such as improved engagement, communication and collaboration to demonstrate the success of the project in other areas of resilience.

Project Aims	Metrics Used	Advantages and Disadvantages of Metrics Used	Metrics for Future Use
• **Consider wider benefits and value of investments;** • **identify how investment in catchment resilience and maintain resilient water supplies and provide environmental benefits, and;** • **identify sustainable levels of abstraction.**		metrics could only be assessed at the end of the project.	
Thames Water Walthamstow wetlands project **Aims to:** **1) Provide free access to green space for local communities** **2) Raise awareness of public water consumption and efficiency;** **3) Improve engagement with industrial heritage**	Number of public visits to the site. The initial expectation of 300,000 visits from October 2017-October 2022 has been greatly exceeded (750,000 to date)	The “visitor numbers” metric acts as a clear and easily measured metric of success.	Future projects of this type could plan to measure other metrics such as knowledge and engagement, potentially including use of questionnaires and/or requests for water meters and water saving devices. This may give a better measure of the impact of this type of project on other resilience outcomes such as water use.

5. Legislation, regulatory frameworks, policies and incentives to enhance resilience

This section reviews legislation, regulatory frameworks, policies and incentives across the water environment and water management sectors (Table 5-1) which have a bearing on resilience in both sectors. It focuses on identifying where these instruments act to facilitate enhanced resilience, but as importantly, where they act as a barrier to delivering shared resilience in both sectors. These have been identified through a targeted literature review, discussions with the project Steering Group and responses to Question 11 of the online survey. Overall, 28 items of legislation, regulatory frameworks, policies and incentives were identified, most relating to the environment, the water sector and/or land management.

There is a range of legislation, regulatory frameworks, policies and incentives based on EU Directives, as well as UK/England only legislation, regulatory frameworks, policies and incentives. All of the EU Directives that were identified have been translated to UK Law. This includes for example the revised Bathing Water Directive (rBWD) and the Water Framework Directive (WFD). Although the European Union (Withdrawal) Act 2018 will ensure that all relevant EU Law will continue immediately after the transition period, post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period. Following the transition, changes to EU legislation that has been translated into UK law could take place over a range of timescales.

Some case study participants mentioned political and other sources of uncertainty concerning legislation, regulatory frameworks, policies and incentives that are forthcoming and/or in development e.g. the new Agriculture Bill Defra's Environmental Land Management (ELM) scheme.

In developing water company case studies, some stakeholders mentioned their organisations' codes of practice as drivers for certain interventions. Table 5-1 is intended to highlight generally applicable drivers and levers for actions to enhance resilience. For this reason, company-specific codes of practice and policies are not included.

It is worth noting that further analysis of relevant legislation, regulatory frameworks, policies and incentives has been undertaken by the Wildlife and Countryside Link as well as Water UK[9].

The suite of documents in Table 5-1 can create key opportunities for increasing resilience, both within the water sector and the natural environment. In particular, their collective influence can contribute towards encouraging collaboration between the two sectors, which can lead to more efficient measures and programmes to increase resilience. However, there is also potential for legislation or policies to work against resilience or make environmental improvements more difficult to deliver.

Table 5-1: Legislation, regulatory frameworks, policies and incentives for enhanced resilience

1. EU Regulation 1143/2014 on Invasive Alien Species[10]	
Provides a series of measures in relation to invasive species that are included on the list of Invasive Alien Species (IAS) of Union Concern (the Union list).	
Enabler to Resilience:	The regulation supports resilience in both sectors and provides opportunities for better resilience management by adopting measures which aim to prevent the intentional or unintentional introductions of IAS of Union Concern into the EU, detect and eradicate IAS of Union Concern early and rapidly, and manage IAS of Union Concern that have already established to prevent further spread and minimise harm

[9] See https://www.wcl.org.uk/policy-hub.asp and https://www.water.org.uk/policy-topics/ respectively.
[10] https://ec.europa.eu/environment/nature/invasivealien/index_en.htm

	As explored in Section 3, there are several interdependencies between the water and environment sector. To facilitate effective disease and pest control, wild species diversity is required, comprising diverse resilient species. Management is also important with respect to accidental transportation and spread. Increasingly, water companies are being encouraged to consider cross-country water transfers as new sources of water supply, which could increase the risk of spreading invasive, non-native species. Disease and pest control allow for healthy ecosystems with continued wild species diversity. Where disease and pest control is compromised, wild species diversity can be undermined, with an increased abundance and distribution of invasive, non-native species.
Barrier to Resilience:	No barriers to resilience have been identified within these regulations.
Source of Information:	Case studies
Likely effect of Brexit:	Regulation has been translated into UK law, including amendments It is possible that short-term to medium-term changes could take place following the Brexit transition period. In the longer-term further changes could occur as post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period.
2. EU Water Framework Directive, 2000[11]	
The purpose of the Water Framework Directive (WFD) is to establish a framework for the protection of inland surface waters, estuaries, coastal waters and groundwater.	
Enabler to Resilience:	The WFD supports resilience in both the environment and water sector by requiring the protection of all waterbodies and the continued improvement of water bodies to good status. Through an integrated approach to defining good status, the WFD requires protection and improvements to the hydromorphological condition of waterbodies, as well as the water quality and biological/habitat condition and for groundwater, both the quantitative and quality condition of aquifers. This has driven a catchment-based approach to the management of water bodies through better land management, management of pollution sources and active management of our waterway/aquifers and how they are used for abstraction, navigation and other anthropogenic purposes.
Barrier to Resilience:	Article 4.7 of the Directive provides a means for derogation of the Directive's objectives. This can be the case for schemes which may cause deterioration (or prevent target status) and also applies when the competent authority (the Environment Agency in England and Wales) seeks to classify waterbodies has to not being able to achieve good status if the measures required to do so are considered disproportionately expensive. The Directive is therefore not a guarantee of resilience as its objectives can be derogated in certain circumstances and canthe disproportionate test can lead to some solutions which would provide resilience not being explored further.
Source of Information:	Literature review, Project Steering Group and online survey
Likely effect of Brexit:	Framework has been translated into UK law. However, post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period. Following the transition, it is possible that changes to EU legislation, that has been translated into UK law, could take place over a range of timescales.
3. The Conservation of Habitats and Species Regulations, 2010[12]	

Further Information can be found at:
[11] https://ec.europa.eu/environment/water/water-framework/index_en.html
[12] http://www.legislation.gov.uk/uksi/2010/490/contents/made

The objective of the Habitats Directive[13] is to protect biodiversity through the conservation of natural habitats and species of wild fauna and flora. The Habitats Directive requires all 28 EU Member States to:

- Restore protected habitats and species to favourable conservation status;
- Contribute to a coherent network of protected sites by designating Special Areas of Conservation (SAC) for habitats listed in Annex I and species in Annex II;
- Manage SACs and Special Protected Areas (SPAs) designated under the Birds Directive, and assess any development plans likely to significantly affect a SAC or a SPA. Projects may still be permitted if there are no alternatives, but compensatory measures must be taken to ensure the coherence of the Natura 2000 network (Article 6);
- Encourage good management of landscape features that support the Natura 2000 network (Articles 3 and 10);
- Monitor habitats and species (Article 11);
- Ensure strict protection of species listed in Annex IV; and
- Report on the implementation of the Directive every six years (Article 17).

Enabler to Resilience:	The Regulations directly supports resilience in the natural environment by providing a high level of protection (and requirement to enhance conditions) of designated sites which provide biodiversity as well as a range of ecosystem services upon which the water industry is reliant. SAC and SPA sites in the UK are afforded a significant level of protection by the regulations, including limitations on new development and how they impact on protected sites. The regulation also encourages good management of landscape features linking the network of protected site which can aid to enhance resilience in land uses connecting protected sites.
Barrier to Resilience:	An indirect barrier related to the regulations is that they only afford protection to designated sites and protection of designated species and therefore have a limited spatial reach with effect to influencing resilience more widely
Source of Information:	Project Steering Group and online survey
Likely effect of Brexit:	The regulations translate EU Directives into UK law. However, post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period. Following the transition, it is possible that changes to EU legislation, that has been translated into UK law, could take place over a range of timescales.

4. Eels (England and Wales) Regulations, 2009[14]

Affords powers to the Environment Agency to implement measures for the recovery of European eel stocks. The regulations have implications for operators of abstractions and discharges.

Enabler to Resilience:	These regulations support resilience in both sectors but primarily through enhancement of river and estuarine environments to provide habitat and safe passage for eels. They require structures which act as migration barriers to be removed or altered to facilitate migration and to ensure abstractions do not adversely impact on eel population through entrainment into intakes. All of these measures have secondary implications for provision of more resilient river and estuarine environments by encouraging a more natural flow and hydromorphological regime.
Barrier to Resilience:	The need to manage abstractions presents a minor barrier to water supply resilience
Source of Information:	Project Steering Group

Further Information can be found at:
[13] https://ec.europa.eu/environment/nature/natura2000/index_en.htm
Further Information can be found at:
[14] http://www.legislation.gov.uk/uksi/2009/3344/contents/made

Likely effect of Brexit:	The regulation translates the Eel Directive into UK law. However, post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period. Following the transition, it is possible that changes to EU legislation, that has been translated into UK law, could take place over a range of timescales.
5. The Environmental Impact Assessment (EIA) Directive, 2014[15]	
The EIA Directive aims to ensure a high level of environmental protection and that environmental considerations are integrated into the preparation and authorisation of projects. Recent changes in regards climate change, resilience and reference to natural capital increases the relevance of the Directive to natural resilience.	
Source of Information:	Literature review
Likely effect of Brexit:	None, as this regulation has been subsumed into England's Town and Country Planning (Environmental Impact Assessment) Regulations 2017 (the '2017 Regulations').
6. Flood and Water Management Act, 2010[16]	
The Flood and Water Management Act provides for better, more comprehensive management of flood risk for people, homes and businesses, helps safeguard community groups from unaffordable rises in surface water drainage charges, and protects water supplies to the consumer[17]. Water and Sewerage Companies are responsible for managing the risks of flooding from water and foul or combined sewer systems providing drainage from buildings and yards.	
Enabler to Resilience:	In creating Lead Local Flood Authorities, the Act has increased the requirement on new development to better manage surface water flood risk, and through the changes to the NPPF and PPGs, has driven a requirement for development to provide reduced surface water flood risk through sustainable drainage (SuDS). SuDS provide natural resilience through the creation of biodiversity in urban landscapes, provision of water quality benefits and greater potential for returning water to ground and aquifers through infiltration. They also help to improve resilience in the operation of sewer networks by controlling the rate and volumes of discharge to sewer.
Barrier to Resilience:	The Flood and Water Management Act creates barriers to better management of resilience through a catchment based approach as responsibilities are left unclear or fractured across many risk management authorities. For example, the Act aimed to provide more comprehensive management of flood risk for people, homes and businesses. However, the legislation also results in a very complex distribution of responsibilities for flooding and natural and artificial water management infrastructure with no one body having overall oversight. The Environment Agency considers main river flooding, while Lead Local Flood Authorities (single tier authorities and county councils) are responsible for monitoring and responding to flooding on ordinary watercourses and local sources of flooding such as surface water and groundwater. Water and Sewerage Companies are responsible for managing the risks of flooding from water and foul or combined sewer systems providing drainage from buildings and yards, however it is often not possible to distinguish between sewer flooding and surface water flooding as the same events and processes cause both. Local Planning Authorities (LPA's) decide planning applications but the LLFA decides on the appropriateness of surface water drainage proposals, including sustainable urban drainage systems (SuDS). These SuDS may discharge into main rivers (in which case Environment Agency consent may be needed), ordinary watercourses or sewers (in which case the consent of the sewerage company is needed, however they are not statutory consultees). For this reason, any proposals to systematically increase the resilience of a system to extreme rainfall and flooding will involves at least four regulatory stakeholders and an unknown number of local, non-governmental stakeholders.

[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0052
[16] http://www.legislation.gov.uk/ukpga/2010/29/contents
[17] https://www.gov.uk/guidance/flood-risk-management-information-for-flood-risk-management-authorities-asset-owners-and-local-authorities

Source of Information:	Project Steering Group
Source of Information:	Literature review
Likely effect of Brexit:	None
7. Wildlife & Countryside Act, 1981	
The Wildlife and Countryside Act is the primary legislation which protects animals, plants and habitats in the UK[18].	
Enabler to Resilience:	This Act supports resilience in both sectors and provides opportunities for better resilience management through the protection of animals, plants and habitats.
Barrier to Resilience:	No barriers to resilience have been identified within this Act.
Source of Information:	Project Steering Group
Likely effect of Brexit:	None
8. Water Act, 2014[19]	
The aim of the Act was to reform the water industry to make it more innovative and responsive to customers and to increase the resilience of water supplies to natural hazards such as droughts and floods. The Act was intended to introduce competition into the market and bring benefits to businesses and the economy.	
Enabler to Resilience:	The Act supports resilience in both sectors and provides opportunities for better resilience management. The Act states that the resilience objective is: • To secure the long-term resilience of water undertakers' supply systems and sewerage undertakers' sewerage systems with regards to environmental pressures, population growth and changes in consumer behaviour; and • To secure that undertakers take steps for the purpose of enabling them to meet, in the long-term, the need for the supply of water and the provision of sewerage services to consumers, including by promoting: – Appropriate long-term planning and investment by relevant undertakers; and – The uptake of a range of measures to manage water resources in sustainable ways, and to increase efficiency in the use of water and reduce demand for water to reduce pressure on water resources. The above actions highlight interdependencies between sectors.
Source of Information:	Project Steering Group and literature review
Likely effect of Brexit:	None
9. Revised Bathing Water Directive, 2006	

[18] https://www.rspb.org.uk/birds-and-wildlife/advice/wildlife-and-the-law/wildlife-and-countryside-act/
[19] http://www.legislation.gov.uk/ukpga/2014/21/contents/enacted

The revised Bathing Water Directive (2006/7/EC) (rBWD) came into force in 2015, replacing and updating the previous Directive (76/10/EEC). It sets more stringent water quality standards for the protection of public health and places stronger emphasis on beach management and public information. Waterbodies are classified based on their bacteriological quality according to the status levels 'poor', 'sufficient', 'good' or 'excellent'.	
Enabler to Resilience:	The revised Directive supports resilience in both sectors and provides opportunities for better water quality resilience management as it is intended to: • Be based on scientific knowledge on protecting human health and the environment, as well as environmental management experience; • Provide better and earlier information about the quality of bathing waters; • Move from simple sampling and monitoring of bathing waters to bathing water quality management; and • Be integrated into all other EU measures protecting water quality (rivers, lakes, groundwater and coastal waters) through the Water Framework Directive. As discussed in Section 3, both sectors are fundamentally reliant upon water quality regulation. For water quality regulation, assets which filter water naturally are required. Initial water quality (prior to filtering) should also be considered, with good raw water quality of importance.
Barrier to Resilience:	No barriers to resilience have been identified within this Directive.
Source of Information:	Literature review
Likely effect of Brexit:	Directive has been translated into UK law. However, post-Brexit compliance with UK regulations will no longer be accountable to the European Courts after the transition period. Following the transition, it is possible that changes to EU legislation, that has been translated into UK law, could take place over a range of timescales.
10. Natural Environment and Rural Communities Act, 2006[20]	
An Act to make provision about bodies concerned with the natural environment and rural communities; to make provision in connection with wildlife, sites of special scientific interest, National Parks and the Broads; to amend the law relating to rights of way; to make provision as to the Inland Waterways Amenity Advisory Council; to provide for flexible administrative arrangements in connection with functions relating to the environment and rural affairs and certain other functions; and for connected purposes.	
Enabler to Resilience:	The Act supports resilience in both sectors and provides opportunities for better resilience management by ensuring that the natural environment is conserved, enhanced and managed for the benefit of present and future generations, thereby contributing to sustainable development by: • Promoting nature conservation and protecting biodiversity; • Conserving and enhancing the landscape; • Securing the provision and improvement of facilities for the study, understanding and enjoyment of the natural environment; • Promoting access to the countryside and open spaces and encouraging open-air recreation; and

[20] http://www.legislation.gov.uk/ukpga/2006/16/section/2

	• Contributing in other ways to social and economic well-being through management of the natural environment The above actions highlight interdependencies between sectors. There are ongoing discussions about whether priority habitats identified under this Act should be afforded a higher level of protection (e.g. for chalk-streams)
Barrier to Resilience:	No barriers to resilience have been identified within this Act.
Source of Information:	Project Steering Group and online survey
Likely effect of Brexit:	None

11. Environment Bill

The Environment Bill will place environmental ambition and accountability at the centre of Government and create a new environment body (Office of Environmental Protection). It supports resilience in both sectors and provides opportunities for better resilience management through direct actions to address the biggest priorities of the age, relating to: air quality, the protection and enhancement of our landscapes, wildlife and habitats, more efficient handling of resources and waste, and better management of our surface, groundwater and wastewater.

Enabler to Resilience:	The Bill includes measures that are intended to help secure long-term, resilient water and wastewater services to ensure a cleaner, greener and more resilient country for the next generation. This includes implementation of abstraction reform which aims to restore watercourses to a close to a natural state as possible and making WRMPs a legal requirement. The Bill introduces additional requirements for water companies' planning for future water supply and wastewater and drainage networks, enabling more resilient solutions to drought and flooding. It includes a specific aim for drainage and wastewater management plans to increase the potential for water quality impacts of wastewater discharges to be managed in a longer-term and more holistic way. The bill sets out a requirement for legally-binding targets on air, water quality, biodiversity which would support the resilience agenda through protection of environmental quality. It also places extra duties on local authorities to provide local nature recovery strategies. The bill enshrines the requirement for biodiversity net gain into law – requiring new development to increase or improve biodiversity through planning which has significant potential to increase natural resilience and water company resilience where landscape, biodiversity and surface water management are integrated for example, through the provision of SuDS.
Barrier to Resilience:	Whilst the bill sets out a requirement for legally-binding targets on air, water quality, biodiversity there is no commitment to upholding existing environmental standards after the end of the Brexit transition; new standards therefore have the potential to negatively affect natural resilience if environmental protection is changed. Changes to abstraction reform will not be immediate. The requirement for removing the abstraction licencing process under the Environment Permitting Regulations limits the immediacy of the potential to improve natural resilience in catchments. The bill does not set mandatory water efficiency targets for new development, instead leaving the burden on local planning authorities to set and justify water efficiency targets through local planning policy (or in the case of London Boroughs through the London Plan). This is a missed opportunity to provide a national requirement to minimise water use and encourage the update of rainwater harvesting and other re-use technologies at development or community scales which would contribute to national water supply resilience as well as a secondary improvement in natural resilience through minimising requirement for new water resource schemes.

	The bill would promote the creation of new Internal Drainage Boards (IDB) further increasing the number of risk management authorities managing surface water and local flood risk reducing the potential to deliver cohesive catchment approaches to water management and flood risk.
Source of Information:	Online survey
Likely effect of Brexit:	n/a (forthcoming regulation, partly driven by Brexit)

12. New Agriculture Bill

A new agricultural bill will be required upon leaving the European Union and the Common Agricultural Policy. The Agriculture Bill sets out how farmers and land managers will be paid in the future for 'public goods', such as better air and water quality, improved soil health, higher animal welfare standards, public access to the countryside and measures to reduce flooding[21].

Enabler to Resilience:	The Agriculture Bill will provide opportunities for better resilience management through incentivising activities and services which support resilience in both the natural and water environment. The legal commitment to produce regular Food Security Reviews included in the Agriculture Bill will encompass the impacts of climate change, including flooding, drought, and extreme weather events, in addition to biodiversity loss, such as declines in beneficial insects and pollinators on the resilience and diversity of food supplies. In particular, the Bill encompasses the principle of public money for public goods with subsidies for farmers moving towards the socio-environmental goods they provide to the public as opposed to payments for the amount of land owned. Some of the public goods include managing land or water in a way that protects or improves the environment; Interdependencies between the two sectors are strongly tied within the Agriculture Bill. For example, both sectors are fundamentally reliant upon water quality regulation, as explored in Section 3.
Barrier to Resilience:	The Agriculture Bill may result in barriers to better management of resilience in both sectors by the prioritisation of some activities and services, notably food supply. Also, the Bill lacks powers to enforce a new regulatory framework for farming and land management practices which are critical to the provision of resilient environment and hence a co-dependent resilient water industry.
Source of Information:	Online survey
Likely effect of Brexit:	New agricultural bill in development

13. National Planning Policy (NPPF) 2012 and Planning Practice Guidance (and relevant updates)[22]

The National Planning Policy Framework was published in 2012 and revised in 2018. It sets out the Government's planning policies for England and how these are expected to be applied. The NPPF is supported by Planning Practice Guidance which spans various topics including flood risk and coastal change and climate change.

Further Information can be found at:
[21] https://www.gov.uk/government/news/landmark-agriculture-bill-to-deliver-a-green-brexit
[22] https://www.gov.uk/government/collections/planning-practice-guidance

Enabler to Resilience:	The NPPF states how the planning system should support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change. The NPPF supports resilience in both sectors and provides opportunities for better resilience management. It documents how plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply, biodiversity and landscapes, and the risk of overheating from rising temperatures. Policies should support appropriate measures to ensure the future resilience of communities and infrastructure to climate change impacts, such as providing space for physical protection measures, or making provision.
Barrier to Resilience:	The NPPF stops short of supporting the resilience agenda with regards to setting nationally based water consumption targets and driving lower water demand. It also reduces the effectiveness of LLFAs in driving sustainable drainage forward by not committing developers to long-term maintenance of SuDS systems (in the absence of SuDS Approval bodies not being put in place by reduced enactment of the sections of the Flood and Water Management Act).
Source of Information:	Online survey
Likely effect of Brexit:	None
14. Defra (2016) Creating a great place for living – Enabling resilience in the water sector[23]	
Provides a policy framework to secure the long-term resilience of the water sector, helping to deliver a cleaner, healthier environment, benefitting people and the economy. The framework is intended to shape and inform the policy framework and the water resources management plans that companies develop.	
Enabler to Resilience:	To better understand the public water supply and future needs, Defra has asked the water industry to develop a national water resources long-term planning framework which will establish water needs over the next 50 years and the strategic options which could meet these needs, supporting resilience in the water sector. Within the report, Defra welcomes Water UK's work to establish a Water and Wastewater Resilience Action Group to promote and enhance the sector's resilience, and to develop a sector-wide strategic dashboard which should enable Defra and others to compare levels of resilience, now and in the future. As explored in Section 3, there are several interdependencies between the water and environment sector. Both the natural environment and the water sector rely on streams, rivers and aquifers to supply unpolluted water. Water companies directly influence the supply of water across ecosystems as a function of abstraction and the discharge of treated effluent.
Barrier to Resilience:	Defra's report[24] provides several key messages and recommendations including the case for the UK and Welsh Governments to consider adopting consistent national minimum levels of resilience, recognising that there are significant issues to address, including inter-regional and inter-generational fairness, which may be considered as possible barriers to resilience.
Source of Information:	Literature review
Likely effect of Brexit:	None
15. Defra (2016) Guiding principles for water resources planning – For water companies operating wholly or mainly in England[25]	

[23] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/504681/resilience-water-sector.pdf
[24] https://www.water.org.uk/wp-content/uploads/2018/11/Water-UK-WRLTPF_-Summary-Report_FINAL-PUBLISHED-min.pdf
[25] http://www.wrse.org.uk/wp-content/uploads/2018/04/Defra-Guiding-Principles-for-Water-Resource-Planning.pdf

• The document explains the key policy priorities the government expects water resources management plans (WRMP) to address.	
Enabler to Resilience:	The document supports resilience in both sectors by identifying opportunities for better resilience management through four guiding principles for water resources planning, including: Take a long-term, strategic approach to protecting and enhancing resilient water supplies; Consider every option to meet future public water supply needs; Protect and enhance our environment, acting collaboratively; and Promote efficient water use and reduce leakage. The document highlights the interdependencies between the water sector and natural environment by noting how the government looks to water companies as leaders of the natural environment and how management roles will increase. It reports that water companies should demonstrate how nature is valued in water company decisions and consideration should be given to where new and innovative opportunities for investment in our natural assets can be provided.
Barrier to Resilience:	The document reports how water supply must support the growth predicted by local authorities within an area and water companies should provide clear evidence of engagement with local authorities on joint planning. Timescale differences between the local plan making process and water company planning cycles (business plans and WRMPs) limit the effectiveness of Joint planning which may present a barrier to better management of resilience. The need for water companies to support local plan growth also creates the potential for conflicting priorities where proposed development targets set for authorities do not take account of location specific limitations in the capacity of the natural environment to provide resilient, clean and reliable water supplies or to continue to provide assimilative capacity related to wastewater discharges.
Source of Information:	Literature review
Likely effect of Brexit:	None
16. Defra (2017) The Government's Strategic Priorities and Objectives for Ofwat[26]	
The statement sets out Defra's strategic priorities and objectives for Ofwat. The statement complements Ofwat's existing duties, and places emphasis on areas where Defra expects Ofwat to lead a shift in the water industry's strategic direction, using the range of tools and approaches available to them.	
Enabler to Resilience:	The statement supports resilience in both the water and environment sector and provides opportunities for better resilience management through identifying two priorities for Ofwat: • Ofwat should challenge the water sector to plan, invest and operate to meet the needs of current and future customers, in a way which offers best value for money over the long term; and • Ofwat should promote markets to drive innovation and achieve efficiencies in a way that takes account of the need to further: (i) the long-term resilience of water and wastewater systems and services; and/or (ii) the protection of vulnerable customers. The statement identifies a number of objectives to support these priorities where interdependencies can be seen between the two sectors: • Ofwat should further a reduction in the long-term risk to water supply resilience from drought and other factors, including through new supply solutions, demand management and increased water trading; • Ofwat should challenge water companies to improve planning and investment to meet the wastewater needs of current and future customers;

[26] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/661803/sps-ofwat-2017.pdf

	• Ofwat should challenge water companies to make sure that they assess the resilience of their system and infrastructure against the full range of potential hazards and threats and take proportionate steps to improve resilience where required; and, • Ofwat should challenge companies to further the resilience of ecosystems that underpin water and wastewater systems, by encouraging the sustainable use of natural capital and by encouraging water companies to have appropriate regard to the wider costs and benefits to the economy, society and the environment.
Barrier to Resilience:	The statement makes pertinent recommendations, however there is no statutory basis to Defra's expectation of Ofwat and therefore, this may have limited reach as a means to ensure resilience is delivered.
Source of Information:	Literature review
Likely effect of Brexit:	None
17. Government's 25-Year Environment Plan[27]	
The 25-Year Environment Plan sets out the Government's goals for improving the environment. It details how the government will work with communities and businesses over the next 25 years.	
Enabler to Resilience:	The Government's 25 Year Environment Plan supports resilience in both sectors and provides opportunities for better resilience management. It states that clean and plentiful water will be achieved by improving at least three quarters of our waters to be close to their natural state as soon as is practicable by: • Reducing the damaging abstraction of water from rivers and groundwater, ensuring that by 2021 the proportion of waterbodies with enough water to support environmental standards increases from 82% to 90% for surface waterbodies and from 72% to 77% for groundwater bodies; • Reaching or exceeding objectives for rivers, lakes, coastal and ground waters that are specially protected, whether for biodiversity or drinking water as per River Basin Management Plans; • Supporting Ofwat's ambitions on leakage, minimising the amount of water lost through leakage year-on-year, with water companies expected to reduce leakage by at least an average of 15% by 2025; and • Minimising by 2030 the harmful bacteria in our designated bathing waters and continuing to improve the cleanliness of waters. The plan also calls for ensuring that potential bathers are warned of any short-term pollution risks.
Barrier to Resilience:	Whilst the plan sets out some key targets linked to providing resilience in both sectors, many of the targets are long term and would take many years to begin to deliver outputs. Additionally, there is a lack of legislative framework to ensure many of the aims and objectives are delivered, and in some cases, it lacks clarity on how the objectives will actually be delivered.
Source of Information:	Literature review
Likely effect of Brexit:	None

[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

18. National Infrastructure Commission (2018) Preparing for a drier future – England's water infrastructure needs[28]	
The paper sets out a range of measures which the Commission believes Government, water companies and the regulator should take to increase investment in supply infrastructure and encourage more efficient use of water – halving leakage by 2050, extending metering and developing plans for a national water network.	
Enabler to Resilience:	The paper supports resilience in both sectors and provides opportunities for better resilience management. The National Infrastructure Commission recommends that Government should ensure plans are in place to deliver additional supply and demand reduction of at least 4,000 Ml/day, as follows: • Ofwat should launch a competitive process by the end of 2019 complementing the Price Review so that at least 1,300 Ml/day is provided through (i) a national water network and (ii) additional supply infrastructure by the 2030s; • Defra should set an objective for the water industry to halve leakage by 2050, with Ofwat agreeing five-year commitments for each company (as part of the regulatory cycle) and reporting on progress; and • Defra should enable companies to implement compulsory metering beyond water stressed areas by the 2030s, by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters as a first step in a concerted campaign to improve water efficiency. The paper documents interdependencies between sectors. It is considered that the above actions will deliver a more resilient water supply and reduce the chance of expensive and intrusive emergency responses to droughts being required, or, worse, homes having their water supply cut off were a prolonged extreme drought to happen. This will also improve the situation for the environment and lessen risks for other users of water, such as agriculture, industry and power generation.
Barrier to Resilience:	The report advocates planning for a 1 in 500 year drought. Whilst this would improve water supply resilience, there is currently nothing is statute which would set this requirement and as such, if it were followed it could be challenged at Public Inquiry.
Source of Information:	Literature review
Likely effect of Brexit:	None

19. Ofwat (2015) Inputs, outputs and outcomes – what should price limits deliver? A discussion paper[29]	
In 'Beyond limits' Ofwat reported: "We are keen to focus more on incentivising outcomes, rather than outputs or inputs." This discussion paper considers why such an approach may be beneficial to customers and deliver sustainable water. It suggests a possible framework within which a methodology could be drawn up for developing Ofwat's approach to accountability for delivering outcomes and incentivising the companies through the price review process.	
Enabler to Resilience:	Ofwat state that adopting an outcome-focused approach to regulation means that the focus is on incentivising water companies efficiently to deliver what customers and society need, want and are willing to pay for. 'A more outcome-focused approach would encourage the companies to concentrate more on the things that people value. In turn, this would encourage them to understand better the needs and wants of their customers and constantly to review the best way to achieve those. Moving to a more outcome-focused approach is not thought to have a negative effect on the environment and drinking water quality, especially if overall compliance with legislation (and other standards) is included as

Further Information can be found at:
[28] https://www.nic.org.uk/wp-content/uploads/NIC-Preparing-for-a-Drier-Future-26-April-2018.pdf
Further Information can be found at:
[29] https://www.ofwat.gov.uk/wp-content/uploads/2015/12/prs_inf1103fploutcomes.pdf

	an outcome. Rather, it will incentivise the companies to find the best way of achieving compliance'.
Source of Information:	Literature review
Likely effect of Brexit:	None

20. Ofwat (2016a) A consultation on the outcomes framework for PR19[30]

This consultation discusses how Ofwat can make outcomes better reflect customer preference at the 2019 price review (PR19). Outcomes are the objectives valued by customers and society which companies aim to deliver. The outcomes framework is one of the key elements of PR19.

Enabler to Resilience:	The proposal supports resilience in both sectors and provides opportunities for better resilience management. The proposal reports that to ensure the interests of future customers and the environment are taken into account they are considering ways in which the outcomes framework can better encourage companies to deliver resilient services and systems. More stretching performance commitments, more powerful ODIs and more transparent performance commitments can all contribute to this. The proposal documents interdependencies between sectors. Ofwat covers a range of proposals which they consider will better reflect resilience within the outcomes framework at PR19. These proposals are consistent with the approach set out in Towards Resilience: that Ofwat will enable, incentivise and encourage water and wastewater service providers to step up to the challenge of making their systems and services resilient and responsive to customer, environmental and societal priorities.
Source of Information:	Literature review
Likely effect of Brexit:	None

21. Ofwat 'Tapped In' report[31]

This report focusses on the questions surrounding customer participation in service delivery. The report draws on emerging practices from inside and outside the water sector. It taps into a wider movement to connect people to the things that really matter in their lives, to give them a voice, facilitated in part by new technologies and to provide greater input and control[32].

Enabler to Resilience:	The proposal supports resilience in both sectors and provides opportunities for better resilience management. The focus of the document is to move from passive consumption to active participation. This approach could help promote resilience, including the prioritisation of customer education and the promotion of partnership working with other agencies. Encouraging behaviour change amongst customers can help water companies achieve their strategic and tactical goals. For example, persuading more customers to adopt water-saving behaviours improves the resilience of supply, while empowering customers to only put the right things down the down the drain directly reduces sewer blockages.
Barrier to Resilience:	The report documents how people's beliefs shape the actions they take and may act as a barrier to resilience. For example, some people believe that helping to ensure the future resilience of the water supply of homes and workplaces is the sole responsibility of the water companies.

[30] https://www.ofwat.gov.uk/wp-content/uploads/2016/11/Consultation-on-the-outcomes-framework-for-PR19.pdf
Further Information can be found at:
[31] https://www.ofwat.gov.uk/wp-content/uploads/2017/03/1941_OFWAT_Cust_Participation_Report_final.pdf
[32] https://www.ofwat.gov.uk/wp-content/uploads/2017/03/1941_OFWAT_Cust_Participation_Report_final.pdf

Source of Information:	Online survey
Likely effect of Brexit:	None

22. Ofwat 'Resilience Task & Finish Group' Report[33]

This report presents the ten recommendations that the Task and Finish Group has identified to help facilitate resilience-building in the water and wastewater sectors. The details of the analysis that has been undertaken by and for the group are then set out. The analysis has been used to draw out the main resilience challenges and identify specific areas that need to be addressed. The Task and Finish Group set out how it tested the ten recommendations through a sector-wide workshop.

Enabler to Resilience:	The report supports resilience in both sectors and provides opportunities for better resilience management. The report includes the following recommendations among others: • **Ensure clear routes for funding legitimate resilience investment: t**here should be a clearer and smoother pathway for funding legitimate resilience-building measures. Ofwat should provide water companies with a clear framework; it is important that water companies retain ownership of their plans built using this framework. There needs to be clear guidance from Ofwat on its treatment of resilience investments when it considers business plans. There needs to be flexibility to fund innovation against a wide assessment of costs and benefits and future generational aspects should be factored into assessment of business plans; and • **Establish wastewater, sewerage and drainage plans:** there should be national wastewater and sewerage strategies and each company should have a wastewater and sewerage plan. This should link to SuDS, wider drainage issues (highway and land drainage) and rainwater and greywater harvesting through the parallel development of drainage plans. Potentially these plans should be statutory, and there may be scope under the existing statutes.
Barrier to Resilience:	The report identifies the main challenges to resilience, including: • A step change in approach is needed to build resilience with a greater need for partnership and softer infrastructure solutions where appropriate. This step change will require far greater engagement with customers to understand their expectations on service levels and to enable a more active role for customers in building resilience. • A clear overview of the resilience of the sector does not exist; this has come from a lack of an agreed definition of resilience, a dearth of consistent measures and no fixed resilience standards. • It is unclear as to whether the current structure of the sector and the form of economic regulation encourage legitimate resilience investments to be made. It is also unclear if decisions are being made on the appropriate geographical scales to build resilience in an effective way.
Source of Information:	Literature review
Likely effect of Brexit:	None

23. Water Abstraction Plan, 2017 (and relevant updates)

This document sets out how the government will reform water abstraction management over the coming years and how this will protect the environment and improve access to water.

[33] https://www.ofwat.gov.uk/wp-content/uploads/2015/12/rpt_com20151201resiliencetaskfinish.pdf

Enabler to Resilience:	The plan supports resilience in both sectors and provides opportunities for better resilience management as it is accepted that the current abstraction management service is outdated. Defra want to modernise the service to enhance and expand the range of digital services available and simplify regulatory requirements. This will underpin work to improve both the environment and access to water by providing a modern and simple service for abstractors[34]. The abstraction licensing service is part of the Water Abstraction Plan[35]. The plan documents interdependencies between sectors by setting out aspirations for abstraction management to take a catchment focus, by applying catchment-based approaches.
Barrier to Resilience:	Environmental Flow Indicators (EFI) play a key role in the water abstraction plan, however, EFIs are a generic screening too, which in most cases, have not been developed specifically for each river system and how it functions which means they can result in erroneous conclusions. This could present a barrier to resilience as it could recommend abstraction reductions which may not be necessary or not indicate correctly where an abstraction may be having an impact on habitats or species (particularly a risk for high flow abstraction where spate flows are important for fish migration or sediment movement) . River specific EFIs would be a key requirement to deliver the water abstraction plan which would require a significant research effort across England which is currently not planned for the majority of river systems
Source of Information:	Online survey
Likely effect of Brexit:	None

24. Water Industry National Environment Programme (WINEP)

The Water Industry National Environment Programme (WINEP) is supported by WISER (Water Industry Strategic Environmental Requirements). WINEP represents a set of actions that the Environment Agency have requested all 20 water companies operating in England to complete between 2020 and 2025 in order to contribute towards meeting their environmental obligations. It is noted that the current round of river basin management planning (RBMP3) is subject to Secretary of State sign off at the end of 2021 which may have an effect on the final WINEP programme.

Enabler to Resilience:	The set of actions are bespoke and site-specific, which investigate and tackle the environmental impacts of water industry operations. These actions create opportunities for local collaboration to enhance resilience. The measures in WINEP represent the basic measures required by water companies to meet their environmental outcomes. However, this also presents an opportunity for the industry to develop innovative approaches which will benefit customers, communities, the environment and natural capital, demonstrating interdependencies between sectors.
Barrier to Resilience:	The WINEP is reliant on legislative drivers to ensure delivery of the schemes – without a legislative driver, a water company is unlikely to receive funding from Ofwat to implement the measure, which is a barrier to resilience, particularly if legislation is changed post Brexit.
Source of Information:	Online survey
Likely effect of Brexit:	None

25. Water Resources Planning process (i.e. Water Resource Management Plans WRMPs)

Further Information can be found at:
[34] https://www.gov.uk/government/publications/water-abstraction-plan-2017/water-abstraction-plan-abstraction-licensing-service
[35] https://www.gov.uk/government/publications/water-abstraction-plan-2017/water-abstraction-plan

Every five years statutory water resources management plans (WRMPs) set out a company's intended approach for at least the next 25 years.	
Enabler to Resilience:	Opportunities include optimising key activities and resources beyond traditional company boundaries – through water trading or third parties, for example. The opportunities are not just focussed on reducing cost, but also about making the best use of resources, improving resilience and finding new methods.
Barrier to Resilience:	To date WRMPs only aspire to meet established legislative drivers with no account for environmental ambition. The latest guidance is looking to address this by requiring the regional groups to agree a level of environmental ambition to plan for but it is currently unclear how this will be achieved.
Source of Information:	Online survey
Likely effect of Brexit:	None

5.1 Impacts of Legislation on Case Studies

Given the very wide range of aspects considered under the concept of "resilience," it is not possible to give a definitive prediction of the impacts of the legislative and policy-based instruments on any given system. The list in Table 5-1 above is not exhaustive and the relative weight of each instrument will vary depending on the proposed measures to be taken. For example, with reference to the case studies in Appendix B, the legislation and policies affecting British Canoeing's invasive species project will vary from those affecting the Environment Agency's water abstraction project. Both projects affect resilience, but the same legislative instruments do not apply. In addition, other statutory instruments such as the Data Protection Act[36] may become relevant from some projects and inhibit data sharing between stakeholders.

Table 5-2 provides an outline of the relevant statutory and non-statutory legislation, policy and guidance that had to be considered in each of the case studies. What is clear is the diversity of legislation, policy and guidance which can impact on projects to improve resilience in very different ways. However, some themes do repeat, with the most common themes being:

- a balance must often be struck to ensure compliance with different pieces of legislation. This requires engagement and agreement with all relevant stakeholders;
- multiple stakeholders being involved in projects can make the regulatory framework less clear or add complexity to arrangements for ongoing funding and responsibilities, and;
- moving from engagement with public or private bodies to engagement with individual members of the public can be a point at which conflict arises.

In view of the complexity of the legislation affecting the resilience of water management systems in the UK, the diversity of potential impacts, and the potential for future change, projects to improve resilience in both sectors should include a review of the relevant legislation before any work begins. This will identify the main regulatory stakeholders, as well as the potential for legislative and regulatory frameworks and policies to inhibit any proposed work. All parties involved (see Section 6 for a discussion of key stakeholders) should clearly record the legislative drivers and barriers to resilience which exist and their impacts. This can then be clearly communicated to regulators so that the case for legislative change can be made clearly, transparently and consistently.

[36] https://services.parliament.uk/bills/2017-19/dataprotection.html

Table 5-2: Review of Impacts of Legislation on Case Studies

Project	Relevant Legislation, Policy, Guidance and Drivers	Impacts of Current Legislative, Policy and Guidance Framework
British Canoeing invasive species programme	- EU regulation on Invasive Alien Species - EU Water Framework Directive - The Wildlife and Countryside Act 1981	This project includes many stakeholders which were either NGOs or water companies. These stakeholders are regulated by very different frameworks, e.g. National Council for Voluntary Organisations and the Charity Commission for the NGOs, Ofwat and Defra for water companies. The project relies on volunteers, but the line between volunteers and employees, and the legal obligations of the stakeholders to the volunteers, must be clear, consistent and sustainable for the lifetime of the project. The project was impacted by laws concerning land ownership, riparian rights and ease and availability of access. There is currently a lack of coordination and specific legislation at a national level to give clarity on responsibilities for invasive non-native species. This results in a lack of capacity within governing bodies to dedicate resources to the problem.
Environment Agency – water abstraction	- The National Environment Programme (NEP) funded by the water company Asset Management Plan (AMP5) - The EU Water Framework Directive - Environment Agency's Restoring Sustainable Abstraction (RSA) programme - The statutory requirements of Natural England's AONB designations. - Section 52 of the Water Resources Act (1991) to compulsorily change the licence - The Secretary of State decision processes	This project includes many stakeholders, including the Environment Agency, water company and NGOs. These stakeholders are regulated by very different frameworks, e.g. National Council for Voluntary Organisations and the Charity Commission for the NGOs, Ofwat and Defra for water companies. The Secretary of State also ruled on this project. The success of this project relied on United Utilities being able to maintain the supply while reducing abstraction. Had they not been able to do so then legislative complexities would have arisen because there would have been conflict between the requirement to sustain supply and the need to protect the water environment. This project also required river works. The legal consenting process for works to watercourses can be complex and involve multiple regulators. Flood Risk Activity Permits from the Environment Agency are required for works on main rivers, while works to Ordinary Watercourses require consents from the Lead Local Flood Authority. Proposals may also require planning permission from the Local Planning Authority. These issues can hinder this type of work going forward particularly around the delivery of quick wins.
South East Water – PROWATER-Interreg project	- Innovation proposals approved by Ofwat	The project could be relevant in the context of future regulation such as Defra's forthcoming Environmental Land Management scheme. Land management subsidies could influence land use surrounding South East Water land holdings, as well as in wider catchments. There is potential for conflicts between the requirements of individual land owners and large scale work to improve natural resilience. The Spatial Analysis Tool produced as part of this project allows the modelling of land use and puts the trade-offs between agriculture, housing development, the natural environment and the water sector into context. However, if this is used to inform the Local Planning process then there is a risk of legal challenge if the model results cannot be shown to be robust.

Southern Water – instream catchment resilience scheme	- Requirements for investing in natural capital and achieving sustainable water resource requirements. - Water Resource Management Plan (WRMP) - AMP7 Business plan - The EU Water Framework Directive - Abstraction polices from the Environment Agency - The 25-Year Environment Plan - Advice from regulators, including the Environment Agency and Ofwat regarding resilience and natural capital	This project, and others like it, seek to fill a gap in evidence to quantify benefits and build a business case for improving natural resilience rather than defaulting to tried and tested engineering focused solutions to water supply. Commitments to deliver such improvements need to be carefully worded to avoid being unable to deliver the hoped-for solutions using methods that are currently untested at scale. Regulators need to be aware of this in their approach to enforcing legislation and delivering improved status under the Water Framework Directive so that water companies and other stakeholders are free to try new approaches. This is particularly important in view of the time taken to realise and measure the benefits of natural solutions which occur over relatively long timescales. Natural resilience schemes can have a complex stance and position within the regulatory framework, particularly in terms of whether it is accepted as a form of mitigation. This project has also identified political and legal issues associated with delivering schemes on the ground at catchment scale, e.g. land ownership restrictions.
Thames Water – Walthamstow wetlands project	- Thames Water's Codes of Practice which was prepared under section 182 of the Water Industry Act 1991 - Code of Practice on Conservation, Access and Recreation (CAR) - Reservoirs Act - Water Industry National Environment Programme (WINEP) - The site is designated as a Special Site of Scientific Interest (SSSI), a Special Protection Area (SPA) and a Ramsar site, and is protected under international, European, and national legislation.	There are many legislative requirements for this site, and a balance is required between operational requirements, environmental impacts and delivering the project objective to increase the number of visitors on site. The site requires constant structural and environmental monitoring under the legislation. There is an uncertain long-term governance and funding structure. The number of stakeholders involved has led to uncertainty over how much the site costs to run. Legal aspects have caused challenges to the project and it is critical that Thames Water maintain involvement and control over what happens on the site. Sites such as the Walthamstow wetlands need to be advertised and signed correctly to prevent incorrect use of the area and unwelcome behaviours. For example, making clear to visitors that the site is a Nature Reserve rather than a park.

6. Key stakeholders

This section identifies the key stakeholders with respect to resilience in the water sector and the natural environment. Section 6.2 relates how the responsibilities of these stakeholders are linked to UKWIR's "Big Questions" around challenges which the water sector is currently seeking to address. Whilst it is acknowledged that the UKWIR work is primarily research driven, it is still considered a useful framework around which to present this stakeholder analysis; this is because it encompasses the biggest issues affecting the water industry and incorporates the issues and concerns of many of the regulators and water companies. The section is supported by Appendix D.

The key stakeholders with responsibilities to enhance resilience were identified using a variety of resources, including:

- The literature reviewed (see Section 2.1), which allowed for organisations that published or were mentioned in the literature to be identified;
- Other strategic national policy documents including the Government's 25-Year Environment Plan (Defra, 2018a);
- The interdependencies between the environmental and water sectors in Section 3, which highlighted other sectors and organisations that impact and/or depend on resilience;
- The current and future risks to resilience in Section 7, which other organisations are affected by and/or could help manage; and
- Partners and beneficiaries that were identified in Section 8 as part of the literature review and case studies focused on collaboration between the environmental and water sector.

This process identified a significant number of key stakeholders. The list of key stakeholders was then refined by considering the extent to which they could enhance resilience with their remit based on:

- Key stakeholders' organisational objectives and responsibilities;
- Whether key stakeholders have a direct or indirect responsibility to enhance resilience; and
- Whether key stakeholders impact and/or depend on resilience.

6.1 Overview

Table 6-1 presents an overview of the sectors with key stakeholders that have a role with respect to enhancing resilience. Most of the organisations identified are public sector organisations (33%). Table 6-2 presents the full list of 49 organisations identified.

Table 6-1: Sectoral overview of key stakeholders with respect to enhancing resilience (in alphabetical order)

Sector	n	%
Industry associations	2	4%
NGO	13	27%
Other multi-sector partnerships	5	10%
Private	13	27%
Public	16	33%
Total number of organisations	49	100%

Table 6-2: Key stakeholders with respect to enhancing resilience (in alphabetical order)

Organisation	Sector
Amphibian & Reptile Conservation Trust	NGO

Organisation	Sector
Angling Trust	Public
British Canoeing	NGO
British Land	Private
Business in the Community	NGO
Canal and River Trust	NGO
Catchment partnerships	Other multi-sector partnerships
Committee on Climate Change	Public
Defra	Public
Department for Business, Energy and Industrial Strategy	Public
Developers	Private
Environment Agency	Public
Floodplain Meadows Partnership	NGO
Forestry Commission / Forestry England	Public
Green Alliance	NGO
Historic England	Public
Homes England	Public
Housing associations (e.g. Habinteg)	Public
Innovate UK	Public
Land agents	Private
Land owners and land managers (agriculture)	Private
Land owners and land managers (aquaculture/fisheries)	Private
Land owners and land managers (other e.g. investors)	Private
Local Authorities (including Lead Local Flood Authorities (LLFAs), Local Planning Authorities (LPAs) and Highways Authority)	Public
Local businesses	Private
Local Development Corporations	Public
Local Enterprise Partnerships	Other multi-sector partnerships
Local Nature Partnerships	Other multi-sector partnerships
Manufacturers of water-intensive appliances	Private
Marine Management Organisation (MMO)	Public
National Parks England	NGO
Natural Capital Committee	Public
Natural England	Public
Ofwat	Public
Pharmaceutical companies	Private
Property agents (e.g. Savills)	Private
River Restoration Centre	Other multi-sector partnerships
Small-scale developers (e.g. Peabody, Igloo)	Private
The Rivers Trusts	NGO
The Royal Society for the Protection of Birds (RSPB)	NGO
The Wildlife Trusts	NGO
UKWIR	Industry associations
Volume house builders (e.g. Bovis, Persimon)	Private
Water companies	Private
Water Resource Planning Programmes (e.g. Water Resources East)	Other multi-sector partnerships
Water UK	Industry associations

Organisation	Sector
Wildfowl & Wetlands Trust (WWT)	NGO
Wildlife and Countryside Link	NGO
World Wide Fund for Nature (WWF)	NGO
Total number of organisations	49

6.2 Links to UKWIR priorities

The aim of the naturally resilient study is to consider how resilience in the natural water environment can improve resilience in the water industry sector, and how the water sector can influence the resilience of the natural environment. The previous sections have established that resilience in the water environment is complex and involves may interacting system components, and that stakeholder engagement is essential. However, Table 6-2 shows the large number and diversity of different interested stakeholder groups, and each group will have a different frame of reference, different priorities and different ways of relating to water resilience. Good stakeholder engagement therefore needs to start from a common base to which all parties can refer, as well as an understanding of common goals and shared ideals.

For this study, it was useful to consider how the stakeholders identified in Table 6-2 are relevant to delivery of UKWIR goals which reflect the overarching needs of the water sector but also take into account the overriding need for supporting a resilient environment. In this way, stakeholders working to deliver resilience in the natural water environment are directly related to delivery of resilience in the water industry sector. It would also be possible to "close the loop" by considering how the water sector can contribute to the natural resilience aims of the other stakeholder groups, however since the aims of the other stakeholders are extremely diverse in type and scale, this is best done on a case by case basis.

UKWIR's priorities were considered in terms of their 12 'Big Questions' associated with the challenges faced by the industry (Table 6-3[37]). UKWIR is responsible for shaping the research agenda of the water industry, specifically by developing the research programme, managing the research and disseminating the findings. In this context, the 12 'Big Questions' developed by UKWIR represent the priority questions that the water industry is aiming to answer by 2050.

Table 6-3: UKWIR's Big Questions

Theme	Description	Big Question
1. Drinking water production & distribution	**'Drinking water – where will it come from?'** We are facing a future where we will need to make less water go even further, as the population grows and the climate changes.	1. How do we halve our abstractions by 2050?
		2. How will we achieve zero leakage in a sustainable way by 2050?
		3. How do we achieve zero interruptions to water supplies by 2050?
		4. How do we achieve 100% compliance with drinking water standards (at point of use) by 2050?
2. Wastewater collection & recycling	**'Recycling and rethinking our future'** Protecting the planet now is the only way to be sure we'll have access to what we need in the future.	5. How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?
		6. How do we achieve zero uncontrolled discharges from sewers by 2050?
3. Cross cutting	**'Putting customers at the heart of a whole new way of working'** Evolving customer needs and priorities have to be accurately reflected in our plans for the future.	7. How do we achieve zero customers in water poverty by 2030?
		8. What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process?

[37] https://ukwir.org/eng/big-questions-facing-uk-water-industry

Theme	Description	Big Question
		9. How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
4. Global challenges	**'Making a positive contribution to a greener and more sustainable future'** It's vital that we explore new ways to remove our carbon impact, minimise our waste and address emerging issues.	10. How do we remove more carbon that we emit by 2050?
		11. How do we maximise recovery of useful resources and achieve zero waste by 2050?
		12. How do we achieve zero harmful plastics in the water cycle by 2050?

Table 6-4 shows the number of key stakeholders which may be relevant to each of the 'Big Questions.' Links between stakeholders and UKWIR 'Big Questions' have been identified through the following process:

1. The UKWIR 'Big Questions' have been related directly to natural resilience by identifying which of the risk management measures set out in Section 8 will contribute towards answering the Questions;
2. The stakeholder groups were then listed where they could contribute towards delivery of the relevant risk management measures for each Question.

Both direct and indirect links were found, for example a direct link could exist where the stakeholder in question is a water company. In contrast, an indirect link could exist where an organisation has an impact on water quality which has an impact on drinking water compliance (Big Question 4). Table 6-5 provides a breakdown by organisation, with more detail provided in Appendix D. Stakeholders do not have to be responsible for delivery of a specific Big Question solution in order to be relevant to it, it was only necessary that their work may contribute. For example, the work of NGOs can raise awareness of environmental problems, an increased awareness can result in public pressure to change regulatory frameworks and incentives.

Table 6-4: Sectoral mapping of key stakeholders against UKWIR priorities (in alphabetical order)

Sector	UKWIR Big Questions											
	1	2	3	4	5	6	7	8	9	10	11	12
	Reduce abstraction by 2050	Achieve zero leakage	Zero supply interruptions	100% drinking water compliance	Sustainable wastewater services	Zero uncontrolled sewer discharges	Zero customers in water poverty	True maintenance cost of assets reflected in decision-making	Regulatory incentives for efficient delivery of right outcomes	Net positive carbon sequestration	Maximise resource recovery and zero waste	Zero harmful plastics in water cycle
Industry associations	2	2	2	2	2	2	2	2	2	2	2	2
NGO	4	2	2	8	8	2	1	1	11	5	3	4
Other multi-sector partnerships	4	3	3	3	3	3	1	3	4	3	4	4
Private	4	3	1	7	6	1	1	1	8	3	3	3
Public	6	4	6	10	9	4	1	3	13	8	6	6
Total number of organisations	**20**	**14**	**14**	**30**	**28**	**12**	**6**	**10**	**38**	**21**	**18**	**19**

The results indicate that UKWIR's Big Question 9 is the most closely aligned priority to key stakeholders' organisational responsibilities. On first review this appears unexpected as relatively few of the stakeholders have direct influence on regulations. However, this 'Big Question' actually covers a broad range of

environmental outcomes as well as the resilience of the water industry (e.g. the ability of water companies to provide uninterrupted services to customers). Most of the stakeholders identified in Table 6-5 are NGOs involved in achieving these environmental outcomes, e.g. through raising awareness, or else are public sector organisations that do have a more direct influence on regulations.

Big Question 4 is also shown in be relevant to a large number of stakeholders. This Question relates to water companies achieving 100% compliance with drinking water standards, which is also closely aligned to key stakeholders' organisational responsibilities. This finding may be explained by the fact that there is a wide range of organisations involved in driving environmental change which impacts indirectly on drinking water compliance, including land managers, catchment groups and others.

Overall, the findings show that the greatest potential for partnership and collaboration between water companies and other stakeholders occurs when projects have broad objectives and can deliver multiple outcomes. Achieving multiple benefits is a key theme and principle of resilience (see Section 3) and identifying opportunities to deliver multiple benefits will lead to better engagement with stakeholders. Communication, resourcing and conflicts can be more easily overcome if there is clarity as to the benefits that will arise for each group.

Issues that are solely focused on the water sector without an explicit environmental component, such as investing in reducing water poverty, are less likely to overlap with other stakeholders' remits and are therefore less likely to secure the support of environmental stakeholders. There will be other stakeholders relevant to those projects, such as charities focussed on reducing poverty, but this report focusses on the interplay between resilience in the natural water environment and in the water industry, so these other stakeholders are not considered further at this time.

Table 6-5: Mapping of key stakeholders against UKWIR priorities (in alphabetical order)

Organisation	UKWIR Big Questions											
	1	2	3	4	5	6	7	8	9	10	11	12
	Reduce abstraction by 2050	Achieve zero leakage	Zero supply interruptions	100% drinking water compliance	Sustainable wastewater services	Zero uncontrolled sewer discharges	Zero customers in water poverty	True maintenance cost of assets reflected in decision-making	Regulatory Incentives for efficient delivery of right outcomes	Net positive carbon sequestration	Maximise resource recovery and zero waste	Zero harmful plastics in water cycle
Amphibian & Reptile Conservation Trust				x	x				x			
Angling Trust				x	x				x			x
British Canoeing				x	x				x			x
British Land				x								
Business in the Community											x	
Canal and River Trust				x	x				x			x
Catchment partnerships	x	x	x	x	x	x		x	x	x	x	x
Committee on Climate Change			x						x	x		
Defra	x		x	x	x				x	x	x	x
Department for Business, Energy and Industrial Strategy		x	x			x		x		x	x	
Developers				x	x				x			
Environment Agency	x	x	x	x	x	x		x	x	x	x	x
Floodplain Meadows Partnership									x			
Forestry Commission / Forestry England									x	x		
Green Alliance	x	x	x			x				x	x	
Historic England									x			

Organisation	UKWIR Big Questions											
	1	2	3	4	5	6	7	8	9	10	11	12
	Reduce abstraction by 2050	Achieve zero leakage	Zero supply interruptions	100% drinking water compliance	Sustainable wastewater services	Zero uncontrolled sewer discharges	Zero customers in water poverty	True maintenance cost of assets reflected in decision-making	Regulatory Incentives for efficient delivery of right outcomes	Net positive carbon sequestration	Maximise resource recovery and zero waste	Zero harmful plastics in water cycle
Homes England				x	x				x			
Housing associations (e.g. Habinteg)				x	x				x			
Innovate UK	x	x	x			x					x	
Land agents				x	x							
Land owners and land managers (agriculture)	x			x	x				x	x		
Land owners and land managers (aquaculture/fisheries)	x			x	x				x	x		
Land owners and land managers (other e.g. investors)									x			
Local Authorities (including Lead Local Flood Authorities (LLFAs), Local Planning Authorities (LPAs) and Highways Authority)	x			x	x				x			
Local businesses		x									x	x
Local Development Corporations				x	x				x			
Local Enterprise Partnerships		x	x			x		x			x	x
Local Nature Partnerships	x			x	x				x	x	x	x
Manufacturers of water-intensive appliances	x	x									x	
Marine Management Organisation (MMO)												x
National Parks England									x			
Natural Capital Committee	x			x	x				x	x		x
Natural England				x					x	x	x	

Organisation	UKWIR Big Questions											
	1	2	3	4	5	6	7	8	9	10	11	12
	Reduce abstraction by 2050	Achieve zero leakage	Zero supply interruptions	100% drinking water compliance	Sustainable wastewater services	Zero uncontrolled sewer discharges	Zero customers in water poverty	True maintenance cost of assets reflected in decision-making	Regulatory Incentives for efficient delivery of right outcomes	Net positive carbon sequestration	Maximise resource recovery and zero waste	Zero harmful plastics in water cycle
Ofwat	x	x	x	x	x	x	x	x	x	x	x	x
Pharmaceutical companies												x
Property agents (e.g. Savills)									x			
River Restoration Centre	x								x			x
Small-scale developments (e.g. Peabody, Igloo)									x			
The Rivers Trusts	x			x	x				x			x
The Royal Society for the Protection of Birds (RSPB)				x	x				x	x		
The Wildlife Trusts	x			x	x				x	x		
UKWIR	x	x	x	x	x	x	x	x	x	x	x	x
Volume house builders (e.g. Bovis, Persimon)				x	x				x			
Water companies	x	x	x	x	x	x	x	x	x	x	x	x
Water Resource Planning Programmes (e.g. Water Resources East)	x	x	x	x	x	x	x	x	x	x	x	
Water UK	x	x	x	x	x	x	x	x	x	x	x	x
Wildfowl & Wetlands Trust (WWT)				x	x				x	x		
Wildlife and Countryside Link	x	x	x	x	x	x	x	x	x	x	x	x
Word Wide Fund for Nature (WWF)									x			
Total number of organisations	20	14	14	30	28	12	6	10	38	21	18	19

7. Current and future risks to resilience

This section explores the current and future risks to resilience. It is supported by Appendix F.

7.1 Risk themes

This sub-section presents the risks to resilience that were identified via the high-level literature review. Table 7-1 divides the risk into twenty themes that were identified as being fundamental to the natural environment and to the water sector. The detailed findings from the literature review can be found in in Appendix F.

Whilst efforts were made to consolidate the number of themes identified to a manageable number, it was important to retain a certain level of granularity to illustrate the nuances. It is recognised that are links between risk themes as different aspects of the water environment impact on one another as discussed in Section 3. Where possible, these links are identified in the table below. Risk themes are provided in order of the frequency in which they were identified as a top five current risk by respondents to the online survey.

Table 7-1: Risks themes for the water sector and the natural environment

Risk theme	Supporting information from the literature
Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	Soil degradation and habitat loss are key risks facing both the urban and rural population. The water sector may have an impact on soil degradation and habitat loss through the land management practices that the sector engages in on land they manage, or practices that their tenants engage in on land that the sector owns. Similarly, the water sector has a dependency on soil degradation and habitat loss because improvements in soil quality and the condition of habitats may reduce surface water run-of and the probability of it negatively affecting the quality of the water environment, with a knock-on effect on the cost of water treatment. Regulators and Government bodies have identified that pollution is one of the biggest problems facing the freshwater environment. The water sector and environment are at risk because there is an increased risk of failure of physio-chemical elements of WFD status as a result of urban diffuse pollution, discharge from highways, septic tanks, oil tanks and increased soil erosion and degradation, in addition to lower summer river flows and more frequent summer hydrological droughts. This may increase the cost of water treatment and may result in interruptions in water supply, which would impact on the resilience of the water sector. Climate change and population growth will increase this risk.
Climate change	Climate change is recognised as a key global risk. It is expected to cause higher land and sea temperatures, rising sea levels, extreme weather patterns (longer periods of drought and increased flood risk) and ocean acidification. Climate change directly impacts water resources in terms of both water quality and water quantity which has implications for water dependent habitats and water body status for the natural environment and for the water sector in terms of increased risk of reduced water availability and lower assimilative capacity within water bodies to receive treated discharges. Additionally, abstraction of scarce water resources by the water sector in times of drought (which are projected to be more intense and frequent with climate change) would adversely impact the natural environment. Risks from climate change are heightened because the natural environment is already stressed as a function of historic and on-going pressures including pollution, habitat loss and fragmentation etc. It is worth noting that climate change has links with various other risk themes, often through exacerbating adverse impacts. For example, climate change can increase the frequency and severity of natural hazards and can result in adverse public health impacts. It also presents a resilience risk in terms of water company asset operation, with many key water

Risk theme	Supporting information from the literature
	company assets such as Wastewater Treatment Works and Water Treatment Works necessarily located in existing flood risk areas which will be exacerbated by climate change (see next row).
Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	Water companies, regulators, and Government bodies have identified natural hazards as a key risk to resilience. Natural hazards pose a risk to both the water sector and the natural environment as they can disrupt infrastructure and cause significant deterioration to the natural environment. Additionally, abstraction of scarce water resources by the water sector in times of drought would adversely impact the natural environment. This risk has a direct link to climate change, which can increase the frequency and severity of natural hazards. This risk is linked in unsustainable abstraction, abstraction reform and changing abstraction licences
Political or regulatory frameworks (current or reformed)	Regulators identify socio-political changes (especially in policies and incentive mechanisms) to be an indirect driver of the use and management of natural resources and ecosystems, posing a risk to both the water sector and the environment. Alternatively, reform of political or regulatory frameworks to encourage more resilient use and management of natural resources, will help to reduce the risks and increase the resilience of the natural environment and the water sector. Political uncertainty, particularly relating to Brexit, results in future uncertainty regarding funding for infrastructure, investment in research and environmental regulation for example. This links to the unsustainable abstraction, abstraction reform and changing abstraction licences risk theme.
Socio-economic factors such as population growth	Water companies, regulators, and Government bodies report on projected growth in their customer base and the general population as well as demographic and behavioural change. These changes pose a risk to both the water sector and the natural environment because they can result in a significant increase in water demand and increases in polluting loads from additional wastewater generation. The requirement to secure sufficient water supplies to meet this demand and to discharge additional treated wastewater may result in pressures on the natural environment. There is the possibly that some socio-economic factors such as improved awareness and education could reduce improve water efficiency and positively affect the natural environment. This risk theme is linked to water shortage, as described later in this table. There is also a link between socio-economic factors such as the structure of households, their income and consumption patterns which may affect the ability of households to pay their bill and not fall into water poverty. This could affect the financial resilience of water companies in terms of their ability to provide uninterrupted services to customers.
Unsustainable abstraction, abstraction reform and changing abstraction licences	Water companies and governing bodies have identified that abstractors are vulnerable to future regulatory and legislative changes such as uncertainty around abstraction reform and changes to water quality standards. One of the biggest challenges facing abstractors is the need to meet European legislation, which poses a risk to the water sector as this could significantly reduce the amount of water which can be extracted from the environment. Abstraction reform has some unknown impacts on the natural environment however sustainable abstraction can be beneficial to the water environment. This links to the political or regulatory frameworks (current or reformed) risk theme.
Agricultural intensification/damaging fishing practices	Governing bodies have reported on intensification of farming, which poses a risk to the water sector and environment as it can result in increased flood risk, loss of wildlife and compromised water quality as a function of agricultural run-off. The Government's 25 Year Environment Plan identifies that farming can be a powerful force for environmental enhancement. However, farming activities can result in negative

Risk theme	Supporting information from the literature
	externalities such as emissions from livestock, soil degradation and reduced water environment quality due to farming practices including the use of fertilisers and pesticides. The impacts of farming are considered in more detail in Appendix F.
Declining environmental water quality including known deterioration (nitrate, phosphorus, metaldehyde) and other risks (combined sewer overflows and emerging substances) 	There are several risks to the provision of clean water, for both the water sector and the natural environment, including: • Nutrient enrichment and eutrophication in water bodies and water dependent habitats; • Combined sewer overflows; • Organic pollution[38]; • Specific pollutants, priority substances and 'other' chemical pollutants; and, • Over-abstraction and saline intrusion. Poor water quality has significant and far-reaching consequences for both sectors.
Ageing infrastructure/ asset failure (with associated cost implications) and leakage 	Water companies report on leakage and ageing infrastructure, identifying these issues as one of the key challenges facing the sector. Government bodies have identified that there is a need for modern infrastructure which has sufficient capacity to solve issues for future generations. Where ageing or failing infrastructure results in leakage, this can have negative impacts on the natural environment in the form of increased abstraction and/or contamination of waterbodies by wastewater.
Urbanisation, urban creep and land-use change 	Water companies report on long-term stressors to the water sector and environment, identifying the following risks: urban creep, rising urbanisation, land-use change and coastal erosion. Urbanisation not only concentrates people and properties in areas of potential damage and disruption, it also exacerbates those risks for example by destroying natural sources of resilience and increasing the strain on groundwater reserves[39]. Additionally, urban creep has the potential to reduce the quality of water sources (from increased pollution), which will have impacts on both the water sector and natural environment. This risk theme is linked to the natural hazards (drought and flood risk) including economic resources to prepare for and address risks risk theme owing to the potential for increased urban runoff for example.
Water shortage 	Climate change is bringing periods of hotter and drier weather, raising the long-term risk of severe water shortages. This poses a risk to both the water sector and the environment because the impacts of climate change and the growing demand for water are putting added pressure on water availability and therefore pressures of the natural environment. Additionally, abstraction of scares water resources by the water sector in times of drought will negatively impact the natural environment. Whilst water shortage is linked to natural hazards (specifically drought), the water shortage risk theme focuses on supply and demand. Water shortage risks are considered in more detail in Appendix F. This risk theme is linked to several other risk themes including climate change which will exacerbate water shortages. Water shortages will adversely impact, and is linked to, multiple other risk themes such as public health for example.

[38] The higher the carbon or organic content, the more oxygen is consumed. A high organic content means an increase in the growth of microorganisms which contribute to the depletion of oxygen supplies.
[39] For example, increases in impermeable surfaces and loss of hazard regulation services which specifically regulate flood risk.

Risk theme	Supporting information from the literature
Water efficiency in households e.g. household appliances, water meters	Inefficient water use in households will put added stress on the water sector, and also pose risks for the natural environment from increase abstraction. It has been argued (at recent industry conferences for example) that there is a risk that new housing developments could fail to suitably integrate water efficiency measures, posing a risk to both the water sector and the natural environment, as a function of increased demand. The Government's 25 Year Environment Plan has the target of stipulating high environmental standards for all new builds with the aim that new homes will be built in a way which reduces demands for water.
Affordability and vulnerability of customers along with changing customer expectations	Water Companies report that 'affordability' is one of the key challenges facing the water sector, in addition to inequality/income disparity as a mid-term stressor. Changing customer expectations can also pose risks to both the water sector and the natural environment, if this results in increased use or decreased efficiency, which will both increase abstraction.
Financial crises (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation) and fund improvements in environmental quality	Water companies identify financial crises and growth vs. recession to be a long-term stressor. The costs of wastewater treatment are likely to continue to rise as a function of lower summer river flows, warmer summer temperatures and more frequent summer hydrological droughts. This is likely to cause financial strain which may in turn reduce the availability of financial resources to protect and enhance environmental quality. Increased funds to improve environmental quality will not only reduce risks on the natural environment, but will also reduce risks to the water sector since it depends on resilient, health ecosystems. This risk theme is linked to environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents.
Security risks e.g. cyber security	Regulatory bodies identify that future threats to the water sector are likely to increase in frequency, interconnectivity and unpredictability, including cyber security threats. Whereby threats to cyber security negatively impact the water sector, this can have indirect risks for the natural environment since water companies depend on computer systems to maintain sustainable abstraction. Additionally, the Government reports that the water sector needs to maintain resilience to a range of pressures in the short- and long-term inclusive of attacks on computer systems.
Biosecurity/pest and disease management (including invasive, non-native species)	Government and regulatory bodies report on the risk of invasive non-native species to resilience. Invasive non-native species (INNS) pose a risk to the water sector and environment as invasive pathogens or disease spread by INNS can have direct implications on flood risk and soil erosion by causing environmental damage such as degrading habitats, and also resulting in the requirement for additional water treatment. INNS can have direct impacts on water conditions in the natural environment (for example by reducing ground water levels) and this can have cascading impacts on the water sector through potential disruptions to water supply. As a result, this risk theme is linked to environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents.
Changing labour market and skills shortage	A changing labour market and skills shortage may result in uncertainty across the water sector and may impede effective measures to enhance resilience being implemented. If the application of resilience measures is hindered from changing labour markets or skill shortages, this will result in risks for the water sector. If these changes lead to unsustainable abstraction from the water sector, there will be negative impacts on the natural environment.

Risk theme	Supporting information from the literature
Digital revolution benefits, potential for over-reliance on technology and associated risks e.g. system failure	Water companies and regulatory bodies identify risks to the water sector and environment including the digital revolution and critical information infrastructure breakdown. Digital revolution may bring benefits to the water sector and natural environment, including leakage detection and repair, however there is potential for over-reliance and associated risks, including system failure. Whereby system failures negatively impact the water sector, this can have indirect risks for the natural environment since water companies depend on these systems to maintain sustainable abstraction. This is a potentially linked to the risk theme security risks e.g. cyber security.
Public health and Infectious diseases (people and animals)	Water companies report on infectious diseases as a long-term shock, whilst lifestyle changes and rising chronic/lifestyle diseases (which often result in increased water consumption) are considered to be long-term stressors to resilience. Public health risks and infectious diseases can result in changes in the quality and quantity of water demand. Changes in abstraction rates and water treatment processes have the potential to negatively impact the natural environment. The prevalence of invasive, non-native species can have direct implications on the natural environment and biodiversity, whilst having indirect impacts on the water sector as a result of increased water treatment needs.
Water company dependency on other sectors (i.e. telecoms and power failures)	Water companies have identified risks to the water sector as a result of the several shocks and stresses including supply chain failure, resource scarcity, telecoms and power failures as a result of storms for example. Failure other sectors that the water sector depends on, can affect water companies' ability to sustainably abstract and treat water, which can have indirect risks on the natural environment. This risk theme is linked to environmental degradation as power failures can lead to the temporary failure of assets, potentially resulting in pollution events.

The interdependencies between the water industry sector and the water environment mean that both sectors are vulnerable to all the risks outlined above. However, the economic burden of the following risks is likely to fall entirely on the water industry sector:

- Ageing infrastructure/ asset failure (with associated cost implications) and leakage;
- Affordability and vulnerability of customers along with changing customer expectations;
- Security risks e.g. cyber security;
- Changing labour market and skills shortage, and;
- Water company dependency on other sectors (i.e. telecoms and power failures).

The water industry may have to look outside stakeholder groups with an interest in the water environment in order to obtain support to address these risks. For example, charities working to reduce poverty could support in addressing risks around affordability, while working with educational establishments could help to fill the skills shortage. However, consideration of these issues is outside the scope of this report.

7.2 Current and future risks and opportunities for management

The online survey explored the views of respondents regarding current and future risks (through multi-choice response questions), along with opportunities for risk management (through open questions for comment). Table 7-2 shows the number of online respondents which identified each of the risk themes in Section 7.1 as in their top five current and future risks. Respondents were also asked whether they considered these risks to be more or less important in future and the trends shown in Table 7-2 indicate how the relative importance of these risks shifts over time, according to the survey respondents.

Table 7-2: Survey respondents' views on top risks to resilience

Risk theme	% (n = 16)		
	Current risks	Future risks	
	In top 5	In top 5	Change in perceived importance of risk between current and future periods
Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	69%	69%	-
Climate change	62%	75%	↑
Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	56%	37%	↓
Political or regulatory frameworks (current or reformed)	50%	31%	↓
Socio-economic factors such as population growth	44%	50%	↑
Unsustainable abstraction, abstraction reform and changing abstraction licences	37%	31%	↓
Agricultural intensification/damaging fishing practices	31%	19%	↓
Declining water environment quality including known deterioration (nitrate, phosphorus, metaldehyde) and other risks (combined sewer overflows and emerging substances)	31%	19%	↓
Ageing infrastructure/ asset failure (with associated cost implications) and leakage	25%	37%	↑
Urbanisation, urban creep and land-use change	25%	13%	↓
Water shortage	19%	31%	↑
Water efficiency in households e.g. household appliances, water meters	19%	6%	↓

Risk theme	% (n = 16)		
	Current risks	Future risks	
	In top 5	In top 5	Change in perceived importance of risk between current and future periods
Affordability and vulnerability of customers along with changing customer expectations	13%	6%	↓
Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)	6%	13%	↑
Security risks e.g. cyber security	6%	6%	-
Biosecurity/pest and disease management (including invasive, non-native species)	0%	13%	↑
Changing labour market and skills shortage	0%	6%	↑
Digital revolution benefits, potential for over-reliance on technology and associated risks e.g. system failure	0%	25%	↑
Public health and Infectious diseases (people and animals)	0%	6%	↑
Water company dependency on other sectors (i.e. telecoms and power failures)	0%	6%	↑

The survey included the option for respondents to identify additional risk themes, along with risk management opportunities. Whilst new risk themes were not identified, several risk management opportunities were identified. An overview of the key opportunities for risk management, as identified by survey respondents is provided in Section 8.

When all responses from Table 7-2 are consolidated, the following risks in Table 7-3 are considered to be an overall top five:

Table 7-3: Survey respondents' top five current and future risks to resilience (n=16)

	Current risks	Future risks
1	Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	Climate change
2	Climate change	Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents
3	Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	Socio-economic factors such as population growth
4	Political or regulatory frameworks (current or reformed)	Natural hazards (drought and flood risk) including economic resources to prepare for and address risks
5	Socio-economic factors such as population growth	Ageing infrastructure/ asset failure (with associated cost implications) and leakage

This identifies that current and future risks are similar, however there are slight differences in how current and future risks are perceived, as follows:

- Risks surrounding climate change are increasingly important in the future;
- Political or regulatory frameworks (current or reformed) is considered a current risk yet is less of a concern in the future; and,
- Ageing infrastructure/asset failure (with associated cost implications) and leakage become increasingly important when considering future risks.

It is noted, as a limitation of this methodology, that the assumptions being made by survey respondents in their assessment of the change in risk over time were not recorded and therefore cannot be incorporated into this analysis.

7.3 Impact of risks to resilience on people

This sub-section considers the 20 risk themes alongside the effects on people if these risks to resilience were to materialise on either the natural environment, or the water sector and the interdependencies between them. Further information is provided in Appendix F.

The eight key interdependencies between the water sector and the natural environment were identified in Section 3 as follows:

- Water quality regulation;
- Soil quality regulation;
- Wild species diversity;
- Disease and pest control;
- Water supply (including drinking water);
- Global climate regulation;
- Hazard regulation; and
- Recreation.

The following broad effects on people have been identified for all eight interdependencies. It should be noted that adverse or beneficial effects may be experienced depending on the nature of impacts and potential external factors.

- Impacts on public health (either beneficial or adverse) as a function of water supply;
- Societal implications of climate change including public health, living conditions and impacts on infrastructure (likely to be adverse if effective climate change mitigation and adaptation measures are not put in place);
- Impacts on cultural ecosystem services, as a function of abstractor activities (either beneficial or adverse);
- Impacts on public health as a result of changing frequency and severity of extreme weather;
- Flood damages as a result of changing frequency and severity of extreme weather (increased) and/or river restoration projects (reduced);
- Changing agricultural output (and associated public health and financial benefits) which can either be beneficial or adverse in nature;
- Affordability of water bills;

- Potential for temporary use bans;
- Control of disease and pests and associated public benefit benefits; and
- Impacts on recreation and amenity benefit as a function of water quality (either beneficial or adverse).

The following table (Table 7-4) summarises the effects on people as a result of risk themes identified in Section 7.1 materialising. These risks relate to resilience in the environment and/or water sector. Where effects on people have been identified, methods of future management should be considered.

It is clear that many of the effects on people relate to joint risk themes across both sectors (i.e. the interdependencies), demonstrating significant potential for partnership working and opportunity for both sectors to work collaboratively and improve resilience in both sectors. The following section (Section 8) reviews the opportunities for the two sectors to work together to minimise impact on people. Partnership working can be made more complex by the legislative framework outlined in Section 5 and can be improved by linking to shared goals, such as UKWIR's 'Big Questions' in Section 6, and the use of agreed metrics as outlined in Section 4.

Table 7-4: Effects on people due to potential for risk to materialise

Effects on people due risks on resilience materialising	Contributing risk themes
• Impacts on public health as a function of water supply	• Water shortage • Public health and infectious diseases (people and animals)
• Societal implications of climate change including public health, living conditions and impacts on infrastructure	• Public health and infectious diseases (people and animals) • Climate change • Ageing infrastructure/asset failure (with associated cost implications) and leakage
• Impacts on cultural ecosystem services, as a function of environmental degradation	• Unsustainable abstraction, abstraction reform and changing abstraction licences • Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents • Climate change
• Impacts on public health as a result of changing frequency and severity of extreme weather	• Public health and infectious diseases (people and animals) • Climate change • Natural hazards (drought and flood risk) including economic resources to prepare for and address risks
• Flood damages as a result of changing frequency and severity of extreme weather and/or river restoration projects (both beneficial and adverse dependent upon direction of impacts)	• Climate change • Natural hazards (drought and flood risk) including economic resources to prepare for and address risks • Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)
• Continued agricultural output (and associated public health and financial benefits)	• Public health and infectious diseases (people and animals) • Agricultural intensification/damaging fishing practices
• Affordability of water bills (both beneficial and adverse dependent upon direction of impacts)	• Affordability and vulnerability of customers along with changing customer expectations
• Potential for temporary use bans (both beneficial and adverse	• Water shortage • Affordability and vulnerability of customers along with changing customer expectations

Effects on people due risks on resilience materialising	Contributing risk themes
dependent upon direction of impacts)	
• Control of disease and pests and associated public benefit benefits (both beneficial and adverse dependent upon direction of impacts)	• Public health and Infectious diseases (people and animals)
• Impacts on recreation and amenity benefit as a function of water quality	• Declining environmental water quality (nitrate, phosphorus, metaldehyde) • Affordability and vulnerability of customers along with changing customer expectations

8. Managing risks to resilience through collaboration

This section outlines measures to manage the risks to resilience, set out in Section 7, as well as the opportunities for collaboration between sectors with respect to enhancing resilience. The benefits and blockers of collaboration are also explored along with mitigation measures to overcome these blockers. This section is supported by Appendix G.

8.1 Risk management measures

The online survey has been used to identify examples of mitigation measures for the risks to resilience outlined in Section 7. The measures identified fall into five categories, as illustrated in Figure 8-1: management of housing, land, water supply and technological change, in addition to awareness raising and partnership working. Table 8-1 links the mitigation measures to each of the risk themes in Section 7 and specifically highlights in bold those mitigation measures which are nature based and offer the opportunity to improve resilience in both sectors.

Figure 8-1: Summary of management opportunities identified by survey respondents

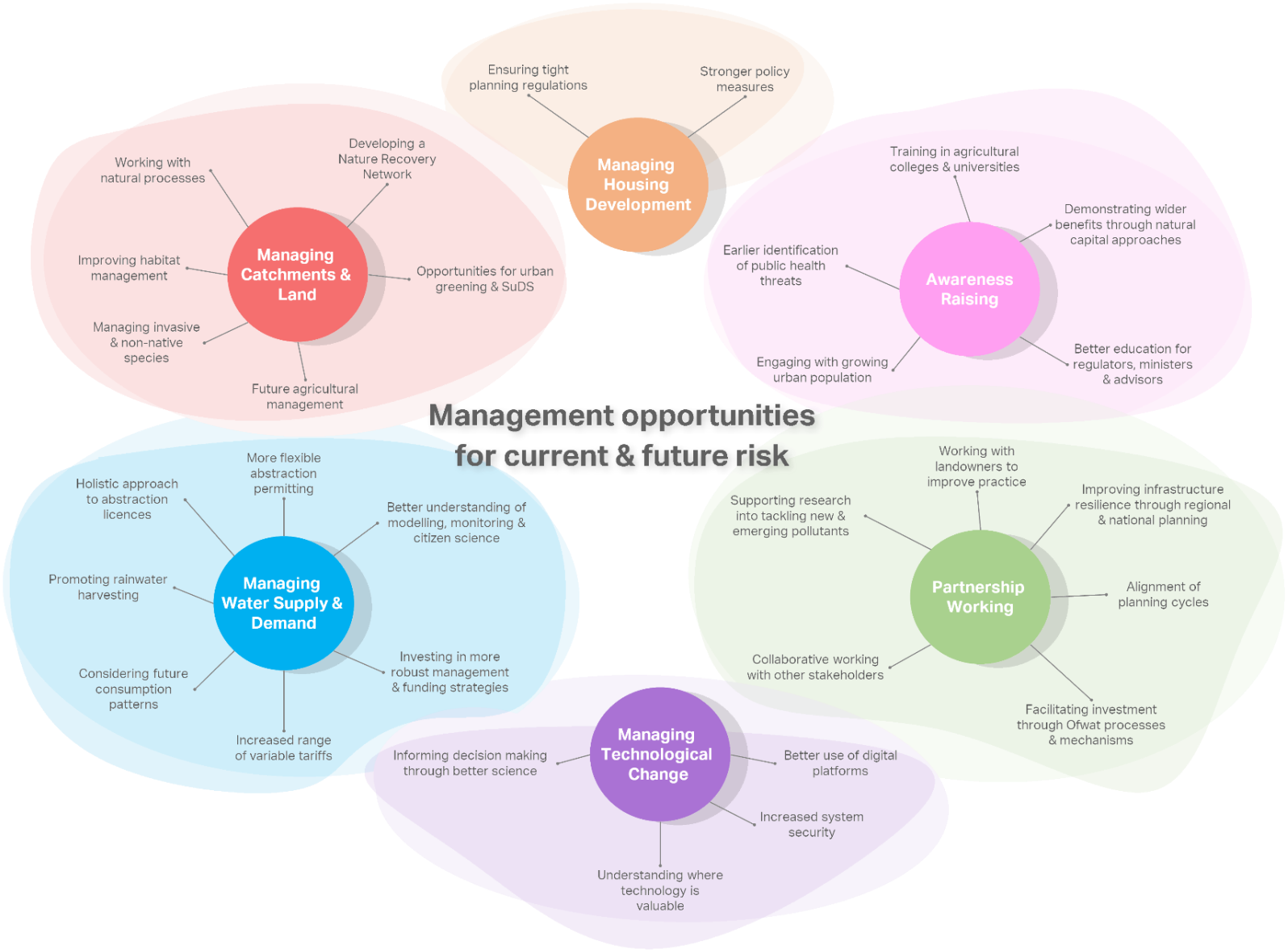


Table 8-1: Management Measures for Risks Themes

Risk theme	Risk Management Measures
Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	• **Working with natural processes** • **Improving habitat management** • **Managing invasive and non-native species** • **Improving future agricultural management** • **Developing a nature recovery network** • **Demonstrating wider benefits through natural capital approaches** • **Working with landowners to improve practice** • **Collaborative working with other stakeholders** • **More flexible abstraction permitting**
Climate change	• **Improving future agricultural management** • **Opportunities for urban greening and SuDS** • **Developing a nature recovery network** • Ensuring right planning regulations • Stronger policy measures • **Demonstrating wider benefits through natural capital approaches** • **Working with landowners to improve practice** • Improving infrastructure resilience through regional and national planning • Facilitating investment through Ofwat processes and mechanisms • Informing decision making through better science • Better understanding of modelling, monitoring and citizen science
Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	• **Working with natural processes** • Ensuring right planning regulations • Working with landowners to improve practice • Improving infrastructure resilience through regional and national planning • Collaborative working with other stakeholders • Informing decision making through better science • Better understanding of modelling, monitoring and citizen science
Political or regulatory frameworks (current or reformed)	• **Improving future agricultural management** • Ensuring right planning regulations • Stronger policy measures • **Demonstrating wider benefits through natural capital approaches** • Better education for regulators, ministers and advisors • Improving infrastructure resilience through regional and national planning • Alignment of planning cycles • Facilitating investment through Ofwat processes and mechanisms • Informing decision making through better science • **More flexible abstraction permitting** • Investing in more robust management and funding strategies • **Holistic approach to abstraction licences**
Socio-economic factors such as population growth	• **Opportunities for urban greening and SuDS** • Ensuring right planning regulations • Stronger policy measures • Earlier identification of public health threats • Better education for regulators, ministers and advisors • Supporting research into tacking new and emerging pollutants • Collaborative working with other stakeholders • Investing in more robust management and funding strategies • Considering future consumption patterns
Unsustainable abstraction, abstraction reform and changing abstraction licences	• **Improving future agricultural management** • Stronger policy measures • Facilitating investment through Ofwat processes and mechanisms • Collaborative working with other stakeholders • Informing decision making through better science • **More flexible abstraction permitting** • Considering future consumption patterns • **Promoting rainwater harvesting** • **Holistic approach to abstraction licences**

Risk theme	Risk Management Measures
Agricultural intensification/damaging fishing practices	• **Improving habitat management** • **Managing invasive and non-native species** • **Developing a nature recovery network** • **Working with landowners to improve practice** • Collaborative working with other stakeholders
Declining environmental water quality including known deterioration (nitrate, phosphorus, metaldehyde) and other risks (combined sewer overflows and emerging substances)	• **Working with natural processes** • **Improving future agricultural management** • Training in agricultural colleges and universities • **Demonstrating wider benefits through natural capital approaches** • Supporting research into tacking new and emerging pollutants • **Working with landowners to improve practice** • Collaborative working with other stakeholders • **Opportunities for urban greening and SuDS**
Ageing infrastructure/ asset failure (with associated cost implications) and leakage	• **Opportunities for urban greening and SuDS** • Ensuring right planning regulations • Improving infrastructure resilience through regional and national planning • Alignment of planning cycles • Facilitating investment through Ofwat processes and mechanisms • Understanding where technology is valuable • Increased system security
Urbanisation, urban creep and land-use change	• **Opportunities for urban greening and SuDS** • **Developing a nature recovery network** • Ensuring right planning regulations • Stronger policy measures • Supporting research into tacking new and emerging pollutants • Alignment of planning cycles
Water shortage	• **Opportunities for urban greening and SuDS** • Ensuring right planning regulations • **Working with natural processes to improve infiltration in catchments** • Facilitating investment through Ofwat processes and mechanisms • Improving infrastructure resilience through regional and national planning • **More flexible abstraction permitting** • Considering future consumption patterns • **Promoting rainwater harvesting** • **Holistic approach to abstraction licences**
Water efficiency in households e.g. household appliances, water meters	• Ensuring right planning regulations • Stronger policy measures • Increased range of variable tariffs • Considering future consumption patterns
Affordability and vulnerability of customers along with changing customer expectations	• Investing in more robust management and funding strategies • Increased range of variable tariffs • Considering future consumption patterns
Financial crises (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation) and fund improvements in environmental quality	• Stronger policy measures • Better education for regulators, ministers and advisors • Improving infrastructure resilience through regional and national planning • Facilitating investment through Ofwat processes and mechanisms • Increased system security • Investing in more robust management and funding strategies

Risk theme	Risk Management Measures
Security risks e.g. cyber security	• Improving infrastructure resilience through regional and national planning • Understanding where technology is valuable • Increased system security • Better use of digital platforms
Biosecurity/pest and disease management (including invasive, non-native species)	• **Improving habitat management** • **Managing invasive and non-native species** • Stronger policy measures • Training in agricultural colleges and universities • Working with landowners to improve practice • Collaborative working with other stakeholders
Changing labour market and skills shortage	• Training in agricultural colleges and universities • Better education for regulators, ministers and advisors • Supporting research into tacking new and emerging pollutants
Digital revolution benefits, potential for over-reliance on technology and associated risks e.g. system failure	• Improving infrastructure resilience through regional and national planning • Facilitating investment through Ofwat processes and mechanisms • Understanding where technology is valuable • Increased system security • Better use of digital platforms • Investing in more robust management and funding strategies
Public health and Infectious diseases (people and animals)	• **Managing invasive and non-native species** • Training in agricultural colleges and universities • Earlier identification of public health threats • Informing decision making through better science
Water company dependency on other sectors (i.e. telecoms and power failures)	• Improving infrastructure resilience through regional and national planning • Alignment of planning cycles • Facilitating investment through Ofwat processes and mechanisms • Collaborative working with other stakeholders • Understanding where technology is valuable • Increased system security • Investing in more robust management and funding strategies

The interconnected nature of the water environment means that there is considerable overlap in mitigation measures that are appropriate for each risk to resilience. Examples of ways of implementing the mitigation measures are given below and each measure could also have benefits for reducing a number of risk themes:

- Managing catchments and land could include:
  - Working with natural processes and nature based solutions (such as Natural Flood Management, water storage and river restoration) to improve connectivity, reconnect habitats (nature recovery networks) and floodplains, encourage water retention and infiltration to groundwater sources and supplement built infrastructure;
  - Improving the management of peatlands, wetlands, freshwater habitats and chalk streams;
  - Improving the management of invasive, non-native species with specific controls such as management of waste transfer and recreational risks, anticipating future trends;

- Future implementation of agricultural management schemes that address environmental issues to be developed at the catchment (rather than national) level, including the Environmental Land Management (ELM) scheme; and
- Identification of opportunities for urban greening and sustainable urban drainage (SuDS) such as green roofs and rain gardens.

- Managing housing developments could include:
  - Stronger policy measures for managing the provision of housing/infrastructure;
  - Tightening misconnection legislation; and
  - Tighter planning regulations and punitive powers to resist growth where appropriate, in order to reduce the incentivisation of 'development' for short term economic gain.
- Managing water supply and demand could include:
  - Promoting rainwater harvesting, using greywater recycling systems for non-potable uses etc. to ease pressure in times of peak demand;
  - Considering changes in consumption patterns in addition to population growth, whilst raising the awareness of the value of water and environmental impacts. Reward tariffs could form part of this approach;
  - Managing the risks to vulnerable customers with an increased range of variable tariffs;
  - Investing in robust, consistent approaches which could change the fundamental management and funding of water, as opposed to the current public water system approach (abstraction, supply, use, treatment and discharge);
  - A more holistic approach to abstraction licences which better reflects interactions between catchments. Better data and modelling would allow for a more flexible abstraction regime;
  - More flexible permitting for abstraction to manage risks more dynamically; and
  - For ageing infrastructure and leakage, a better understanding of modelling, monitoring and citizen science to prioritise investment.
- . Managing technological change could include:
  - Using better and more credible scientific evidence to inform risk management;
  - Better use of digital platforms to manage information and risks in real time;
  - Identifying where technology is valuable and promotes efficiencies (i.e. clean engine technology and manufacturing) and where it could detract from proven processes and techniques (i.e. stewardship of soils and river management); and
  - More resource to maintain security (cyber and physical) to enable systems remain active.
- Partnership working could include:
  - Working with landowners and land managers to facilitate more integrated land management practices including landscape-scale change: improve soil quality, water quality and carbon sequestration. For example, the use of cover crops to manage nitrate leaching whilst providing wider benefits relating to flood risk management;
  - The use of regional and national planning to improve the resilience of infrastructure;
  - Alignment of planning cycles i.e. water company business plans, River Basin Management Plans, Flood Risk Management Plans, Nature Recovery Networks, housing targets etc.;
  - Using Ofwat processes/mechanisms to facilitate investment, for example, by the innovation fund;
  - Collaboration between water companies and other stakeholders such as flood risk managers, NGOs and local businesses to jointly fund solutions. Partnership working should be led through a combination of local and strategic solutions to managing risks;
  - Working with partners to support research into managing the incidence of new and emerging pollutions such as micro plastics and persistent chemicals linked to pharmaceuticals.

- Awareness raising could include:
  - Demonstrating wider benefits of investment to both regulators and the general population by using a natural capital approach;
  - Improving awareness among regulators, ministers and advisors regarding key issues, roles and responsibilities;
  - Training in agricultural colleges and universities to facilitate sustainable change (agri-environment incentivisation and more realistic fines);
  - Earlier identification of public health threats; and
  - Engaging with the growing urban population to be part of the solution through collective action.

8.2 Collaborative opportunities for enhanced resilience

The risk management measures set out in Section 8.1 include a wide variety of actions in many different areas which show significant overlap in terms of the risk themes from Section 7 that they seek to address. This is due to the complex interactions and interdependencies between different aspects of the water system and the ecosystem services it delivers (Section 3) and results in the need for working with multiple different stakeholder groups (see Sections 4, 5 and 6). The current and future risks to resilience affect both sectors and are therefore joint risks. The mitigation measures identified in Section 8.1 can help reduce these risks and deliver multiple benefits through the same interdependencies.

Table 8-2 shows how the risks to resilience identified in Section 7 impact on the interdependencies between the water industry and the natural water environment discussed in detail in Section 3. The table is populated based on the findings from the literature reviewed (Section 2). Both direct and indirect relationships are considered. Impacts are considered to be direct where a change in one sector leads to a corresponding change in another. For example, socio-economic factors such as population growth have direct impacts on water supply because a larger population requires more water. Alternatively, impacts are indirect when a change in one sector affects an additional variable before it results in a change on another sector. For example, population growth has an indirect impact on wild species diversity, due to habitat loss as a result of development projects to support larger populations.

Table 8-2 is intended to provide an illustrative framework to organise the variety of links between resilience, risks and interdependencies. It does not intend to isolate individual links but rather displays the interconnected nature of different components of resilience. There are also often relationships between direct and indirect impacts. For example, when considering the risk of ‘water shortage’, there is a link between water quality, which is in turn a direct impact of water shortage and an indirect impact of soil quality.

More generally, Table 8-2 demonstrates that, for almost 90% of the 120 interactions presented, there is a direct or indirect risk to resilience (section 7) which affects an interdependency between the environmental and the water industry sector (Section 3). This demonstrates the strong case for the two sectors to work together to enhance resilience. Section 8.2.1 gives examples of how stakeholders have worked together to improve natural resilience in the case studies in Appendix B.

Table 8-2: Effect of joint risks to resilience on interdependencies within the water environment

Risk Themes	Interdependencies within the water environment affected by risks							
	Water quality regulation	Soil quality regulation	Wild species diversity	Disease and pest control	Water supply	Global climate regulation	Hazard regulation	Recreation
Socio-economic factors such as population growth	Indirect	Indirect	Indirect	Indirect	Direct	Direct	Indirect	Indirect
Climate change	Indirect	Indirect	Indirect	Indirect	Indirect	Direct	Direct	N/A
Political or regulatory frameworks (current or reformed)	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Water efficiency in households e.g. household appliances, water meters	Indirect	Indirect	Indirect	Indirect	Direct	N/A	Indirect	Indirect
Urbanisation, urban creep and land-use change	Direct	Direct	Direct	Indirect	Direct	Direct	Indirect	Indirect
Digital revolution benefits, potential for and over-reliance on technology and associated risks e.g. system failure	Indirect	Indirect	Indirect	Indirect	Direct	N/A	N/A	N/A
Water shortage	Direct	Indirect	Indirect	Indirect	Direct	N/A	Indirect	Indirect
Public health and Infectious diseases (people and animals)	N/A	N/A	Direct	Direct	Indirect	N/A	N/A	N/A
Declining water environment quality including known deterioration (nitrate, phosphorus, metaldehyde) and other risks (combined sewer overflows and emerging substances)	Direct	Direct	Direct	Indirect	Indirect	N/A	N/A	Indirect
Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	Indirect	Indirect	Indirect	Indirect	Direct	N/A	Direct	Indirect
Agricultural intensification/damaging fishing practices	Direct	Direct	Direct	Indirect	Direct	Direct	Indirect	Indirect
Biosecurity/pest and disease management (including invasive, non-native species)	Indirect	Indirect	Direct	Direct	Indirect	N/A	Indirect	Indirect
Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	Direct	Direct	Direct	Direct	Indirect	Indirect	Indirect	Indirect
Unsustainable abstraction, abstraction reform and changing abstraction licences	Indirect	Indirect	Indirect	Indirect	Direct	N/A	Indirect	Indirect
Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Indirect

8.2.1 Collaborative Working in the Resilience Case Studies

Table 8-3 provides a summary of the case studies in Appendix B in terms of collaborative working. A very wide range of stakeholders and partners are identified (39 named organisations in the public, private and third sectors). The case studies cut across all the interdependencies between the water environment and water industry sector, which demonstrates the spectrum of opportunities for action and collaboration.

The case studies link to improving resilience in terms of the interdependent ecosystems services in Section 3 as follows:

- All five case studies seek to improve water quality regulation and wild species diversity;
- Four out of the five case studies could improve the resilience of water supply;
- Three out of the five case studies link to global climate regulation, hazard regulation or recreation, and;
- One of the five case studies could improve soil quality regulation or disease and pest control.

All eight interdependent ecosystems services would be affected and improved by the case studies, even though only five case studies are presented. This illustrates the ability of programmes to improve environmental resilience over multiple areas, achieving multiple benefits for different stakeholders while still delivering on their primary objective. Delivery of multiple benefits is a key metric for measurement of resilience (Section 4.3) and provides opportunity for diverse stakeholders to find common ground and agree targets and metrics for resilience programmes which are appropriate, specific, measurable, comparable, communicable and transparent (Section 4.3.1). However, it also demonstrates that all resilience projects are likely to impact on the wider community and environment, which may increase the complexity of programmes in terms of the number of groups impacted (Section 6) and the legislative framework which may apply (Section 5). Section 8-3 below provides an overview of the stakeholder groups which may be relevant to delivery of each the mitigation measures in Section 8.1. Section 8.4 provides more discussion concerning the benefits and potential blockers for collaboration.

It should be noted that a relatively small number of illustrative case studies have been developed as part of this project. As such, while the selection of case studies is intended to provide a range of examples, it is not considered to be representative of the breadth of examples and potential opportunities across the two sectors.

Table 8-3: Summary of Stakeholder Collaboration in Resilience Case Studies

Project	Commentary	
British Canoeing – invasive species programme	**Primary Objective**	Invasive species management and control
	Partners and Stakeholders	• Non-Native Species Secretariat • Great Britain Non-Native Species Boating Pathway Action Plan Group • Water companies e.g. Yorkshire Water and South West Water • RiverCare/BeachCare • North Wales Wildlife Trust • Other National Governing Bodies (NGOs), e.g. British Rowing and the Royal Yachting Association • The Angling Trust • Yorkshire Wildlife Trust • Wildlife & Countryside Link • Canal & River Trust • Environmental Audit Committee • Inland Waterways Association
	Benefits to the natural water environment	Improved local biodiversity and ecosystems, In addition, paddlers are now made aware of lots of different environmental issues and are changing their behaviour to protect species that are at risk.
	Benefits to the water industry	Invasive non-native plant species often clog up waterways, and the resulting removal costs are high for the water sector, resulting in benefits in terms of reduced costs of species management and removal.
	Interdependent Ecosystem Services	• Water quality regulation • Wild species diversity • Disease and pest control • Recreation
Environment Agency – water abstraction	**Primary Objective**	To ensure that environmental damage caused by unsustainable abstraction is rectified and/or prevented.
	Partners and Stakeholders	• Environment Agency • United Utilities • Local experts, stakeholders, environmental groups and NGOs (e.g. local Rivers Trust)
	Benefits to the natural water environment	Improved river flow, biodiversity, aesthetics and recreational benefits.
	Benefits to the water industry	Potential for improved water quality and catchment resilience to future changes. The water company benefited reputationally and has enhanced its relationships and trust with local partners.
	Interdependent Ecosystem Services	• Wild species diversity • Water quality regulation • Water supply (including drinking water) • Recreation
South East Water – PROWATER	**Primary Objective**	The PROWATER project aims to build resilience within catchments against droughts and extreme rainfall events through landscape-scale change. Ultimately, the outcomes from this work

		are intended to help South East Water's catchment management and long-term planning.
	Partners and Stakeholders	• University of Antwerpen • South East Water • South East Rivers Trust • Kent County Council • Westcountry Rivers Trust • Flanders: State of the Art • Natuurpunt • Waterschap Brabantse Delta • Provincie Antwerpen • Pidpa water in Beweging
	Benefits to the natural water environment	The Spatial Analysis Tool is able to provide support for all of the goals in the Government's 25-Year Environment Plan, e.g. identifying key areas to recharge aquifers, modelling land use change and linking these changes to ecosystem services.
	Benefits to the water industry	The Spatial Analysis Tool has enabled South East Water to identify how to build more resilience for their water resources, e.g. targeting actions to slow flood water, preserve groundwater and improve specific habitat types that support good groundwater quality.
	Interdependent Ecosystem Services	• Water quality regulation • Soil quality regulation • Wild species diversity • Water supply (including drinking water) • Global climate regulation • Hazard regulation
Southern Water – instream catchment resilience scheme	**Primary Objective**	Catchment First aims to take a more holistic and integrated approach to catchment management, exploring how future investment in instream catchment resilience measures can maintain resilient water supplies for customers as well as providing wider environmental benefits. It seeks to identify sustainable levels of abstraction.
	Partners and Stakeholders	The business plan has been tested with key stakeholders and the initiative has received widespread support. There are plans and opportunities to work with key partners as this initiative develops, such as Blueprint for Water, the Rivers Trust and the Wildlife Trusts.
	Benefits to the natural water environment	Key benefits to the natural environment are anticipated to be: • Improving the form and function of rivers by making them more resilient to extreme weather events • Improving the physio-chemical state of rivers (flow and water quality) • Enhancing fish populations • Improving habitat quality and connectivity • Wider environmental benefits including biodiversity, climate regulation and flood risk attenuation
	Benefits to the water industry	Evidence to demonstrate that investment in environmental resilience can reduce the need for future sustainability reductions. This will allow Southern Water to build a business case and roll out the scheme across more of its catchments where it is cost-effective to do so. The work undertaken as part of the scheme could inform other water companies' water resources planning in the future.
	Interdependent Ecosystem Services	• Water quality regulation • Wild species diversity • Water supply (including drinking water) • Global climate regulation • Hazard regulation

Thames Water – Walthamstow wetlands project	**Primary Objective**	• Provide free access to green space for the local communities with high levels of socio-economic deprivation and lack of access to nature • Raise awareness among visitors regarding their role in the water cycle, including water efficiency • Engage people with the rich industrial heritage of the area e.g. the on-site Mill which has been historically important for delivering clean water to London
	Partners and Stakeholders	• Lee Valley Park Authority • London Wildlife Trust • Environment Agency • Natural England • Greater London Authority • Surrounding local councils. • London Borough of Waltham Forest • Thames Water
	Benefits to the natural water environment	Appropriate management of the SSSI on the site appropriately, including creation and enhancement of habitat.
	Benefits to the water industry	Thames Water has improved interface with the community and customers have a better understanding of where their water comes from and water efficiency.
	Interdependent Ecosystem Services	• Water quality regulation • Wild species diversity • Water supply (including drinking water) • Global climate regulation • Hazard regulation • Recreation

8.3 Linking key stakeholders to risk management measures

Table 8-5 gives a list of stakeholder organisations identified in Appendix A and Section 6 and identifies their interests and responsibilities in terms of potentially supporting to deliver the mitigation measures identified in Section 8.1.

Table 8-4: Mapping of key stakeholders against risk management measures (in alphabetical order)

Organisation	Sector	Management measures for current and future risks to resilience					
		Managing catchments and land	Managing housing developments	Managing water supply and demand	Managing technological change	Partnership working	Awareness raising
Amphibian & Reptile Conservation Trust	NGO	x					
Angling Trust	Public	x				x	x
British Canoeing	NGO	x				x	x
British Land	Private	x	x				
Business in the Community	NGO				x		
Canal and River Trust	NGO	x				x	
Catchment partnerships	Other multi-sector partnerships	x		x		x	x
Committee on Climate Change	Public						x
Defra	Public	x					x
Department for Business, Energy and Industrial Strategy	Public	x			x		
Developers	Private	x	x	x		x	
Environment Agency	Public	x		x		x	x
Floodplain Meadows Partnership	NGO	x				x	
Forestry Commission / Forestry England	Public	x					x
Green Alliance	NGO	x				x	x
Historic England	Public	x					
Homes England	Public	x	x	x			
Housing associations (e.g. Habinteg)	Public	x	x	x			
Innovate UK	Public				x		
Land agents	Private	x		x			
Land owners and land managers (agriculture)	Private	x		x		x	x

Organisation	Sector	Management measures for current and future risks to resilience					
		Managing catchments and land	Managing housing developments	Managing water supply and demand	Managing technological change	Partnership working	Awareness raising
Land owners and land managers (aquaculture/fisheries)	Private	x		x		x	x
Land owners and land managers (other e.g. investors)	Private	x				x	
Local Authorities (including Lead Local Flood Authorities (LLFAs), Local Planning Authorities (LPAs) and Highways Authority)	Public	x		x		x	
Local businesses	Private					x	
Local Development Corporations	Public	x	x	x			
Local Enterprise Partnerships	Other multi-sector partnerships		x			x	
Local Nature Partnerships	Other multi-sector partnerships	x				x	
Manufacturers of water-intensive appliances	Private				x		x
Marine Management Organisation (MMO)	Public	x					
National Parks England	NGO	x				x	x
Natural Capital Committee	Public	x		x	x		x
Natural England	Public	x				x	x
Ofwat	Public	x		x	x		x
Pharmaceutical companies	Private					x	
Property agents (e.g. Savills)	Private	x	x				
River Restoration Centre	Other multi-sector partnerships	x		x		x	x
Small-scale developers (e.g. Peabody, Igloo)	Private	x	x	x			
The Rivers Trusts	NGO	x		x		x	
The Royal Society for the Protection of Birds (RSPB)	NGO	x				x	x
The Wildlife Trusts	NGO	x				x	x
UKWIR	Industry associations					x	x
Volume house builders (e.g. Bovis, Persimon)	Private	x	x	x			

Organisation	Sector	Management measures for current and future risks to resilience					
		Managing catchments and land	Managing housing developments	Managing water supply and demand	Managing technological change	Partnership working	Awareness raising
Water companies	Private	x		x	x	x	x
Water Resource Planning Programmes (e.g. Water Resources East)	Other multi-sector partnerships	x		x	x	x	x
Water UK	Industry associations					x	x
Wildfowl & Wetlands Trust (WWT)	NGO	x		x		x	x
Wildlife and Countryside Link	NGO	x		x		x	x
Word Wide Fund for Nature (WWF)	NGO	x		x		x	x
Total number organisations		40	9	21	8	29	25

Table 8-5 summarises the key stakeholder groups against these risk management measures they could help deliver, based on the role and responsibility of organisations with respect to enhancing resilience.

Table 8-5: Sectoral mapping of key stakeholders against risk management measures

Sector	Management measures for current and future risks to resilience					
	Managing catchments and land	Managing housing developments	Managing water supply and demand	Managing technological change	Partnership working	Awareness raising
Industry associations	-	-	-	-	2	2
NGO	12	-	4	1	11	8
Other multi-sector partnerships	4	1	3	1	5	3
Private	10	5	7	2	7	4
Public	14	3	7	4	4	8
Total number of organisations	**40**	**9**	**21**	**8**	**29**	**25**

The broader risk management areas of 'managing catchments and land', 'partnership working' and 'awareness raising' have the most key stakeholders because most of the organisations identified are NGOs or public sector organisations that tend to act in these interests. The areas with the least key stakeholders are 'managing technological change' and 'managing housing developments.' This can be explained as follows:

- Managing technological change has been considered in its strictest sense i.e. where the responsibilities of key stakeholders explicitly mention that technological change and/or innovation is their objective. The small number of stakeholders with a focus on managing technological change is not considered to be of concern given the focus of this project: other stakeholder organisations will exist outside of the water environment sector which could assist with this.
- Managing housing developments is not explicitly recognised as being the direct responsibility of the organisations surveyed in Appendix A. Only nine organisations identified have responsibilities linked to 'managing housing developments' and these organisations' objectives are not as explicitly linked to the water environment. Their operations do, however, put pressure on land and water resources and are therefore closely linked to the environment. Links between housing developments, the water industry and the environment may become more evident to the housing sector over time because multiple policy targets will have to be met which put competing pressures on land and the water environment. For example, an on-going catchment-based nitrates issue in Hampshire is currently halting housing development in the area, blocking approximately 10,000 planned homes from being built. As a result, regulations are now advising that new housing schemes should demonstrate "nitrate neutrality" to avoid judicial review of their permissions.[40]

Overall, the findings confirm that there is considerable cross-over between individual organisations' objectives and activities that can help manage the current and future risks to resilience. However, the involvement of other, more specialist stakeholders with less of a focus on the environment may be needed to support delivery of some risk management measures.

[40] https://www.planningresource.co.uk/article/1665502/algae-blocking-10000-planned-homes

8.4 Benefits of collaboration, blockers and mitigation measures

Sections 8.2 and 8.3 demonstrate that there are considerable opportunities for collaboration between the environmental and water industry sector to enhance resilience as well as manage its associated risks. The following section sets out:

- The benefits associated with collaboration (Section 8.4.1);
- The potential blockers that may arise (Section 8.4.2); and
- Potential mitigation measures to overcome these blockers (Section 8.4.3).

8.4.1 Benefits of collaboration

This sub-section discusses the benefits of collaborative working to enhance resilience based on the literature review and the case studies. Where specific benefits are based on the case studies, the relevant case study number(s) is included as follows:

- CS1 – British Canoeing – invasive species programme;
- CS2 – Environment Agency – water abstraction;
- CS3 – South East Water – PROWATER-Interreg project;
- CS4 – Southern Water – instream catchment resilience scheme; and
- CS5 – Thames Water – Walthamstow wetlands project.

The benefits of collaborative working are summarised in Box 8.1 below.

Box 8.1: Benefits of collaborative working to enhance resilience

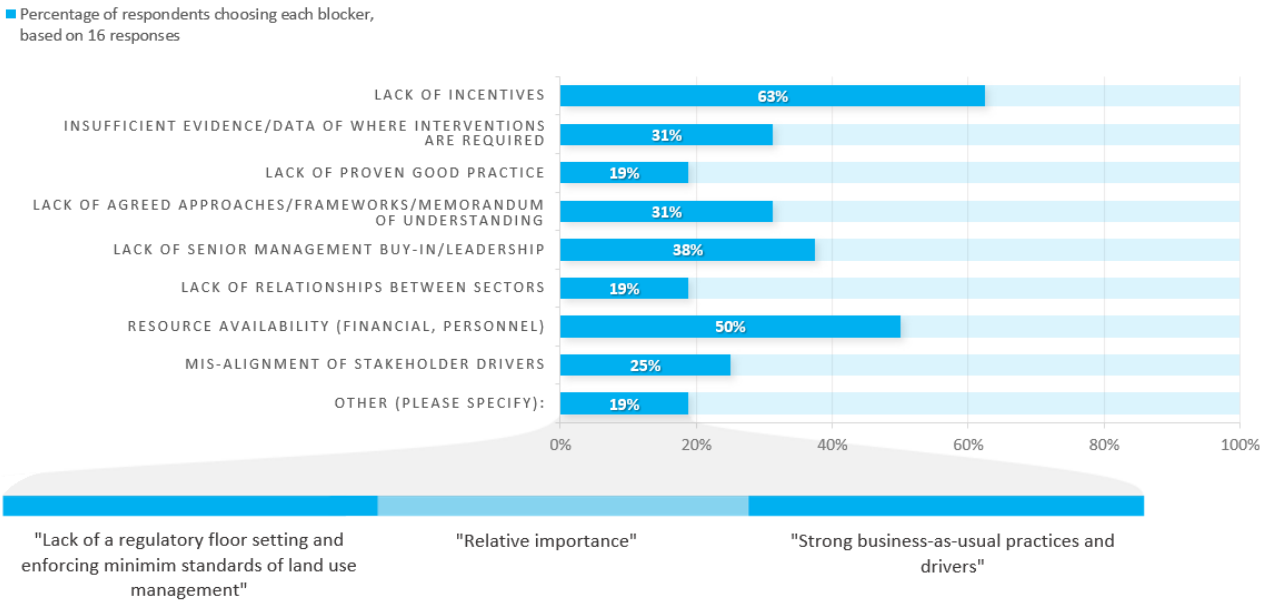
1. Financial savings, with more being delivered for less. Greater opportunities for financial savings are likely where there is alignment of capital programmes.
2. Development of relationships between sectors is likely to promote further opportunities for collaborative working, improved communication and better understanding of the drivers of each sector.
3. More collaborative working/examples of initiatives in the short-term can result in a richer evidence base relating to benefits and lessons learnt, which may encourage subsequent collaboration across the two sectors.
4. Targeted management between the two sectors can reduce risks, thereby limiting impacts on ecosystem service interdependencies and providing benefits to both sectors. For example, the natural environment may benefit from enhanced habitat connectivity and diversity, whereas the water sector may benefit from improved water quality.
5. Jointly overcoming hurdles and restrictions imposed by legislative driven fragmentation of responsibilities. For example delivery of sustainable drainage and green blue infrastructure for urban flood risk management under the FWMA requires several risk management authorities to work collaboratively to deliver strategic solutions
6. Energising and activating the community by raising awareness and incentivising behavioural change (CS1).
7. Early intervention can reduce future costs, for example the cost of managing and removing invasive non-native species (CS1; CS2).
8. Positive environmental benefits such as restored river flows due to reduced abstraction (CS2) or reduced carbon emissions. Improved land management that increases carbon sequestration in soils and also improves raw water quality, subsequently reducing the need for energy-intensive treatment of drinking water. Similarly, greening urban areas reduces surface water run-off to sewers and the need for combined sewer pumping or new network infrastructure with high embedded carbon.
9. Future-proofing green and grey infrastructure and increasing sustainability. Investment in environmental protection and enhancement as a means to secure cleaner river water is a more sustainable option than continually having to upgrade treatment and distribution networks to address deteriorating water quality.
10. Environmental co-benefits e.g. restoring river flow improve biodiversity, aesthetics, and recreational benefits which strengthens resilience (CS2).
11. Reputational benefits from enhancing resilience (CS2).
12. Partnership working can draw on the strengths of different partners from a variety of sectors (public, private, third, academic) as well as different geographies. This can help build knowledge and skills (CS3).

8.4.2 Blockers of collaboration

This sub-section presents the blockers of collaborative working to enhance resilience. The findings are based on the literature review for the project, the survey (Question 12) and the case studies.

As part of the survey, Question 12 asked respondents to identify potential blockers which prevent collaboration between sectors to enhance resilience. The responses are presented in Figure 8-2 below, which compares the percentage of respondents who chose each blocker. Note that a limited number (16) survey responses were received and there may be blockers for some stakeholders which are not captured here, especially for specialist stakeholders who might be asked for assistance with managing technological change and housing development.

Figure 8-2 Perceived 'blockers' of collaboration between the water sector and the natural environment to enhance resilience (online survey; n=16)



The top five blockers identified by survey respondents with respect to collaboration between the environmental and water sector to enhance resilience were:

- Lack of incentives, possibly relating a lack of policy drivers, which was selected by over 60% of respondents (out of 16 respondents in total);
- Resource availability (financial, personnel), which was selected by 50% of respondents;
- Lack of senior management buy-in and leadership, which was selected by nearly 40% of respondents; and
- Insufficient evidence/data of where interventions are required as well as a lack of agreed approaches and frameworks, which were each selected by 31% of respondents.

Box 8.2 presents the blockers that were identified from the survey, literature review and case studies with respect to collaboration between the environmental and water sector to enhance resilience. Where specific blockers are based on the case studies, the relevant case study number(s) is included as above Specific blockers identified based Question 12 of the survey are marked 'Q12.'

Box 8.2: Blockers of collaborative working to enhance resilience

1. Unclear national priorities and incentives may result in unclear responsibilities, hampering coordination (CS1; Q12).
2. Lack of senior management buy-in/leadership with partners organisations (Q12).
3. Limited scientific evidence of certain risks to resilience e.g. invasive non-native species. This affects the urgency and uptake of risk management measures (CS1; CS2; Q12).
4. Limited quantitative and monetary evidence for certain environmental benefits may make it difficult to make the business case for investing in resilience (CS4; Q12).
5. Limitations in funding and resource availability (financial, personnel) when there are multiple and sometime competing priorities and partners (CS1; Q12).
6. Obtaining consent from private landowners can be challenging (CS1; CS4).
7. Delays in habitat recovery may delay returns on investment in measures to enhance resilience thereby making them less attractive options (CS2; CS4).
8. It takes time to establish trust and collaboration as it requires a shared and common well-defined goal by different parties (CS2).
9. Spatially targeted analysis and modelling is needed to support intervention to enhance resilience. This may be costly and subject to scientific data gaps (CS3).
10. There are trade-offs between enhancing resilience and managing socio-economic changes e.g. trade-offs between reducing floodplain development and building homes for a growing population (CS3).
11. Partnership working with EU partners is subject to political uncertainty due to Brexit (CS3).
12. Competing pressures and objectives may challenge the success of interventions that seek to enhance resilience e.g. increasing public visits to a SSSI versus meeting the environmental objectives of the site (CS5).

8.4.3 Mitigation measures to overcome blockers

Box 8.3 presents mitigation measures to overcome the blockers to collaboration. These have been identified based on the online survey, literature review and case studies. The measures marked as identified from the case studies proved effective in each case, however this list should not be considered exhaustive due to the low number of survey responses and case studies in this project. Further mitigation measures are likely to be identified as projects to enhance resilience become more common, and it is recommended that parties involved in delivering resilience should carefully record blockers encountered, mitigation measures tried and results achieved. This will allow improvement in collaboration over time, or development of an evidence base to show where blockers are too difficult to be overcome and legislative or policy change may be required. The full impact of blockers may be difficult to identify given the interactions between different aspects of the water system (Section 3) so any obvious indirect impacts on receptors should also be recorded.

Box 8.3: Mitigation measures to overcome blockers of collaborative working to enhance resilience

1. Linking interventions to regulatory outcomes incentivises participation and collaboration (Q12).
2. Developing an overarching strategy makes policy priorities clear to different sectors and organisations (CS1; CS3; CS5; Q12).
3. Developing a business plan and governance model for certain natural capital assets (e.g. wetlands) with multiple pressures and objectives can help improve and secure future funding for the sustainable management and resilience of that asset (CS5).
4. Co-designing and co-delivering interventions can improve trust and collaboration (CS4).
5. Understanding and communicating the opportunities and risks during the design phase of a project is beneficial in addressing them prior to the development and implementation of a project (CS5).
6. Using a catchment-based approach can be more effective than ad-hoc smaller scale intervention given that resilience relies on a systems approach (CS2).
7. Using a catchment-based approach can provide the impetus for engaging with relevant stakeholders (CS2).
8. Developing and sharing case studies can help future planning and interventions in terms of lessons learnt etc. (CS1; CS4).
9. Using available quantitative and monetary evidence, despite some gaps in the evidence base, can help make a business case for enhancing resilience (CS4).
10. Where data challenges exist, it may be helpful to develop pilot case studies to collect initial data which may be transferable to other contexts (CS3).
11. Seeking feedback as early as possible is beneficial and can help inform future work (CS4).
12. Training and education of stakeholders can help bring them up to speed with respect to resilience, risks and interdependencies (CS1).
13. Delays in habitat recovery can be better accounted for with more regular monitoring of the effectiveness of interventions. However, if monitoring programmes must be affordable to avoid making projects financially unviable (CS2).
14. Effective communication between relevant stakeholders can help develop wider knowledge of the opportunities for collaboration to deliver greater resilience.

Nearly half of the 12 blockers presented in Box 8.2 can be linked to a lack of regulatory incentives, which is suggested as the first mitigation measure in Box 8.3. More specifically, with regards to:

- Blocker 1: National priorities and incentives regarding resilience are currently unclear, resulting in difficulties coordinating local parties. There are multiple factors that contribute to this blocker including a lack of consensus regarding how to define, measure and track resilience over time. This is coupled with the absence of an overarching policy framework to anchor and drive actions to maintain and enhance resilience. For example, the WFD and legislation driving statutory environmental designations (e.g. SACs, SSSIs, etc.) (see Section 5) are the primary levers to incentivise action when it comes to protecting the natural environment and hence providing resilience in that sector. Without these regulatory requirements, the incentive for action to deliver environmental resilience and subsequently to co-deliver water industry resilience is lacking. Taking this further, it can be inferred that non-designated priority habitats are not adequately protected and the protection of these sites and habitats is even less incentivised. There is a need for coordinated policy drivers to incentivise partnership working and co-deliver resilience benefits in both sectors, e.g. through considering designated and non-designated habitats and sites. This also links to Blocker 2.
- Blocker 2: The current lack of leadership or buy-in from senior managers and partner organisations would likely be improved if more explicit and integrated drivers were in place to help make resilience a priority. At the root of this blocker is the fact there is no overall

accountability for environmental resilience and, as identified by the project steering group, it can be argued that one of the main reasons for lack of investment in natural resilience is the current varied and mixed responsibility for different aspects of the environment. Significant effort and will from all parties would be needed to fully address this but small improvements could be made. For example, setting out the impact that reductions in environmental protection would have on the provision of resilient water industry services (water supply, wastewater provision).

- Blocker 7: Delays in habitat recovery create a disconnect between undertaking an action and receiving a payoff. This blocker could be addressed by providing more certainty in the incentives used to promote actions to enhance resilience or flexibility in the outcomes of those actions. An example of this is the forthcoming Environmental Land Management scheme (ELM) which provides land managers with payments to deliver public goods. Payments may be delivered upfront or over time which may help address the uncertainty associated with long-term actions and habitat recovery.
- Blocker 8: Establishing trust and collaboration between parties can be time-consuming and difficult. Policy drivers (see Blocker 1) can provide the incentive needed to develop clear shared goals between parties, including giving clearer responsibilities to different sectors. Similarly, co-designing and co-delivering interventions can improve trust and collaboration. The Catchment Based Approach (CaBA) partnerships are a good example of how organisations can work together, building trust over time to deliver environmental resilience in the context of limited central government funding. The CaBA partnerships achieve this both by maximising efficient use of available funding via shared expertise and collaborative working, but also by identifying additional funding sources through more connected partnership routes where there are several beneficiaries to environmental interventions. However, it was noted by the project Steering Group that in practice the success and maturity of these catchment partnerships is extremely wide, due in part to the insecurity of funding and the fact the guidance around CaBA partnerships is vague rather than specific (e.g what a partnership should do and how it should be structured). This would need addressing if CaBA partnerships were to be used as an effective measure to mitigate this blocker.
- Blocker 11: Partnership working with EU partners is difficult to anticipate due to the political uncertainty surrounding Brexit. Although the European Union (Withdrawal) Act 2018 will ensure that all relevant EU Law will apply in the UK immediately after the transition period, compliance with UK regulations will no longer be accountable to the European Courts. Following the transition, it is possible that UK legislation will diverge from that of the EU. Regulatory environmental standards may change in the medium- to long- term, with impacts on environmental resilience and securing the funding for future resilience projects. If environmental standards are less stringent as a result of new legislation, and this in turn adversely affects the resilience of water industry services, it is possible that water companies may turn to investing in hard/grey/capital solutions as opposed to improving environmental resilience.

9. Summary of key findings

The overall objective of this project was to explore the interplay between resilience in the water industry and the resilience of the natural environment, as well as how investments in one area can benefit both.

The project methodology included:

- An iterative literature review which fed into all project objectives including to identify: (i) legislation, regulatory frameworks, policies and incentives that could facilitate enhancements in resilience; (ii) a definition, principles and metrics for resilience; (iii) interdependencies between the resilience of the water sector and the natural environmental; and (iv) current and future risks to resilience in both these sectors; and;
- An online survey targeted towards stakeholders within the water industry and the environmental sector, to gather their views regarding the current and future risks to resilience and to identify case studies of examples of work to improve environmental resilience.

The following sub-sections set out the key findings from the project.

9.1 Interdependencies between the water sector and the natural environment

The project identified key interdependencies between the water industry and the natural water environment within the water cycle. The following ecosystem services have been identified as having interdependencies:

- Hazard regulation;
- Water quality regulation;
- Soil quality regulation;
- Wild species diversity;
- Disease and pest control;
- Water supply (including drinking water);
- Global climate regulation; and
- Recreation.

Opportunities for providing benefits to both the water environment and water industry can be identified with reference to these interdependent ecosystems services.

9.2 Definition and principles of resilience

A shared definition of resilience is needed which reflects the needs of the water industry and wider water environment. Box 9.1 presents the definition of resilience that was identified by drawing on the breadth of evidence reviewed.

Box 9.1: Definition of resilience

Resilience is the extent to which a system can withstand stressors and continue to provide benefits in the long term.

Improving resilience requires taking into account the system dynamics and implementing effective measures to facilitate long-term flows of benefits, whilst protecting and enhancing society, the environment and the economy.

The definition provides an insight into principles that underpin the concept of resilience within the reviewed literature. The principles are as follows:

- Transparency
- Response
- Recovery
- Resistance/providing protection
- Resourcefulness
- Reliability
- Thresholds
- Risk-based approach
- Redundancy
- Robustness
- Adaptability
- Diversity
- Condition
- Connectivity
- Extent
- Stakeholder-led
- Delivering multiple benefits
- Proactivity
- Informed approach
- Whole-life costing
- Efficiency
- Alignment
- Effectiveness

9.3 Metrics for resilience

The literature review identified an extensive list of metrics which are currently used to measure a range of resilience pressures and challenges within the water industry and the water environment. However, there is currently no published record of progress to enhance resilience across the sectors based on consistent, comparable and centralised metrics.

Measuring resilience is complex and therefore requires a nuanced collection of metrics, including both quantitative and qualitative measures. Resilience metrics can be broad, operating across habitat types (e.g. Habitats Directive Article 17), or local and specific (e.g. Resilience framework for resilience and tree health). Metrics can also assess a range of different hazards and pressures, including flooding, drought, water quality, asset health and environmental condition, with some measures focusing on one specific pressure and others being applied generally across several pressures.

Overall, there is a vast number of potentially relevant metrics and the metrics identified in this study underestimate the importance of the interdependencies between the water sector and the natural environment, the risks to resilience and the range of key stakeholders. Metrics should therefore be chosen on a case-by-case basis to ensure that the relevant information is captured and changes can be monitored. For the purpose of measuring the impact of measures aimed at improving resilience, a suite of metrics should selected which are appropriate, specific, measurable, comparable over time and space, communicable and transparent. Metrics should also be agreed with all relevant stakeholders, ideally prior to the start of implementation of measures. Cross-sector teams (e.g. the Water and Wastewater Resilience Action group) are the most effective way to develop resilience metrics which cover the full range of challenges facing the sectors both directly and indirectly.

One important consideration is whether to use forward-facing or backward-facing metrics. Forward-facing metrics are predictions of future trends or outcomes, while backward facing metrics use information or observations collected in the past to describe trends in resilience or the outcomes of actions. At present, forward-facing metrics are most commonly used metrics to assess resilience, as they can be applied consistently, are meaningful to customers and allow stakeholders to better understand the issues surrounding resilience. However, the complex system dynamics in the water environment makes predicting the outcome of measures very difficult. Using forward facing metrics can cause problems if aspirations are not delivered, and forward-facing metrics can also lack historical and comparative performance data. It is therefore important to use traditional backward facing metrics in addition to forward facing metrics, which allows clear comparisons to be made with past trends, actions and system status, and improved understanding of how resilience changes and systems interact. Use of backward facing metrics also permits a critical review of whether specific measures delivered the expected benefits, reasons for success or failure and whether any unexpected benefits were realised.

In addition to the resilience-focused metrics identified above, more general metrics such as customer satisfaction, value for money and key labour market trends may be important to consider as changes

in social capital and labour capacity can result in resilience issues. However, these metrics may only give limited insight into long-term resilience issues if used independently.

9.3 Legislation, regulatory frameworks, policies and incentives to enhance resilience

The project set out to identify legislation, regulatory frameworks, policies and incentives across the two sectors, with a focus on the instruments which could facilitate enhanced resilience or may be acting as a barrier. Overall, 28 documents were identified, mostly related to the water environment, the water industry and/or land management.

There is a range of documents based on EU Directives, UK legislation and England only legislation. All of the EU Directives that were identified have been translated to UK Law. Although the European Union (Withdrawal) Act 2018 will ensure that all relevant EU Law will continue immediately after the transition period, compliance with UK regulations will no longer be accountable to the European Courts. UK law could diverge from EU law after the transition.

The legislation and regulatory frameworks affecting resilience can create opportunities for collaboration between the water industry and stakeholders working to address problems in the water environment. The review of legislation included in this document identifies where guidance or policy identifies opportunities for or blockers to greater resilience. Further analysis of relevant legislation, regulatory frameworks, policies and incentives has been undertaken by the Wildlife and Countryside Link as well as Water UK[41].

9.4 Key stakeholders

Table 9-1 presents an overview of key stakeholders that were identified as having a role with respect to enhancing water environment resilience.

Table 9-1: Sectoral overview of key stakeholders with respect to enhancing resilience (in alphabetical order)

Sector	n	%
Industry associations	2	4%
NGO	13	27%
Other multi-sector partnerships	5	10%
Private	13	27%
Public	16	33%
Total number of organisations	49	100%

Resilience in the water environment is complex and involves may interacting system components. Stakeholder engagement is essential but includes a large number and diversity of different interested stakeholder groups. Good stakeholder engagement needs to start from a common base to which all parties can refer, as well as an understanding of common goals and shared ideals.

This report considers how the identified stakeholders are relevant to delivery of UKWIR goals, as set out in their 12 ‘Big Questions,’ which reflect the overarching needs of the water sector. In this way, stakeholders working to deliver resilience in the natural water environment are directly related to delivery of resilience in the water industry sector. Closest alignment between the needs of water industry and water environment stakeholders was found when water industry goals were broad, such as ensuring the right outcomes for customers and the environment, including achieving 100% compliance with drinking water standards. This finding reflects the potential impact of the water industry on the

[41] See https://www.wcl.org.uk/policy-hub.asp and https://www.water.org.uk/policy-topics/ respectively.

water environment, and the fact that there is a wide range of organisations that have a direct or indirect influence on the quality of water from which drinking water supplies are sourced from.

Overall, the findings suggest that the greatest potential for partnership and collaboration between water companies and other stakeholders lies with issues that are more closely related to environmental resilience, either as an end itself or as a means to securing the resilience of the water sector. Issues that are solely focused on the water sector without an explicit environmental component, such as investing in reducing water poverty, are less likely to overlap with other stakeholders' remits and are therefore less likely to secure their widespread support.

9.5 Current and future risks to resilience

A high-level literature review identified 20 risk themes, many of which are joint risks to resilience in both the water sector and natural environment. Based on these risks, the online survey asked respondents to select their top five current and future risks, as shown in Table 9-2.

Table 9-2: Survey respondents' top five current and future risks to resilience (n=16)

	Current risks	Future risks
1	Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	Climate change
2	Climate change	Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents
3	Natural hazards (drought and flood risk) including economic resources to prepare for and address risks	Socio-economic factors such as population growth
4	Political or regulatory frameworks (current or reformed)	Natural hazards (drought and flood risk) including economic resources to prepare for and address risks
5	Socio-economic factors such as population growth	Ageing infrastructure/ asset failure (with associated cost implications) and leakage

The results show that risks surrounding environmental degradation are considered highly important, with climate change risks perceived to be increasingly important in the future. Political or regulatory frameworks are considered a current risk but are less of a concern in the future. Ageing infrastructure and asset failure (with associated cost implications) become increasingly important in future.

9.6 Managing risks to resilience through collaboration

Six categories of measures to manage the risks to resilience have been identified as follows:

- Management of Catchment and Land;
- Managing Housing Development;
- Awareness Raising;
- Partnership Working, and;
- Managing Water Supply and Demand.

Examples have been provided of on-the-ground initiatives and changes which would support delivery of each of these measures. The case studies identified as part of the project demonstrate successful projects to deliver these measures as follows:

- The British Canoeing Invasive Species Programme is an example of partnership working and awareness raising;

- The Environment Agency Water Abstraction case study is an example of managing catchments and land as well as managing water supply and demand;
- The South East Water PROWATER-Interreg Project is an example of managing water supply and demand, managing catchments and land, managing technological change and partnership working;
- The Southern Water Instream Catchment Resilience Scheme is an example of managing water supply and demand, managing catchments and land, and managing technological change; and
- The Thames Water Walthamstow Wetlands Project is an example of awareness raising, partnership working, and managing catchments and land.

The benefits of collaborative working between the two sectors to enhance resilience included:

- Delivering environmental benefits;
- Future-proofing infrastructure and increasing sustainability;
- Financial savings including reduction in costs;
- Developing relationships and trust between partners while drawing on different parties' strengths;
- Providing a proof concept for future initiatives to learn from; and
- Reputational benefits.

The blockers of collaboration were also explored and half were linked to a lack of regulatory incentives:

- National priorities and incentives regarding resilience are currently unclear, resulting in difficulties coordinating local parties. There are multiple factors that contribute to this blocker, including a lack of consensus regarding how to define, measure and track resilience over time. This is coupled with the absence of an overarching policy framework to anchor and drive actions to maintain and enhance resilience.
- There is currently a lack of leadership or buy-in from senior managers and partner organisations. This would also be improved if more explicit and integrated legislative drivers were in place to help make resilience a priority.
- Delays in habitat recovery create a disconnect between undertaking an action and receiving a payoff. This blocker could be addressed by providing more certainty on incentives used to promote actions to enhance resilience, e.g. in the forthcoming Environmental Land Management scheme.
- Establishing trust and collaboration between parties can be time-consuming and difficult. In some cases, policy drivers can provide the incentive needed for collaboration, including clearer responsibilities for different sectors. Co-designing and co-delivering interventions can improve trust and collaboration, as can developing and using an agreed suite of metrics to measure and monitor resilience and the effectiveness of interventions, including focussing on delivery of multiple benefits.
- The political uncertainty surrounding Brexit creates challenges in anticipating partnership working with EU partners. There is uncertainty with respect to what UK regulatory environmental standards might be in the medium- to long- term and what this means for ensuring environmental resilience and securing the funding to continue protecting resilience.

10. Recommendations

The top current and future risks to resilience in both the water industry and the natural water environment are

a. Environmental degradation;

b. Climate change;

c. Natural hazards;

d. Political or regulatory frameworks, and;

e. Socio-economic factors such as population growth.

Each of these risks impact on the key interdependent ecosystems services which are important for the resilience of both the water industry and the natural water environment, as follows:

f. Water quality regulation;

g. Soil quality regulation;

h. Wild species diversity;

i. Disease and pest control;

j. Water supply;

k. Global climate regulation;

l. Hazard regulation, and;

m. Recreation.

The management measures that can help address these risks include managing catchments and land, managing housing developments and managing water supply and demand and will require multiple stakeholder input. These stakeholders' remits include delivery of actions which will impact on, and could assist, water company actions to deliver industry resilience as set out in UKWIR's 12 'Big Questions.'

This study emphasises the complexity of resilience in terms of the water environment, with many inter-related factors and numerous affected stakeholders. This complexity makes it difficult to give specific recommendations which will address the resilience of the system as a whole. Instead, work to address resilience should begin with identifying a specific problem and relating that problems to the natural water environment or water industry actions. This gives a clear objective to be addressed by any proposed actions and assists with identifying and communicating with stakeholders. Actions to address the problem through improved environmental resilience should be related to delivery of multiple benefits. The flow chart in Figure 10-1 sets out the recommended approach to programmes to improve environmental resilience. A key consideration is to record all outcomes from all projects, regardless of success or failure, in order to build up the evidence base and inform the design of future projects.

The nature of environmental resilience means that a combination of localised and more generalised, national measures will be necessary in the long term and this may require proactive lobbying of government departments to strengthen policy and legislative direction. Four additional recommendations for large sale, long term measures are set out below. It is recognised that these measures cannot be delivered by any one stakeholder but the recorded findings from the resilience projects undertaken at a local scale would provide justification for these broader scale changes.

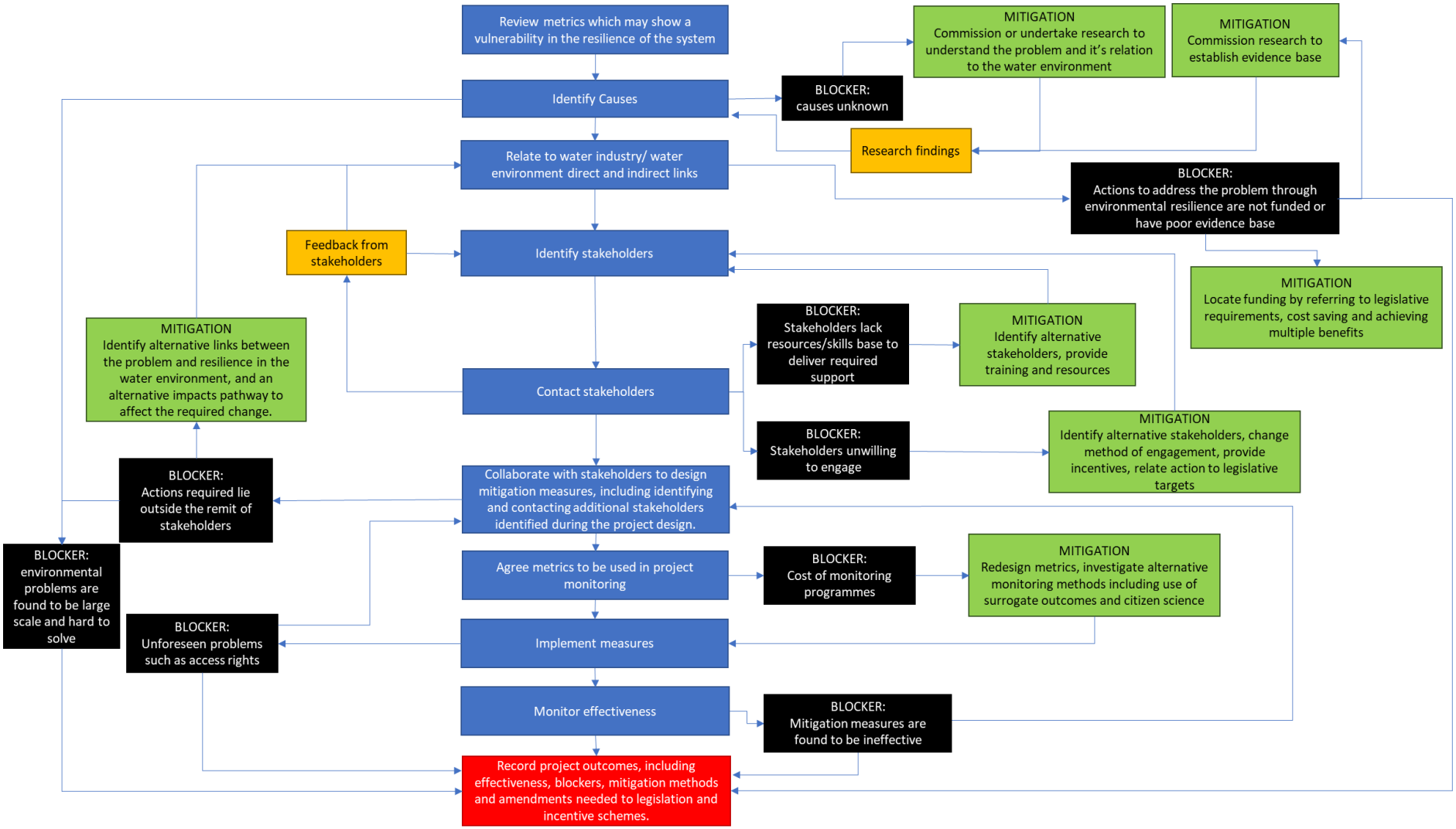


Figure 10-1: Flow Chart for Resilience Projects Involving the Water Industry and Natural Water Environment

Recommendation 1
Develop an online repository of case studies
Overview
Resilience project case studies need to be collated in an online, searchable database which is maintained and easy to contribute to. This will help build the evidence base to show the value of improved resilience, provide examples of good practice and set out lessons learnt. It could refer to, or expand on, the CaBA website which already has a series of readily available examples to draw from. Alternatively, this recommendation could be delivered through UKWIR in order to capture more industry-centric projects such as work to manage new technology and address security risks, although this may risk excluding projects which do not include a water industry stakeholder.
Indicative timescale and costs
On-going activity
Indicative cost
~ £10,000 upfront to set up process and platform to compile, receive and store case studies online. Excludes the on-going cost of maintaining the online repository.

Recommendation 2
Develop agreed metrics for resilience
Overview
Section 4 reported that there is currently no published set of metrics for resilience across the water sector and the natural environment which consistent, comparable and centralised. There are a range of sources with potentially relevant metrics including: • The metrics used to monitor water companies' performance commitments (including on Discover Water[42]). • The metrics from Wildlife Countryside Link's Blueprint for Water (WCL, 2017). • The metrics used by the Natural Capital Committee in its State of Natural Capital Reports.[43] • Natural England's natural capital indicators.[44] Drawing on the case studies in the online database, as well as their own specialist knowledge, water companies and other stakeholders should come together to advise regulators on an appropriate list of metrics to: • establish a baseline so that environmental resilience can be monitored in future; • justify future investments in resilience by the water industry; • secure stakeholder support and partnership in future projects, and; • communicate with customers to demonstrate how their actions help enhance environmental resilience and the resilience of their water and wastewater services. The initial stage of this work would include workshops with representatives from the water industry, regulators and stakeholders in the environmental sector to discuss and agree a priority list of metrics. This may include, or lead onto, a discussion of what type of metrics, indicators and criteria might be needed to justify investment in environmental resilience within PR24 business plans.
Indicative timescale and costs
Short-term activity (6 – 8 months)
Indicative cost
~ £30,000 upfront, excluding on-going cost of maintaining and improving the metrics

[42] See https://discoverwater.co.uk/
[43] See https://www.gov.uk/government/groups/natural-capital-committee
[44] See http://publications.naturalengland.org.uk/publication/6742480364240896

Recommendation 3

Work to improve and rationalise the legislative and policy framework for environmental resilience.

Overview

This is a long-term recommendation as it is recognised that legislation needs to balance the needs of multiple interests and the evidence base for many aspects of resilience is not sufficient to form the basis for legislative change. However, the water industry and other stakeholders working to improve the natural water environment could collaborate on shared statements emphasising the interconnectedness of the water environment and recommending specific regulation changes to improve resilience. The case studies in the database (Recommendation 1) should also note where legislation has previously been a blocker to resilience as this will provide the evidence base which justifies legislative change.

The currently proposed Environment Bill provides an opportunity to develop a national environmental resilience policy. The Bill sets out targets, plans and policies for improving the natural environment, including the water environment, but still relies on underlying or secondary legislation which may change as a result of Brexit. There will be future opportunities to influence legislation and guidance as laws change following Brexit and in future iterations of the water industry price review process.

Improvements to the legislation and policy instruments affecting resilience should aim to:

- Address the lack of clarity identified in this project around national priorities and incentives regarding resilience.
- Mitigate the potential risks associated with changes in legislation following the Brexit transition period. EU Directives have been a major driving force for the protection and enhancement of environmental resilience in the UK and there is therefore a need for a national policy framework to anchor and drive actions to maintain and enhance resilience over time.
- Complement the Environment Bill by setting out the pathway for the water sector to manage its resilience as it impacts and depends on environmental resilience;
- Tie together the different legislation, regulatory frameworks, policies and incentives that currently exist, and;
- Provide policy incentives for stakeholders to collaborate.

Given the volume and complexity of the legislation and policy affecting the water industry and natural water environment (Section 5), it is recommended that a specific, detailed review of legislation is undertaken as a first stage. This should include a combination of desk-based research and workshops with representatives from the water sector and other sectors including land managers and the housing sector. The review should analyse how the different pieces of legislation impact on each other, on resilience case studies and on environmental and water industry resilience, including direct and indirect links, and should also consider the history of the legislation and the way it seeks to balance competing interests. The review would them identify opportunities and priorities for legislative reform.

Indicative timescale and costs

Medium-term activity (12 – 18 months)

Indicative cost

~ £50,000 - £100,000 for initial review, excluding revisions which would be additional

Recommendation 4

Work with land managers and the housing sector to specify measures to improve environmental resilience

Overview

The water industry and stakeholders working to improve the natural water environment should work with selected stakeholders to identify opportunities to co-design management measures to improve environmental resilience while benefitting both parties. This requires identifying where improving the resilience of the water environment through partnership working can benefit land managers and the housing sector. For example:

- Habitat improvements and river and floodplain hydromorphological improvements could be provided as part of urban regeneration schemes. This could be incorporated into proposals for blue-green corridors, SuDS and natural flood alleviation measures, and may also deliver improvements in river quality and ecological value.
- Management of land to maximise its carbon sequestration potential could assist with meeting the UK's net zero carbon emissions target by 2050. One option is tree planting and a woodland creation project would be additional under the Woodland Carbon Code[45] and could generate verified credits that could be sold to partners within the project or other parties to generate an income stream for the landowner. An alternative income stream could be the Peatland Carbon Code which applies to peatland restoration projects.;[46]
- Delivering other environmental benefits besides carbon sequestration, for example biodiversity or recreational benefits, could increase land value, particularly if land is designated which may restrict alternative land management options. This could include creating priority habitats to generate biodiversity credits through the delivery of biodiversity net gain.
- Parties could enter into Conservation Covenants, assuming that they are brought into effect once the Environment Bill is enacted.[47]

An initial stage of this work would be to identify and prioritise potential locations where partnership working with land managers or the housing sector might be viable, as well as determining appropriate management measures. This would be achieved by:

- Identifying priority stakeholders to approach in terms of specific land managers and organisations in the housing sector;
- Discussing each party's respective goals and objectives when it comes to environmental resilience in order to identify overlaps where partnership working may be viable;
- Identifying locations for partnership projects to take place, either on land currently owned by either party or on land to be acquired; and
- Co-designing management measures to balance the objectives of enhancing the resilience of both parties while enhancing environmental resilience.

Note that successful delivery of this recommendation will require a strong evidence base. The use of results from previous projects, as set out in the case study database, will be vital to secure buy-in to the broader principles of improving resilience.

Indicative timescale and costs

Medium- to long-term activity (18 – 24 months)

Indicative cost

~ £50,000 - £100,000 for development of land management options, excluding implementation and monitoring costs which would be additional

[45] The Woodland Carbon Code is the voluntary standard for UK woodland creation projects where claims are made about the carbon dioxide they sequester. The term additionality is used to mean the carbon sequestration over and above that which would have happened anyway in the absence of a given project or activity. See: https://woodlandcarboncode.org.uk/

[46] See https://www.iucn-uk-peatlandprogramme.org/funding-finance/peatland-code

[47] A conservation covenant is an agreement between a landowner and a body like a charity or public body to do or not do something on their land for a conservation purpose. This might be, for example, an agreement to maintain woodland and allow public access to it, or to refrain from using certain pesticides on native vegetation. These agreements are long lasting and can continue after the landowner has parted with the land, ensuring that its conservation value is protected for the public benefit. See: https://www.lawcom.gov.uk/project/conservation-covenants/

Glossary

Biodiversity net gain: Delivering more or better habitats for biodiversity and demonstrating this measurable gain through use of a biodiversity metric. Development that adopts a biodiversity net gain approach seeks to make its impact on the environment positive, delivering improvements through habitat creation or enhancement after avoiding or mitigating harm (Defra 2019).

Ecosystem services: Ecosystems provide a number of direct and indirect contributions, goods and services to human wellbeing, otherwise known as ecosystem services. Ecosystem services are typically classified into four broad categories: provisioning, regulating, cultural and supporting services.

Environmental net gain: A method to drive measurable improvements for all aspects of the environment such as air quality, flood defences and clean water, particularly alongside development. Collaboration with water companies has been identified as a key step in better understanding how profitable development can drive environmental improvement.

Interdependency: The dependence of two or more systems or elements of systems on each other.

Natural capital: World's stocks of natural assets, which include geology, soil, air, water and all living things.

Natural environment: The air, water, soil and ecosystems that support all forms of life.

Price Review: As the regulator, Ofwat regulates the price, investment and service package that customers receive every five years, known as the price review period.

Resilience: Resilience is understanding how stressors affect and are affected by system dynamics, and subsequently implementing effective measures to facilitate long-term flows of benefits, whilst protecting and enhancing society, the environment and the economy.

Stressors: Relates to any disruption/disturbance/change and is associated with trends and inherent variability. Specific examples could include demographic change, customer behaviour, economic or political disruption, climate and weather etc.

System dynamics: Relates to understanding the relationships between elements of a system and dependencies and interdependencies with other systems. Specifically, for the purposes of this project, the water sector and natural environment.

Risk: For the purposes of this project, risk is defined as follows: Risk = Hazard (Likelihood) x Hazard (Impact)

Social value: Wider financial and non-financial impacts of projects and programmes including the wellbeing of individuals and communities, social capital and the environment.

Sustainability: Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs. Sustainability encompasses three pillars: society, the environment and the economy.

Water sector: The water sector refers to the water industry (i.e. water supply and wastewater companies) in addition to any other sectors that rely on water inclusive of agriculture.

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Appendix A – Online survey questionnaire

This appendix provides supporting information for Section 2. The full online survey questionnaire completed by stakeholders as part of this project is provided below.

UPPER CASE TEXT EXPLAINS THE FORMAT AND ROUTING OF THE SURVEY. IT IS NOT VISIBLE TO RESPONDENTS.

Introduction

This survey has been developed by AECOM on behalf of Wildlife and Countryside Link as part of the Naturally Resilient project and is supported by several environment non-governmental organisations (eNGOs) and water companies. The project aims to: explore the interplay between resilience in the water sector and resilience of the environment, and how investment in one can benefit both.

This primary purpose of this survey is to explore the areas that you think present current and future risks to resilience for the environment and the water sector. The survey builds on an evidence review that we have undertaken.

Specifically, the survey will cover:

1. How you define resilience within your organisation
2. What you think the top risks to resilience for both sectors are
3. Opportunities to manage these risks
4. How you recommend interdependencies between resilience in the water sector and the natural environment are managed
5. The regulatory frameworks and incentives that help improve resilience
6. Blockers to building resilience

The outputs of the survey will be combined with other findings from the project. Please be assured that all your responses are anonymous and confidential and will only be used in aggregate form. It will therefore not be possible to identify any individual from their responses. We also confirm that we adhere to the requirements set out in the **General Data Protection Regulation (2016/679 EU)** (GDPR).

Please complete the survey by 20th September. This survey should take approximately 10 minutes to complete.

If you are a representative of a water company, you will be asked whether you would like to be involved in the next phase of the project where we will develop case studies on how resilience was incorporated into water companies' latest business plans. We hope that you are open to this opportunity to demonstrate best practice as your feedback will be invaluable.

If you have any questions about the survey or the project overall, please do not hesitate to contact me.

Please click the '**Next Page**' button below to start the survey.

Best wishes,

AECOM Project Manager

About You and Your Views on Resilience

Q1. Please provide your name and contact details in the space provided below. These details are only used to track responses to the survey. They will not be used to identify your response in the analysis and reporting.

Your name and role are used to check that you do not complete the survey more than once. Your organisation's name is used to ensure that the survey provides representative coverage of different stakeholders. Your email address would be used if you agree for us to contact you to clarify incomplete responses.

OPEN-ENDED WITH TEXTBOXES

Name	
Role	
Organisation	
Email Address	

Q2. Are you a water company representative?

SINGLE CODE

1 Yes
2 No

Q3. Please select the option below that best reflects the perspective you intend to adopt when completing this survey.

SINGLE CODE

1 For my entire organisation
2 For my team only
3 For me and my projects only
4 Other (PLEASE SPECIFY)

Q4. The following definitions of resilience have been developed as part of the Naturally Resilient project:

Technical definition: Resilience is understanding how stressors affect and are affected by system dynamics, and subsequently implementing effective measures to facilitate long-term flows of benefits, whilst protecting and enhancing society, the environment and the economy.

Non-technical definition: Resilience is the effective protection and enhancement of society, the environment and the economy, based on our understanding of the systems and environments which we all live and operate in.

Do you agree with these definitions?

SINGLE CODE

1 I agree with both definitions
2 I agree with the technical definition only
3 I agree with the non-technical definition only
4 I do not agree with either of these definitions

About You and Your Views on Resilience II

ASK ALL EXCEPT IF CODE 1 IN Q4

Q5. What changes would you recommend to the proposed definition(s)?

OPEN-ENDED WITH TEXTBOX

Current and Future Risks to Resilience I

Q6. We have identified the following potential risks (20) to resilience as part of the project.

Please select your top 5 current risks to resilience. Please remember to think about current risks only as you will be able to consider future risks later in the survey.

MULTI CODE

1 Socio-economic factors such as population growth
2 Climate change
3 Political or regulatory frameworks (current or reformed)
4 Affordability and vulnerability of customers along with changing customer expectations
5 Water company dependency on other sectors (i.e. telecoms and power failures)
6 Security risks e.g. cyber security
7 Water efficiency in households e.g. washing machines, water meters
8 Urbanisation, urban creep and land-use change
9 Digital revolution and over-reliance on technology
10 Ageing infrastructure/asset failure (with associated cost implications) and leakage
11 Water shortage
12 Public health and Infectious diseases (people and animals)
13 Changing labour market and skills shortage
14 Declining environmental water quality (nitrate, phosphorus, metaldehyde)
15 Natural hazards (drought and flood risk) including economic resources to prepare for and address risks
16 Agricultural intensification/damaging fishing practices
17 Biosecurity/pest and disease management (including invasive, non-native species)

18 Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents
19 Unsustainable abstraction, abstraction reform and changing abstraction licences
20 Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)

Current and Future Risks to Resilience II

Q7. For the top 5 current risks that you selected:

[PIPING – INSERT ANSWERS from Q6]

Please tell us what opportunities you think exist to manage these risks.

You can also identify any further risks and suggest opportunities for management of these risks within the text box.

OPEN-ENDED WITH TEXTBOX

Current and Future Risks to Resilience III

Q8. Please select your top 5 future risks to resilience. Please remember to think about future risks only as you already considered current risk earlier in the survey.

MULTI CODE

1 Socio-economic factors such as population growth
2 Climate change
3 Political or regulatory frameworks (current or reformed)
4 Affordability and vulnerability of customers along with changing customer expectations
5 Water company dependency on other sectors (i.e. telecoms and power failures)
6 Security risks e.g. cyber security
7 Water efficiency in households e.g. washing machines, water meters
8 Urbanisation, urban creep and land-use change
9 Digital revolution and over-reliance on technology
10 Ageing infrastructure/asset failure (with associated cost implications) and leakage
11 Water shortage
12 Public health and Infectious diseases (people and animals)
13 Changing labour market and skills shortage
14 Declining environmental water quality (nitrate, phosphorus, metaldehyde)
15 Natural hazards (drought and flood risk) including economic resources to prepare for and address risks
16 Agricultural intensification/damaging fishing practices
17 Biosecurity/pest and disease management (including invasive, non-native species)
18 Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents
19 Unsustainable abstraction, abstraction reform and changing abstraction licences
20 Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)

Current and Future Risks to Resilience IV

Q9. For the top 5 future risks that you selected:

[PIPING – INSERT ANSWERS from Q8]
Please tell us what opportunities you think exist to manage these risks.

You can also identify any further risks and suggest opportunities for management of these risks within the text box.

OPEN-ENDED WITH TEXTBOX

Management of Risks

Q10. Throughout the project to date, we have identified key interdependencies between the water sector and the environment in the following areas:

01Water quality regulation (environment not drinking water)
02Soil quality regulation
03Wild species diversity
04Disease and pest control
05Water supply (including drinking water)
06Global climate regulation
07Hazard regulation
08Recreation

For each of these areas, please state:

09How do you think each of the areas could be better managed?
10Who would manage each of these areas?

Please provide examples from your organisation if relevant.

OPEN-ENDED WITH TEXTBOXES

Water quality regulation (environment not potable)	
Soil quality regulation	
Wild species diversity	
Disease and pest control	
Water supply (including drinking water)	

Global climate regulation	
Hazard regulation	
Recreation	

Q11. What regulatory frameworks (such as the Water Framework Directive) and incentives could encourage resilience in the water sector or environment?

This could include frameworks which (a) have the potential to be strengthened and/or (b) are considered to have significant gaps in promoting resilience across the two sectors.

Please provide examples from your organisation if relevant.

OPEN-ENDED WITH TEXTBOX

Q12. Please identify any 'blockers' (perceived or otherwise) which may affect the two sectors in working together to enhance resilience.

You can also explain why you consider your choices to be blockers within the text box.

MULTI CODE

1 Lack of incentives
2 Insufficient evidence/data of where interventions are required
3 Lack of proven good practice
4 Lack of agreed approaches/frameworks/memorandum of understanding
5 Lack of senior management buy-in/leadership
6 Lack of relationships between sectors
7 Resource availability (financial, personnel)
8 Mis-alignment of stakeholder drivers
9 Other (PLEASE SPECIFY)

OPEN-ENDED WITH TEXTBOX

ADDITIONAL COMMENTS BOX

Case Study Development I

ASK IF CODE 1 IN Q2

Q13. As part of the project we are going to develop case studies to show how resilience was incorporated into water companies' latest business plans.

Would you be interested in working with us to develop a best-practice case study?

SINGLE CODE

1 Yes
2 No

ASK IF CODE 1 in Q13

Case Study Development II

Q14. Thank you for indicating that you would be interested in working with us on a case study.

Please provide further information about the potential case study including whether it links to the interdependencies between the water sector and the environment that we mentioned earlier:

11Water quality regulation (environment not drinking water)
12Soil quality regulation
13Wild species diversity
14Disease and pest control
15Water supply (including drinking water)
16Global climate regulation
17Hazard regulation
18Recreation

OPEN-ENDED WITH TEXTBOX

Any Final Thoughts?

Q15. In the space below, please provide any further information or views that you would like to add in the context of this project.

OPEN-ENDED OPTIONAL QUESTION

Q16. Would you be happy for us to contact you if we have any queries about your responses to the survey?

SINGLE CODE

- Yes
- No

Thank you

That's the end of the survey. Thank you taking the time to complete the survey. Your input to the project is much appreciated.

Appendix B – Case studies

This appendix provides supporting information for Section 2. The case studies developed as part of this project are provided in detail below. These case studies demonstrate examples of collaboration between the water sector and the natural environment with respect to enhancing resilience.

B.1 British Canoeing – invasive species programme

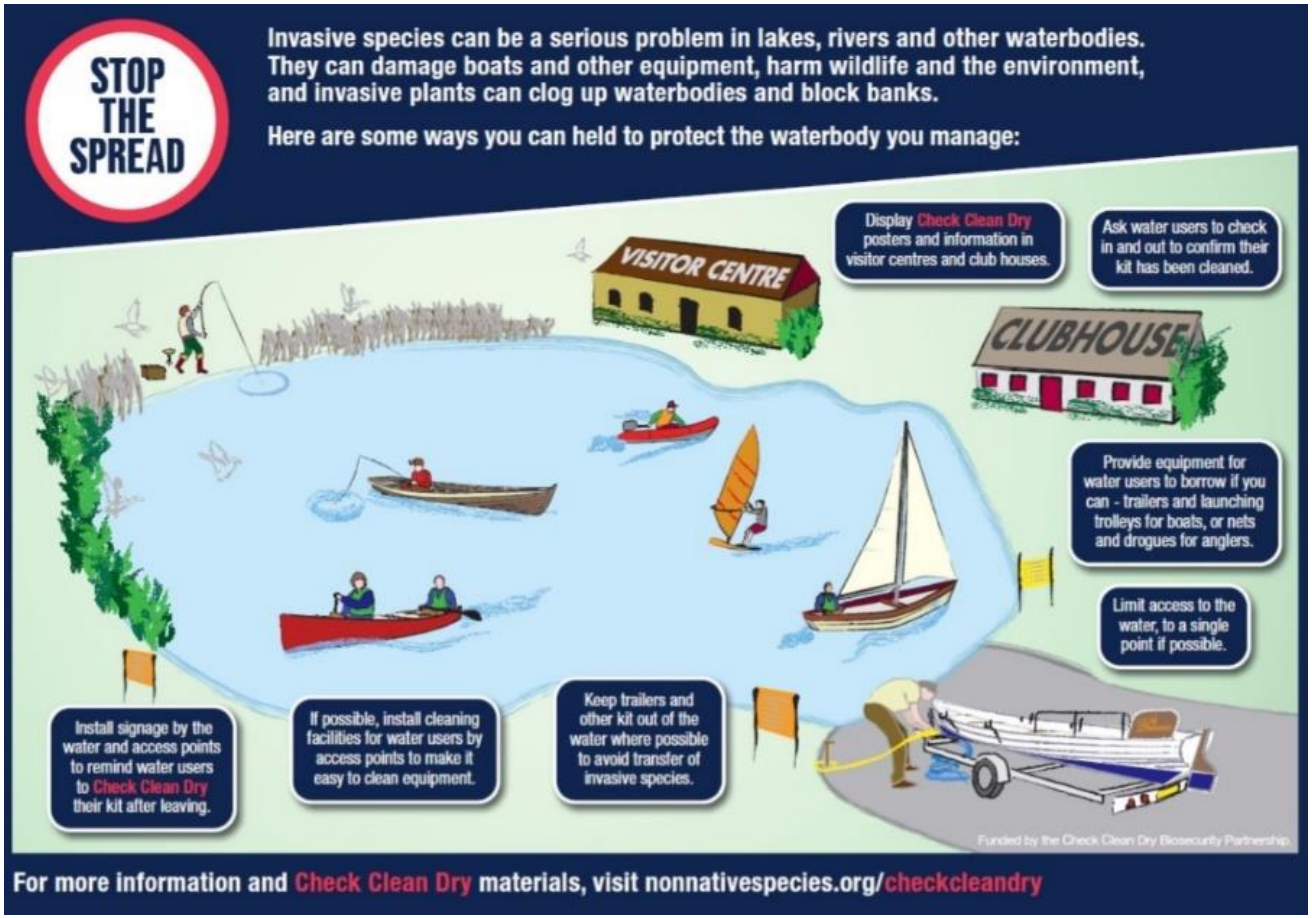
Name of the initiative	British Canoeing – invasive species programme
Organisation	British Canoeing, the national governing body for paddlesports in the UK.
Sector	Third (NGO)
Location	National
Start and finish dates of the initiative	This initiative began a few years ago through the development of partnerships between several organisations (detailed below). The programme is a long-term initiative and work and objective setting is taking place on an on-going basis.
Who were the partners and stakeholders involved in the delivery of this natural resilience initiative?	British Canoeing is working across all different levels including its affiliated canoe clubs, its members and its volunteers. The programme is led by Defra. However, British Canoeing are also working with the following groups and organisations: • Non-Native Species Secretariat • Great Britain Non-Native Species Boating Pathway Action Plan Group • Water companies e.g. Yorkshire Water and South West Water • RiverCare/BeachCare • North Wales Wildlife Trust • Other National Governing Bodies (NGOs), e.g. British Rowing and the Royal Yachting Association • The Angling Trust • Yorkshire Wildlife Trust • Wildlife & Countryside Link • Canal & River Trust • Environmental Audit Committee • Inland Waterways Association
Objective	British Canoeing are actively working to develop a programme of invasive species promotion, education and control. The programme aims to develop more partnerships, secure more volunteers and reach more people, both nationally and internationally.

Were they any regulatory frameworks which drove the initiative?	The paddling community has a vested interest in clean and good quality waterbodies. They are therefore committed to supporting all efforts to keep waters free from invasive non-native species. The main regulatory frameworks driving this programme are: • EU regulation on Invasive Alien Species • EU Water Framework Directive • The Wildlife and Countryside Act 1981
Does the initiative have links/deliver benefits to any of the interdependencies between the water sector and natural environment, as identified in Section 6?	Water quality regulation ☒ Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☒ Water supply (including drinking water) ☐ Global climate regulation ☐ Hazard regulation ☐ Recreation ☒
Approach	British Canoeing launched its Stronger Together strategy in 2017 which provides a clear vision and direction for the sport. One of the 11 key ambitions is to improve access and promote environmental awareness. Specifically, when it comes to invasive non-native species, British Canoeing has committed to widespread promotion of Check, Clean and Dry (CCD) and greater inclusion of environmental awareness in the coaching scheme and performance awards. British Canoeing were given resources and information from Defra to inform their training and education programmes. British Canoeing are currently working to promote and educate the impacts of invasive non-native species as well as being actively involved in the control of certain species such as floating pennywort. To date, the following has been undertaken: • Development of environmental modules within its coaching structure to influence both new paddlers and seasoned paddlers (there are currently 10,000 affiliated coaches) • Dissemination of web-based information, including an e-learning module freely accessible on their website • Numerous news items relating to invasive non-native species • Social media campaigns e.g. Love Water Campaign led by the Environment Agency and supported by water companies • Working with Yorkshire Wildlife Trust to train volunteers, to train others and, disseminate information on invasive non-native species issues • An active member of the Wildlife & Countryside Link campaigning for a national coordinated and cooperative process to address invasive non-native species • Working with the Royal Yachting Association (The Green Blue) on promotional material • Working with the Great Britain Non-Native Species Boating Pathway Action Plan Group to develop a plan to address pathways of introduction or spread of invasive non-native species into and within the UK

	• Addition of permanent Check, Clean and Dry signage placed at all own British Canoeing places to paddle • Installation of a permanent wash down facility on the River Washburn with Yorkshire Water (see Box 1 for more information) • Working with the Canal & River Trust to pilot some local invasive non-native species removal events, which have proved very successful • Highlighting key issues for canoeing to the Environmental Audit Committee Throughout 2018 and 2019, British canoeing targeted its messaging at competitive paddlers at the following domestic competitions: • 2018 Canoe Polo and White-Water events at the National Water Sports Centre (NWSC), where the North Wales Wildlife Trust and British Canoeing Team carried out 'Check, Clean and Dry' on boats involved in the events with around 500 people participating in each event • Five 2019 Sprint Regatta events with between 3,000-4,000 people taking part, with the North Wales Wildlife Trust washing down boats and supplying invasive non-native species information • 2019 National Marathon Championships with 700 people participating over the two-day event, and providing biosecurity guidance and facilities • At all of the above events, British Canoeing clearly informed paddlers to clean their boats prior to attending the event, through guidance sent through the responsible discipline committees More generally, British Canoeing has formed a key partnership with Yorkshire Water to enable around 20-25 paddling events per year to take place on the River Washburn below Thruscross Reservoir in North Yorkshire. Yorkshire Water allow the release of water from the reservoir to ensure sufficient water passes down the river on the day of the event. Paddlers come from all over the country, therefore there were concerns that there may be a risk that paddlers could transfer invasive non-native species to and from the Washburn Valley (e.g. New Zealand Pygmy Weed (Crassula H) is present in Thruscross Reservoir). Between 70 and 200 paddlers enjoy the slalom course at each event, which makes this site one of the most popular paddling venues in England. By the start of 2019, British Canoeing and Yorkshire Water had installed a wash down facility along with an interpretation board informing why and how to Check, Clean and Dry their boats. British Canoeing and Yorkshire Water have attended a number of events to promote and inform paddlers of the risks associated with invasive non-native species as well as demonstrate how to Check, Clean and Dry their boats.
Results	As a result of the work undertaken to date, the canoeing community is already active and engaged on environmental matters, specifically invasive non-native species, which is demonstrated clearly by their readiness to undertake clean-ups on waterways across the country.
Please provide information on the benefits to the water sector	Invasive non-native plant species often clog up waterways, and the resulting removal costs are high for the water sector. Therefore, work by British Canoeing to reduce invasive non-native species and prevent their spread will benefit the water sector in terms of reduced costs of species management and removal.
Please provide information on the benefits to the natural environment	In addition to the invasive non-native species work benefiting local biodiversity and ecosystems, British Canoeing have also developed various environmental modules in their coaching syllabus, with biosecurity being just one aspect. Consequently, paddlers are made aware of lots of different environmental issues and are changing their behaviour to protect species that are at risk.
Were there trade-offs between benefits to the water sector vs. the natural environment?	No trade-offs between the water sector and the natural environment were identified.

Were any blockers experienced?	The following challenges have been experienced during the programme to date: • There is currently a lack of coordination at a national level which means that there is a lack of clarity over the prioritisation of actions and overarching responsibility for the management of invasive non-native species • Initially, there was a lack of easily accessible opportunities for volunteers • Until recently, there was a lack of understanding about the impact of invasive non-native species • There is often a lack of capacity within governing bodies to dedicate resources to invasive non-native species amongst competing priorities • Disputes on access to waterways on private land can make it difficult to get to land to undertake measures without land owner consent
Lessons learnt	• There is a need to develop an overarching strategy to ensure that a joined-up approach is taken across different organisations. Additionally, building partnerships and sharing resources with organisations that have shared interests can allow for greater progress to be made • It is important to develop case studies to show the work that is being undertaken, inspire future work and guide best practice • Input from the government is needed to get the training and resources that is required to support volunteers
Next steps	British canoeing is aiming to increase volunteer numbers and continue working with its affiliated clubs and members to address issues around invasive non-native species. Specially, they are aiming to work with their club development team who are already involved in environmental improvements. British Canoeing is considering whether paddlers can get involved with their initiatives by collecting data on various environmental indicators themselves using mobile applications. This could be particularly useful for the Canal & River Trust who need measures to assess the ecological condition of rivers for the EU Water Framework Directive. Ultimately, British Canoeing would like to have a webpage which maps access points across rivers and provides environmental information on factors that are relevant to paddlers. British Canoeing mentioned the possibility of working with canoe manufacturers and retailers to target paddlers who are not necessarily British Canoeing members. This could allow the programme to have an international impact which is particularly important given the scale of the issue of invasive non-native species. Finally, there are also future plans to work with the National Trust to install biosecurity stations in the Lake District.
Are there opportunities for further work as a result of this natural resilience initiative?	The programme has created motivation amongst an energised and active canoeing community. If opportunities to volunteer and get involved are presented, there is likely to be good support among this group. Future natural resilience initiatives would be able to benefit from a huge pool of volunteers from British Canoeing's affiliated clubs, centres and partnership organisations.
Financial information (including cost-benefit information, if available)	Invasive non-native species have a significant annual cost to the economy and the damage to wildlife is often irreparable. It is estimated that on average invasive non-native species cost the UK economy £1.8 billion per year (House of Commons Environmental Audit Committee, 2019) and water companies in the UK at least £7.5 million per year (Water Companies Steering Group, 2017). Currently, expenditure on biosecurity in Great Britain is £220 million per year, however invasive non-native species only receive £0.9 million per year from that total (House of Commons Environmental Audit Committee, 2019). A key area for British Canoeing to investigate is the measurable and quantitative impact of their work on the management of invasive non-native species as the programme progresses.
Do you have any images to support case study development?	Example posters educating canoeists and kayakers on the Check, Clean, Dry process:

STOP THE SPREAD
Invasive plants and animals harm the environment and other wildlife, block waterways and make paddling difficult. They can be small and hard to spot so are easily spread on damp equipment and clothing.
Protect the environment you love by keeping your kit free of invasive plants and animals.
Don't forget these places
Check boats, equipment and clothing after leaving the water for mud, live animals or plant material. Remove anything you find and leave it at the site, don't put anything down the drain.
Clean everything thoroughly as soon as you can, pay particular attention to areas that are damp and hard to access. Use hot water if you can.
Dry - drain water from every part of your boat and dry with a towel before leaving the site. Dry everything thoroughly for as long as possible before using elsewhere as some invasive plants and animals can live for over two weeks in damp conditions.
CHECK
CLEAN
DRY
Watch out for:
KILLER SHRIMP
QUAGGA MUSSEL
FLOATING PENNYWORT
natural scotland
NNSS
BRITISH CANOEING
RAPID
Find out more about invasive plants and animals and how you can help to stop the spread at:
nonnativespecies.org/checkcleandry


STOP THE SPREAD
Invasive species can be a serious problem in lakes, rivers and other waterbodies. They can damage boats and other equipment, harm wildlife and the environment, and invasive plants can clog up waterbodies and block banks.
Here are some ways you can held to protect the waterbody you manage:
VISITOR CENTRE
CLUBHOUSE
Display Check Clean Dry posters and information in visitor centres and club houses.
Ask water users to check in and out to confirm their kit has been cleaned.
Provide equipment for water users to borrow if you can - trailers and launching trolleys for boats, or nets and drogues for anglers.
Limit access to the water, to a single point if possible.
Install signage by the water and access points to remind water users to Check Clean Dry their kit after leaving.
If possible, install cleaning facilities for water users by access points to make it easy to clean equipment.
Keep trailers and other kit out of the water where possible to avoid transfer of invasive species.
Funded by the Check Clean Dry Biosecurity Partnership.
For more information and Check Clean Dry materials, visit nonnativespecies.org/checkcleandry

B.2 Environment Agency – water abstraction

Name of the initiative	Environment Agency – water abstraction
Organisation	Environment Agency, a non-departmental Government body within England that is responsible for regulating major industry and waste; treatment of contaminated land; water quality and resources; fisheries; inland river, estuary and harbour navigations; conservation and ecology; the management of flood risk from main rivers, reservoirs, estuaries and the sea.
Sector	Public
Location	Cumbria
Start and finish dates of the initiative	Investigations began in 2002. The project commenced in 2011 and was completed in 2015.
Who were the partners and stakeholders involved in the delivery of this natural resilience initiative?	The Environment Agency worked with United Utilities (the water company), as well as local experts, stakeholders, environmental groups and NGOs, for example the local Rivers Trust.
Objective	The Environment Agency's Restoring Sustainable Abstraction (RSA) programme aims to ensure that environmental damage caused by unsustainable abstraction is rectified and/or prevented. This project changed two United Utilities abstraction licences to protect flows in the Rivers Dunsop, Brennand and Whitendale, whilst still providing enough water for United Utilities' customers.
Were they any regulatory frameworks which drove the initiative?	The process was conducted under the detailed regulatory framework for changing abstraction licences, which falls under the Water Resources Act. The following policies also played a key role in driving this project: • The National Environment Programme (NEP) funded by the water company Asset Management Plan (AMP5) • The EU Water Framework Directive • Environment Agency's Restoring Sustainable Abstraction (RSA) programme Finally, the abstraction occurred in the Forest of Bowland Area of Outstanding Natural Beauty (AONB). Therefore, the project was also driven by the statutory requirements of Natural England's AONB designations.
Does the initiative have links/deliver benefits to any of the interdependencies	Water quality regulation ☒

between the water sector and natural environment, as identified in Section 6?	Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☐ Water supply (including drinking water) ☒ Global climate regulation ☐ Hazard regulation ☐ Recreation ☒
Approach	The process to change an abstraction licence involves the Environment Agency firstly identifying the problem based on evidence, and then formulating a proposal to change the licence. With respect to this particular project, United Utilities held two abstraction licences: one surface water licence (from two rivers and a number of tributaries) and one groundwater licence. These licences were held in the Ribble management catchment for over a century. Since the early 1990s, it was evident that these abstractions were leading to adverse effects to the local environment which were closely monitored. Water abstraction resulted in dry river channels and slow and low flows, particularly in the two main rivers, the Brennand and the Whitendale. Additionally, the abstraction had significant impacts of fish and other species. More specifically: • Insects that you would normally expect to find in slow-flowing rivers or ponds were living downstream of these abstraction points, in what should have been be fast-flowing upland rivers at Brennand and Whitendale • Salmon and trout struggled to survive close to abstraction points due to low river flow, although they were surviving in most other parts of the Ribble management catchment Since the licences were found to be damaging a sensitive and important catchment, the Environment Agency invoked Section 52 of the Water Resources Act (1991) to compulsorily change the licence. The Secretary of State upheld the Environment Agency's proposals to change the licence and this was the first case in the RSA programme. The licence was changed to include a hands-off flow condition at the main intakes, stop abstraction from small streams in the local area, and limit abstraction from the underground aquifer at Footholme to times when river flows are healthy. The change also included river works, structural changes, and the re-opening of a spring line.
Results	As a result of the abstraction licence change, the river is closer to its natural state, with river flows equating to around 22 million litres per day in the River Dunsop. The wildlife response has been promising but is currently being studied. Specifically, river-dependent insect communities have been able to recover and fish species, such as salmon and trout have more space to live, move and lay their eggs. The overall ecology of the rivers has improved, contributing to Good Ecological Status under the Water Framework Directive[48].

[48] See https://environment.data.gov.uk/catchment-planning/WaterBody/GB112071065360

	Additionally, the visual appearance and aesthetics of the two rivers improved. This is likely to have encouraged recreational visits to the waterbodies in the catchment area, with approximately 14,000 informal recreational users recorded per year.
Please provide information on the benefits to the water sector	Returning the rivers flow may in turn improve water quality and make the whole catchment more resilient to future changes. The water company benefited reputationally from the change in its abstraction licenses as it was seen as acting in the interest of the wider environment and catchment. Through working in collaboration with other local groups, the water company has also enhanced its relationships and trust with local partners.
Please provide information on the benefits to the natural environment	Improved river flow, biodiversity, aesthetics and recreational benefits.
Were there trade-offs between benefits to the water sector vs. the natural environment?	Prior to the licence change, there was a trade-off between water abstraction and the resilience of the wider environment. The project was considered to be a win-win situation for the environment and the water sector, as United Utilities was still able to deliver water to its users without adversely affecting the catchment. The water company had to implement certain measures in response to the change in abstraction licenses. The Environment Agency incurred upfront capital costs that would be expected to deliver long-term benefits.
Were any blockers experienced?	Overall, the project was considered to be a good example of collaboration between the Environment Agency and the water company, as well as the other local groups involved. The extent of collaboration between different parties took time to be established. Collaboration improved over time as the shared, and common, goal of different parties became more well-defined.
Lessons learnt	Since this was the first compulsory abstraction licence change under this process, there were a number of lessons learnt which were used to inform the process going forward including the process of liaising with Defra: • Due to lag-times in wildlife recovery, monitoring after the change in abstraction licences was found to be key to determining the effectiveness of the intervention • Good engagement with local stakeholders was found to be fundamental to project success • A catchment-based approach was found to be effective when undertaking projects to improve natural resilience
Next steps	Continued monitoring of fish and macroinvertebrate populations (for over ten years). Monitoring is essential to learn how successful changes have been. The studies are costly, time-intensive and rare, however knowing what can be done as water becomes increasingly in demand requires robust data to inform decision-making.
Are there opportunities for further work as a result of this natural resilience initiative?	Since this project, there have been over 400 water abstraction licences that have been changed across England and there are opportunities to successfully continue to change abstraction licenses moving forward.
Financial information (including cost-benefit information, if available)	n/a

Do you have any images to support case study development?	The following picture shows the River Brennand flowing down to one of the main abstraction intakes (prior to the licence change): The following picture shows the dry river bed of the River Brennand, downstream of the abstraction point (prior to the licence change):

B.3 South East Water – PROWATER-Interreg project

Name of the initiative	South East Water – PROWATER-Interreg project

Organisation	South East Water, a water services provider serving customers in the South East of England.
Sector	Private
Location	South East
Start and finish dates of the initiative	The project was approved in 2018, and then formally kicked off in March 2019. There is funding for four years, with the project due to end September 2022.
Who were the partners and stakeholders involved in the delivery of this natural resilience initiative?	This project is a European partnership which is led by the University of Antwerpen, and made up of the following partners from Southern England, Belgium and France, who all feed in and steer the outcomes: • South East Water • South East Rivers Trust • Kent County Council • Westcountry Rivers Trust • Flanders: State of the Art • Natuurpunt • Waterschap Brabantse Delta • Provincie Antwerpen • Pidpa water in Beweging To date the project has also attracted over 25 organisations that are interested in learning about the work, including: • South West Water • Southern Water • Affinity Water • The Rivers Trust • Natural England • Catchment Sensitive Farming • SES Water
Objective	The PROWATER project aims to build resilience within catchments against droughts and extreme rainfall events through landscape-scale change. This project uses ecosystem-based adaptation measures and aims to identify instances where resilience should be maintained or enhanced to improve raw water quality and quantity. The overarching objective of the work is to examine how land use can be changed to help with infiltration and ground water resources. In addition to this, the project will also provide resilience to catchments, help base flows to chalk streams, prevent flooding by slowing down flows, incorporate water quality considerations and work on the ground with farmers. The project aims to also recognise the ecosystem services delivered by priority habitats, for example showing the value of chalk heathland for retention of water resources. Ultimately, the outcomes from this work are intended to help South East Water's catchment management and long-term planning.

Were they any regulatory frameworks which drove the initiative?	South East Water's involvement in the PROWATER project was not driven by specific regulatory frameworks; it was instead driven by a desire for innovation. The idea initially was raised in discussions with an Environmental Scrutiny Group that South East Water is a member of. The project could be relevant in the context of future regulation such as Defra's forthcoming Environmental Land Management scheme. Land management subsidies could influence land use surrounding South East Water land holdings, hence it is important to model these changes and look at their impacts on ecosystem services.
Does the initiative have links/deliver benefits to any of the interdependencies between the water sector and natural environment, as identified in Section 6?	Water quality regulation ☒ Soil quality regulation ☒ Wild species diversity ☒ Disease and pest control ☐ Water supply (including drinking water) ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☐
Approach	The PROWATER includes six different work packages: • Policy: Looking at how the project can influence future policy among the different partners • Spatial Analysis Tool: A tool developed by the University of Antwerp, which is based on spatial data of each of the geographical regions. Changes and interventions for infiltration are colour coded, for example highlighting those areas that are wetter and better for certain measures • Vision: Exploring what the project is trying to achieve and where this work will go in the longer term • Case studies: Funding was provided to do on-the-ground work in three areas in the South East, as detailed below – Case study 1: A complex arable catchment in Kent, which is impacted by low flows and groundwater flooding. The spatial analysis tool is being used to assess where land use can be changed. These changes will then be implemented on the ground, and success will be assessed against the baseline which is currently being monitored – Case study 2: Area of land in Eastbourne owned by South East Water and currently being managed as a forest by the Forestry Commission. Areas of the forest will be opened to create historic chalk grasslands and heathlands. This habitat creation will help ecosystem services and biodiversity and also provide an opportunity to look at the influence that different vegetation has on infiltration – Case study 3: A clay catchment in Medway, Kent where surface water dominates, and infiltration is less common. Different interventions to slow the flow of surface water and prevent flooding will be explored. This case study will also use different types of engagement • Project management

	• Communication: Increasing engagement with a wide range of stakeholders and organisations, communicating key messages around drought to increase resilience
Results	There is limited information available regarding the findings of this project as it is still in the scoping stage. To date, the Spatial Analysis Tool has been developed and is beginning to be used to inform interventions. The outputs and findings from the three case studies are predicted to be available in late 2020.
Please provide information on the benefits to the water sector	The Spatial Analysis Tool developed as part of this project has enabled South East Water to identify how and where they can build more resilience for their water resources. They are able to target actions that slow flood water, preserve groundwater and target specific habitat types that support good groundwater quality.
Please provide information on the benefits to the natural environment	The Spatial Analysis Tool is able to provide support for all of the goals in the Government's 25-Year Environment Plan. For example, the tool can show key areas to recharge aquifers. It can also model land use change and link these changes to ecosystem service provision. The South East of England has particularly high development pressure, therefore the Spatial Analysis Tool's spatially targeted analysis is very relevant for South East Water's purposes.
Were there trade-offs between benefits to the water sector vs. the natural environment?	The key trade-offs relate to the agricultural sector and the housing development sector, as we need to provide food and housing for the country. However, the Spatial Analysis Tool allows the modelling of land use and puts the trade-offs between agriculture, housing development, the natural environment and the water sector into context.
Were any blockers experienced?	• It was challenging to obtain data that was robust, which is why the project included the case study pilots • There was limited scientific and quantitative evidence regarding recharge and infiltration rates • It is not possible to look at all different variables, therefore designing a tool that considers only the key variables and still produces accurate answers without having a complete picture was complex • There were no blockers experienced in terms of stakeholder support, as all parties were able to see how useful the Spatial Analysis Tool would be. Additionally, the tool provides stakeholders with a simple way of explaining complex issues and provides an alternative to biodiversity quantification
Lessons learnt	• Water resources are projected to changes as a result of climatic events, it is therefore important to understand changes in a catchment as a result of climate change. A Spatial Analysis Tool can help to model changes to water resources and help water companies understand what needs to be built into the system to enable climate change adaptation • When everyone involved is working towards one common goal and everyone can see the need for the project, it becomes well accepted and attracts the attention of multiple observers overtime. This can lead to intelligence sharing among organisations and can allow other water companies to recognise the value of the work • Bringing together different sectors including academics, regulators, private companies and NGOs can help to create an appropriate balance between technical research and application • Including partners from different countries can allow for cross-border knowledge transfer
Next steps	The findings from this project will be used strategically by South East Water, by offering opportunities to better understand their catchments and the impacts of climate change and enabling them to develop alternative ways to ensure water supply. South West Water are getting involved in this project, therefore there is a possibility that the Spatial Analysis Tool could be used as planning tool for the Southern region.

Are there opportunities for further work as a result of this natural resilience initiative?	Due to the uncertainty of Brexit, it is unclear whether this work will lead to other similar European opportunities in the future.
Financial information (including cost-benefit information, if available)	There has currently been no cost-benefit assessment undertaken for this project. However, 60% of the project was funded by the EU, with the remaining 40% being funded by all of the project partners (around 10 different organisations). Due to this funding structure, each partner has only contributed a small amount of financial support; however, they have all been able to receive great benefits from the project and will gain a great return from using the outputs in the future.
Do you have any images to support case study development?	Poster on the PROWATER project can be accessed here.

B.4 Southern Water – instream catchment resilience scheme

Name of the initiative	Southern Water – instream catchment resilience scheme
Organisation	Southern Water, a water and wastewater services company serving customers in Hampshire, the Isle of Wight, West Sussex, East Sussex and Kent.
Sector	Private
Location	South
Start and finish dates of the initiative	This initiative is in Southern Water PR19 business plan (AMP7, from 2020 – 2025. Southern Water will be gathering evidence (including monitoring), assessing and designing options in AMP7 to feed into PR24 for their delivery on the ground in AMP8 i.e. from 2025-2030).
Who were the partners and stakeholders involved in the delivery of this natural resilience initiative?	The business plan has been tested with key stakeholders and the initiative has received wide spread support. There are plans and opportunities to work with key partners as this initiative develops, such as Blueprint for Water, the Rivers Trust and the Wildlife Trusts.
Objective	Catchment First is one of five business transformation themes in Southern Water's 'Water for Life' business plan (2020-2025). Catchment First aims to take a more holistic and integrated approach to catchment management and aims to invest in more natural solutions, looking at the wider benefits and value of investments. The Instream Catchment Resilience Scheme aims to explore how future investment in instream catchment resilience measures can maintain resilient water supplies for customers as well as providing wider environmental benefits. It seeks to identify sustainable levels of abstraction.
Were they any regulatory frameworks which drove the initiative?	There were several key business drivers for this initiative, including investing in natural capital and achieving sustainable water resource requirements. Moreover, Southern Water's Water Resource Management Plan (WRMP) aims to deliver water sustainably, while considering climate change and economic pressures. More specifically, this initiative forms part of the Catchment First Initiative within Southern Waters AMP7 Business plan. The main regulatory frameworks that drove this initiative include: • The EU Water Framework Directive • Abstraction polices from the Environment Agency • The 25-Year Environment Plan • Advice from regulators, including the Environment Agency and Ofwat regarding resilience and natural capital
Does the initiative have links/deliver benefits to any of the interdependencies between the water sector	Water quality regulation ☒ Soil quality regulation ☐

and natural environment, as identified in Section 6?	Wild species diversity ☒ Disease and pest control ☐ Water supply (including drinking water) ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☐
Approach	There are four work streams within the Catchment First Initiative, one of which is resilience under which sits the Instream Catchment Resilience Scheme. The scheme has been costed and run through the WRMP (and has been selected as both least-cost and best-value options). It has been demonstrated that investment in environmental resilience should reduce the need for future sustainability reductions. Precautionary assumptions of benefits have been made - 10% of a worst-case scenario of the sustainability reductions that may be experienced in 2027/28 as will be informed by WINEP investigations. The scheme has been linked directly to abstractions within specific catchments where the scheme is proposed (rather than using business-wide figures). As a result, the focus is on the Arun & Rother and the Test & Itchen catchments (the Medway was not selected as cost-effective). The plan for the scheme is to gather relevant evidence during AMP7 to define the types of measures that will be included in the implementation in AMP8. The current focus is on evidence gathering, to form a baseline to identify and cost in-channel interventions. Information that will be collected includes catchment wide geomorphological, hydrological and land use date. Monitoring will be carried out throughout the process to demonstrate and quantify improvements (e.g. water quality sampling and hydro-ecology modelling). If the scheme is found to be successful, then it will be rolled out to other catchments where it is cost effective to do so. The schemes are linked directly to abstractions within specific catchments (rather than using business-wide figures). As a result, Southern Water plan to focus on the Arun & Rother and the Test & Itchen catchments. Note that the Medway catchment was not found to be as cost-effective as the selected catchment. The sites selected align with the sites where Southern Water intend to pilot the development of natural capital accounts. As such, information on investments and benefits will be available for these sites.
Results	Since the scheme is still in the initial stages, the findings and outcomes are still in development. Work will start in AMP7 (from April 2020) to establish a baseline and identify cost-effective measures that can be implemented in the future.
Please provide information on the benefits to the water sector	The scheme is expected to gather evidence to demonstrate that investment in environmental resilience can reduce the need for future sustainability reductions. Once evidence is available to demonstrate that the initiative works, this will allow Southern Water to build a business case and roll out the scheme across more of its catchments where it is cost-effective to do so. The work undertaken as part of the scheme will also be used by regulators, Water Resources South East and key stakeholders, and therefore could inform other water companies' water resources planning in the future.
Please provide information on the benefits to the natural environment	Key benefits to the natural environment are anticipated to be: • Improving the form and function of rivers by making them more resilient to extreme weather events • Improving the physio-chemical state of rivers (flow and water quality) • Enhancing fish populations

	• Improving habitat quality and connectivity • Wider environmental benefits including biodiversity, climate regulation and flood risk attenuation
Were there trade-offs between benefits to the water sector vs. the natural environment?	In the early stages of the schemes, one of the trade-offs that was observed related to the fact that catchment schemes that are beneficial for the natural environment can be hard to justify due to their long duration. In many cases, this is a reflection of the long recovery periods for water resources after initial investments take place.
Were any blockers experienced?	Key challenges for this scheme include: • Having sufficient evidence to quantify benefits and build a business case rather than defaulting to tried and tested engineering focused solutions • Time taken to realise and measure the benefits of natural solutions which occur over relatively long timescales • Political and legal issues associated with delivering schemes on the ground at catchment scale, e.g. land ownership restrictions • Complex stance and position of the scheme within the regulatory framework, in terms of whether it is accepted as a form of mitigation
Lessons learnt	• Starting to try to quantify the benefits of an initiative helps build support and evidence to include it into a company's business plan. This type of scheme is known to be beneficial and it should form part of the water company's solutions toolbox, as evidenced to decision-makers by quantitative estimates of benefits • Channelling the initiative through the WRMP process helped with gathering evidence and momentum as well as placing the scheme on a planning horizon • Seeking feedback from key stakeholders regarding initiatives as early as possible is beneficial and can help inform future work
Next steps	Work will start on monitoring and evidence gathering in AMP7 (from April 2020 onwards). The business case for the delivery of schemes will inform PR24 business planning. Options for collaboration and partnership working with stakeholders will be explored to maximise multiple benefits and achieve effective outcomes. Southern Water plans to work closely with local stakeholders to collate information that is already available in each catchment and to identify gaps and solutions to fill. The work will be co-designed and co-delivered with partners in each of the pilot catchments.
Are there opportunities for further work as a result of this natural resilience initiative?	The outcomes of the Naturally Resilient project will be used to inform the next steps of the Instream Catchment Resilience Scheme. Southern Water's scheme could be used to test approaches in the follow-on phase of the Naturally Resilient project; particularly in terms of evidence needs to inform design and cost-benefit assessments for inclusion in water company business plans in order to satisfy business processes and regulators.
Financial information (including cost-benefit information, if available)	n/a – however, the initiative has been costed and channelled through the WRMP, where it has been selected as one of the least-cost and best-value options.
Do you have any images to support case study development?	n/a

B.5 Thames Water – Walthamstow wetlands project

Name of the initiative	Thames Water – Walthamstow wetlands project
Organisation	Thames Water, a water and wastewater services provider serving customer in large parts of Greater London, Luton, the Thames Valley, Surrey, Gloucestershire, Wiltshire, Kent, and some other areas of the United Kingdom.
Sector	Private
Location	South East
Start and finish dates of the initiative	This project started with a visioning study in 2007/2008 and then following Stage 1 and Stage 2 of funding from the National Heritage Lottery Fund, the site was opened in October 2017. It is an ongoing project, with no end date.
Who were the partners and stakeholders involved in the delivery of this natural resilience initiative?	The original visioning study was conducted in partnership with the Lee Valley Park Authority, the London Wildlife Trust, the Environment Agency, Natural England, the Greater London Authority and the surrounding local councils. Now, the project is a tri-partnership community project between the London Borough of Waltham Forest, the London Wildlife Trust and Thames Water.
Objective	The Walthamstow wetlands deliver important benefits in terms of biodiversity, drinking water (the ten reservoirs serve approximately 3.5 million customers every day), and recreation (angling and bird watching). A balanced approach to consider these different benefits and associated pressures was therefore required. The main aims of the project were to: • Provide free access to green space for the local communities with high levels of socio-economic deprivation and lack of access to nature • Raise awareness among visitors regarding their role in the water cycle, including water efficiency • Engage people with the rich industrial heritage of the area e.g. the on-site Mill which has been historically important for delivering clean water to London
Were they any regulatory frameworks which drove the initiative?	The inspiration for the project was driven by Thames Water's Codes of Practice which was prepared under section 182 of the Water Industry Act 1991. This code of practice underpins everything Thames Water do as a water company. Additionally, the Code of Practice on Conservation, Access and Recreation (CAR) states that Thames Water should open up their sites to the public wherever possible, unless it is unsafe to do so. This was therefore a key driver for the project. A number of regulatory frameworks were factored into the development of the project: • The site is designated as a Special Site of Scientific Interest (SSSI), a Special Protection Area (SPA) and a Ramsar site, therefore it is protected under international, European, and national legislation due to its importance for wildlife • The reservoir sites had to be managed in line with the Reservoirs Act (e.g. no wild flower meadows could be planted on the reservoir banks, as the grass needed to be cut for access to the reservoirs)

	Aside from the regulatory drivers, a clear vision for the project was set out very early on to ensure that the project improved access to nature, while also enhancing wildlife and biodiversity. Therefore, other policies that were not drivers of the project were still included in the delivery of the site as they contributed to the overarching vision. For example, the Water Industry National Environment Programme (WINEP) was included due to the creation of 1.8 ha of reed bed.
Does the initiative have links/deliver benefits to any of the interdependencies between the water sector and natural environment, as identified in Section 6?	Water quality regulation ☒ Soil quality regulation ☐ Wild species diversity ☒ Disease and pest control ☐ Water supply (including drinking water) ☒ Global climate regulation ☒ Hazard regulation ☒ Recreation ☒
Approach	A visioning study was conducted prior to designing the scheme, which looked at all different possibilities for the site. During this study it was found that bird watching, and fishing were already occurring in the area, and there were approximately 12,000 visitors a year. The visioning study explored a wide range of different options for the site, from business-as-usual to floating hotels. After the visioning study, the London Wildlife Trust undertook a community consultation, which included bringing school children and local groups to the site and exploring what they would like to do on the site. Initially, the approach looked to join up with the Upper Lee Valley Landscape Strategy, by exploring how the site could contribute to the longer-term legacy, benefits and effects of the planning, funding, building and staging of the London 2012 Olympics games. The findings from the visioning study and community consultation were developed into a project plan, which was put forward to Waltham Forest council. At this stage the Lee Valley Regional Park took more of a supporting role, helping to steer the wider issues around the site and provide feedback. At this point in time, the London Borough of Waltham Forest is the lead partner alongside Thames Water and the London Wildlife Trust. Several documents were developed for the Heritage Lottery Fund application, including a conservation management plan (for the built and natural heritage), a 25-year Business plan, management and maintenance plan, a vision plan and detailed design plans. These documents were developed with external consultants and architects. Stakeholder engagement was conducted internally within Thames Water (as the owner of the site). Communications with health and safety, insurance, and operations teams were undertaken to ensure that the project's actions would not impact on Thames Water's ability to deliver good quality water to customers. A wider steering group included Natural England, GLA and the Environment Agency. This allowed us to steer the project decisions in a collative manner.

	Once the project received the go ahead, detailed designs were developed and implemented on the ground. During the planning stages, visitors were identified as having the biggest impact on nature, therefore areas were screened to avoid bird disturbance and seasonal gates were fitted to allow certain area of to be closed off during particular seasons or times of high disturbance. A range of surveys were undertaken throughout the development of the site in order to enable monitoring of the site over time.
Results	Since the site opened in October 2017, there have been 750,000 visitors. This outcome exceeded expectations, which estimated around 300,000 visitors by year five of the project. London Wildlife Trust has carried out extensive community engagement on the site, including school groups and volunteering opportunities. Since opening, there have been 148 school sessions for 4,162 pupils, 27 family friendly activity days for 13,000 participants, 11 holiday activity days for children, and 27 under 5 activities for 608 participants. There has also been a number of informal adult learning opportunities including bird walks and tours. The project has been working with the local health board to offer social prescribing on the site. Additionally, artists and residents have been using the site on a range of activities, including yoga and dance sessions for refugees.
Please provide information on the benefits to the water sector	Being able to engage with people through the partners on the site, has given Thames Water an interface with the community. This has resulted in customers having a better understanding of where their water comes from and how they can use water more efficiently.
Please provide information on the benefits to the natural environment	Working with the project partners and on-site volunteers has allowed Thames Water to manage the SSSI on the site appropriately. For example, 1.8 ha of reed bed was planted, and areas were enhanced for water voles. More of these types of actions are planned as the project develops.
Were there trade-offs between benefits to the water sector vs. the natural environment?	The biggest balancing act is between the number of visitors on site, the operational requirements of the site, and the environmental impacts on the site. There has been consistent monitoring on bird species, however no negative impacts have been recorded to date. There are also competing recreational interests on the site, which can cause conflict between user groups. For example, anglers that had been using the site peacefully for many years now share the site with other users.
Were any blockers experienced?	There is an ongoing challenge regarding the viability of the site. When the project was first planned it was going to go to the Walthamstow Wetland Trust and be funded by endowments. However, endowments became less lucrative and there is now an uncertain governance structure which needs to be resolved for the project, as the funding ends next year. In response to this uncertainty, Thames Water is in the process of creating a business plan for the future of the project. There is some uncertainty over how much the site costs to run, given the variety of partners involved, which requires on-going investigation. Maintaining free access to the site by visitors will continue to be a challenge, with respect the financial viability of the project. However, this free access was a key request from all project partners. In addition to this, legal aspects have caused challenges to the project. London Borough of Waltham Forest received the grant from the National Heritage Lottery Fund and lease the building from the partners, Thames Water. It is critical that Thames Water maintain involvement and control over what happens on the site given the site's critical role in delivering water resources.
Lessons learnt	• It is important to raise opportunities and risks during the design phase of a project so they can be addressed accordingly prior to the development and implementation of a project

	• Sites such as the Walthamstow wetlands need to be advertised and signed correctly to prevent incorrect use of the area and unwelcome behaviours. For example, making clear to visitors that the site is a Nature Reserve rather than a park could be achieved through improved advisement and clearer signage within the site • It is important to develop the right partnerships at the beginning of a project • It is beneficial to ensure that the vision is at the core of the project, by always referring back to the vision and checking that it is still accurate for all of the different partners motivations
Next steps	There are multiple opportunities to enhance areas of the site, for example, there is a sustainable urban drainage system (SuDS) which has resulted in only localised flooding on site after heavy rain. Thames Water aims to develop a future business plan and governance model for the site, to take the project into the future and continue to invest and manage the area moving forward.
Are there opportunities for further work as a result of this natural resilience initiative?	Thames Water would like to look at opportunities to open up more of their sites to the public where possible. For example, through open days, guided tours, better access, and working with partners more closely. Future work could explore the public value of Thames Water's sites, to look at the benefits that are delivered about and beyond drinking water. This could include biodiversity net gain and wider socio-economic benefits to surrounding communities (including recreational access and employment).
Financial information (including cost-benefit information, if available)	It is too early on in the project to have any cost-benefit information. The partnership is currently going through the business planning process and exploring the value of the project to the different partners involved. To date, Thames water has invested £1.8 million into project out of its overall cost of £10.3 million.
Do you have any images to support case study development?	Photos of Walthamstow Wetlands:

Visitor map of Walthamstow Wetlands:

Appendix C – Defining resilience: Supporting information

This appendix provides supporting information for Section 4. Table C 1 summarises the definitions of resilience identified from the literature review and Table C 2 provides an overview of the principles of resilience identified from the literature review. Additionally, Table C 3 details metrics that could be used to measure and track resilience in the water sector and the natural environment.

Table C 1: Definitions of resilience from the literature review

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
Ofwat (2015b) Resilience Task and Finish Group - Final Report	The ability to cope with, and recover from, disruption, and anticipate trends and variability in order to maintain services for people and protect the natural environment now and in the future.	It should be noted that the definition was considered customer-centric, considering more than just infrastructure. For the project, this definition was subject to change following interview, survey and workshop feedback. Participants (largely water companies, water regulators and national governments) were broadly happy with the proposed definition. However, some respondents preferred a more infrastructure-centric approach, with some considering the concept of 'recovery' unfavourable as it indicates failure. Consideration of temporal elements was viewed favourably across the sector. Yet, it was considered that there was a need for more clarity, with there being concern about the inclusion of 'trends'. Owing to the method of development of this definition (i.e. the integration of stakeholder feedback), it provides a reasonable reference point for defining resilience for the purposes of this project, with the primary caveat that the natural environment was not the focus of this work.	• Ability • Cope • Recover • Disruption • Anticipate • Trends • Variability • Maintain • Services • People • Protect • Natural Environment • Longevity/Sustainability	Water sector
Cabinet Office (2011) Keeping the country running: Natural hazards and infrastructure	The ability of assets, networks and systems to absorb and adapt to or rapidly recover from a disruptive event.	Resilience is secured though a combination of activities or components.	• Infrastructure (assets, networks and systems) • Disruption • Events • Recovery • Adaptation	Water sector

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
			• Robustness and redundancy	
Welsh Government (2016) Environment (Wales) Act (2016)[49]	The benefits our natural resources provide are wholly reliant on the way that ecosystems function. Ecosystems are considered to be resilient if they are able to cope with disturbance or change so that they maintain their functioning and ability to deliver benefits.		• Benefits • Natural resources • Reliance • Ecosystem function • Disturbance/change • Cope • Maintain function	Environmental sector
Natural Resources Wales (2016) The State of Natural Resources Report (SoNaRR)	The capacity of ecosystems to deal with disturbances, either by resisting them, recovering from them, or adapting to them, whilst retaining their ability to deliver services and benefits now and in the future.	Resilience relates to a broad range of issues, such as climate change, health, agriculture, community development, financial management, and drought and flood risk management.	• Capacity • Disturbance • Resisting • Recovering • Adapting • Retaining ability • Benefits/services • Longevity/sustainability	Environmental sector
Environment Agency/Natural England (2017) Water industry strategic environmental requirements (WISER)	No clear definition provided.	'[Ensuring]… assets and infrastructure are fit for the country's long-term needs is a vital part of ensuring resilience. We need to protect people and the environment and mitigate the potential economic losses that result from a changing climate, flooding and drought. We also need to build resilient natural systems so that we, and the habitats they support, can continue to benefit from the services they provide'.	• Infrastructure (assets) • Longevity/Sustainability • Protect • People • Environment • Economic losses • Changing climate • Flooding • Drought • Natural systems • Habitats • Benefit/Services	Environmental sector

[49] Neither the Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2017 or The Wildlife and Natural Environment Act (Northern Ireland) 2011 reference resilience.

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
Defra (2018c) National Policy Statement for Water Resources Infrastructure	A reduced risk of water supply interruptions or other issues, including those due to drought.		• Reduced risk • Interruptions • Issues (including drought)	Environmental sector
Water UK (2016) Water resources long term planning framework	For the purposes of this report, when 'Drought Resilience' is referred to, it is generally defined as the severity of a drought event that a water company could experience without having to rely on Emergency Drought Orders (EDOs). EDOs therefore represent the 'point of failure' of resilience for the purposes of this analysis.	Because companies plan to different levels of service and drought severity, as agreed with their customers, there is no consistent view of resilience either in terms of the current availability of resources or the future reliability of water resource options, even for neighbouring companies, against which levels of service to customers can be assessed and compared.	• Severity • Drought • Failure • Levels of service • Customers	Water sector
United Nations Environment Programme (2011) UK National Ecosystems Assessment	Ecosystem resilience is defined as the level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs.	Resilience depends on ecological dynamics as well as the organisational and institutional capacity to understand, manage, and respond to these dynamics.	• Disturbance • Threshold • Change in structure or outputs • System dynamics • Management • Response	Environmental sector
National Infrastructure Advisory Council (2016) Water Sector Resilience: Final Report and Recommendations	The ability to reduce the magnitude and/or duration of disruptive events as determined by the 'ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event'.	In the water sector, resilience focuses on minimising water and wastewater service outages and recovering services as soon as possible following a disruption. To do this, utilities need to have the capacity to maintain operations despite challenges to the system, such as stressors, incidents, or disruptions.	• Ability • Reduce magnitude/duration of disruption • Events • Anticipate • Absorb • Adaptation • Rapid • Recovery • Disruption/stressors/incidents • Outages	Water sector
Sustainability First (2016) Long-run resilience in the energy and water sectors: Are '20th century' approaches for securing resilience relevant for the citizens and consumers of the 21st?	Long-run resilience has two elements. Firstly, it is the ability to anticipate trends and variability in the resources and other factors that impact on services and systems. Secondly, it is the ability to withstand problems and maintain services and systems for people and protect the natural environment now and in the future.	From the public interest perspective, resilience may need to move beyond an assessment of long-run physical capacity plus short-run operational capability to also take on board (to some extent at least) wider systems, including environmental and social considerations. There are clearly issues of scale and scope here. However, citizens and consumers are unlikely to view resilience on a basis that is simply bounded by sector. Instead they may be concerned with the total impact that the resilience of different systems	• Longevity/sustainability • Anticipate trends and variability • Resources • Wider variables which impact services and systems • Withstand problems	Water sector

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
		in combination will have on their daily lives and the lives of future generations. Therefore, some of the other wider aspects of resilience, beyond technical reliability, that may also need to be considered could include: -Interdependencies between systems. -Environmental/ecological resilience.	• Maintain services and systems • People • Protection of the natural environment	
Ofwat (2017a) Ofwat final methodology for PR19	Resilience is the ability to cope with, and recover from, disruption and anticipate trends and variability, in order to maintain services for people and protect the natural environment now and in the future. Resilience in the round is about considering all aspects of resilience, including operational, corporate and financial resilience. Resilience is not just about outcomes and expenditure. It means making sure the right people, leadership, infrastructure, systems and processes, are all in place and working effectively. Operational resilience is about reducing the probability of water supply interruptions and wastewater flooding, as well as mitigating the impact of any disruption through efficient handling, good communication and quick recovery. It also means long-term resilience to environmental pressures, demographic change, shifts in customer behaviour, and the impacts of climate change.	Each element of operational, financial and corporate resilience reinforces overall resilience. Companies will not be able to have good operational resilience if they do not have good corporate and financial resilience.	• Ability to cope • Recovery • Disruption • Anticipate trends • Variability • Maintain services • People • Protection of the natural environment • Longevity/sustainability • Operational • Corporate • Financial • Leadership • Infrastructure (systems and processes) • Working effectively • Interruptions • Disruption • Mitigating impacts • Efficient handling • Good communication • Quick recovery • Environmental pressures	Water sector and environmental sector

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
			• Demographic change • Customer behaviour • Climate change	
Thames Water (2016b) Thames Water's Progress in Planning for Climate Change – Climate Change Adaptation Reporting Power	No clear definition provided.	Changes in natural climate variability and weather extremes present risks and opportunities for our water infrastructure, with decisions made now often shaping our long-term capacity to respond to these changes (our 'resilience'). Therefore, Thames Water recognise these changes and are carrying out a range of activities to adapt to the risks.	• Changes/variability • Climate and weather • Risks and opportunities • Longevity/sustainability • Capacity • Adaptation	Environmental sector
Ofwat (2015a) Towards resilience: how we will embed resilience in our work	Resilience is the ability to cope with, and recover from, disruption, and anticipate trends and variability in order to maintain services for people and protect the natural environment, now and in the future.	There are numerous definitions of resilience in the water and wastewater sector. A coherent set of definitions (or definition) for resilience that is accepted by everyone is essential. Checking if companies are resilient when their definitions of resilience vary is difficult.	• Ability to cope • Recovery • Disruption • Anticipate • Trends • Variability • Maintain services • People • Natural environment • Longevity/sustainability	Water sector and environmental sector
HM Government (2013) National Adaptation Programme: Making the country resilient to a changing climate	Resilience describes the ability of a social or ecological system to absorb disturbances while retaining the same basic ways of functioning, and a capacity to adapt to stress and change.		• Systems • Absorb • Disturbances • Retaining functionality • Capacity • Adaptation • Stress • Change	Water sector and environmental sector
Environment Agency (2015) Water Supply and Resilience and Infrastructure	Resilience is the capacity to maintain essential services under a range of circumstances from normal to extreme. It is achieved through the ability of assets, networks, systems and management to anticipate, absorb and recover from disturbance, whilst ensuring the environment		• Capacity • Maintain • Services • Scenarios	Water sector

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
	and ecosystems support that and can also recover to their original state. It requires adaptive capacity in respect of current and future risks and uncertainties as well as experience to date.		• Infrastructure (assets, networks, systems) • Management • Anticipate • Absorb • Recover • Disturbance • Environment • Ecosystems • Original state • Adaptation • Risks • Longevity/sustainability	
AECOM (2016) Strategic Water Infrastructure and Resilience - Project Summary Report	The ability of the environment, economy and society across England to withstand and recover from water supply shortages, with a focus on shortages caused by drought events that are more severe than those currently planned for. Where: - 'more severe' is with respect to drought event magnitude, duration and frequency, leading to failure of the water supply system (standpipes and rota cuts for public water supply and substantial reductions in available abstraction for non-public water supply including spray irrigation); - 'withstand' and 'recover' refers primarily to the mitigation of unacceptable impacts on the environment, society and economy by (a) implementing strategic options such as new infrastructure and (b) improving the response and recovery measures within strategic plans as the risks and uncertainties in the environment are better understood; and, - 'Across England' refers to a national, regional and city scale.		• Ability to withstand • Environment Economy • Society • Recover • Water supply shortages • Drought	Water sector

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
ClimateXChange (2016) Indicators and Trends - Is Scotland's natural environment resilient to climate change?[50]	Resilience definition not expressly stated. Scottish Natural Heritage's definition is used: 'A property which allows an ecosystem to maintain its characteristics under the impacts of novel processes and shocks'.	The document identifies that the resilience of the terrestrial environment is closely linked to the natural environment. The pressures faced by Scotland's native woodlands (i.e. non-native tree planting, habitat fragmentation, invasive non-native plants and animals, plant pests and diseases, deer browsing and atmospheric pollution) are discussed, with the document stating that pressures may impair the ability of habitats and the species they support to withstand the impacts of climate change. To build resilience, the document suggests that it will be important to manage the pressures which we can influence.	• Pressures • Impair ability • Withstand impacts • Management pressures • Influence	Environmental sector
Scottish Natural Heritage (2016) Climate Change and Nature in Scotland	Resilience definition not expressly stated. The IPCC's (2007) definition is used: 'Resilience is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change'.		• Ability • Social or ecological system • Absorb • Disturbances • Retain same basic structure • Functioning • Capacity • Self-organisation • Capacity • Adapt • Stress • Change	Environmental sector
Department for Regional Development NI (2016) Sustainable Water A Long-Term Water Strategy for Northern Ireland (2015 – 2040)[51]	The document states that: 'Resilient development is about building homes and industrial developments that are capable of withstanding extreme rainfall events with minimal or no flood damage.' Similarly: 'Flood resistance and resilience is about putting structural measures such as flood barriers, and non-structural measures such as flood warning		• Capable • Withstanding • Extreme • Events • Damage • Resistance • Resilience • Impact	Water sector and environmental sector

[50] It should be noted that other Scottish policy documents were reviewed (such as the CLIMATE READY SCOTLAND: Scottish Climate Change Adaptation Programme 2019-2024 A Consultation Draft (February 2019), however specific definitions of resilience were not provided.
[51] It should be noted that other policy documents from Northern Ireland were reviewed (such as the Department from Environment Northern Ireland (2014) Climate Change Adaptation Programme) however specific definitions of resilience were not provided.

Source	Definition of resilience	Additional information	Themes/key words	Relevant sector(s) (water or environment)
	systems, in place to help reduce the impact of flooding when it occurs'.			

Table C 2: Overview of principles of resilience from literature review

Source	Resilience principles	Supporting information
Cabinet Office (2011) Keeping the country running: natural hazards and infrastructure	Infrastructure resilience is considered to comprise of the following four components: **Resistance** **Reliability** **Redundancy** **Response and Recovery** The World Economic Forum's work built on this work and considers the key components to be: **Redundancy** **Robustness** **Resourcefulness** **Response** **Recovery**	The Cabinet Office states that interventions to build resilience should contain the component(s) most appropriate to the issue being addressed. If applied to assets within water companies it would help towards assessing the current state of the infrastructure aspect of resilience. The **Resistance** element of resilience is focused on providing protection. The **Reliability** component is concerned with ensuring that the infrastructure components are inherently designed to operate under a range of conditions and hence mitigate damage or loss from an event. The **Redundancy** element is concerned with the design and capacity of the network or system. The **Response and Recovery** element aims to enable a fast and effective response to and recovery from disruptive events.
Welsh Government (2016) Environment (Wales) Act (2016)	The Environment (Wales) Act takes a pragmatic approach and brings in the idea of building resilience. This recognises five attributes (sometimes termed 'aspects') as building blocks of resilience which can be summarised as: **Diversity** **Extent** **Condition** **Connectivity** **Adaptability** A detailed breakdown of 'aspects' is provided within SoNaRR (see below).	
Natural Resources Wales (2016) The State of Natural Resources Report (SoNaRR)	Attributes of ecosystem resilience: **Diversity** **Extent** **Condition** **Connectivity**	Further information is provided in Chapter 4 of SoNaRR.
Defra (2018) The key principles outlined in Defra's 25 Year	Using the natural capital framework set out by the Natural Capital Committee, DEFRA has framed their goals for environmental improvement	The report refers to specific types of resilience, frequently referring to resilience in terms of 'flood resilience', and 'property resilience', and touches upon 'soil condition

Source	Resilience principles	Supporting information
Environment Plan ('Clean and Plentiful Water & 'Thriving Plants and Wildlife')	over the next 25 years around six primary goods and benefits offered by a healthy environment. Two of these are centred around resilience, including: 3) Thriving plants and wildlife: We will achieve a growing and resilient network of land, water and sea that is richer in plants and wildlife. 10) Enhancing biosecurity: We will enhance biosecurity to protect our wildlife and livestock, and boost the resilience of plants and trees. The Plan states that clean and plentiful water will be achieved by: Improving at least three quarters of our waters to be close to their natural state as soon as is practicable by: • Reducing the damaging abstraction of water from rivers and groundwater, ensuring that by 2021, the proportion of water bodies with enough water to support environmental standards increases from 82% to 90% for surface water bodies and from 72% to 77% for groundwater bodies. • Reaching or exceeding objectives for rivers, lakes, coastal and ground waters that are specially protected, whether for biodiversity or drinking water as per our River Basin Management Plans. • Supporting Ofwat's ambitions on leakage, minimising the amount of water lost through leakage year on year, with water companies expected to reduce leakage by at least an average of 15% by 2025. • Minimising by 2030 the harmful bacteria in our designated bathing waters and continuing to improve the cleanliness of our waters. We will make sure that potential bathers are warned of any short-term pollution risks.	and resilience'.
Ofwat (2017a) Ofwat final methodology for PR19	The methodology follows the Cabinet Office's '4R's Approach': **Resistance**: preventing damage or disruption by providing the strength or protection to resist the hazard or its primary impact. **Reliability**: ensuring that the infrastructure components are inherently designed to operate under a range of conditions, and hence mitigate damage or loss from an event. **Redundancy:** this is concerned with the design and capacity of the network or system. The availability of backup installations or spare capacity will enable operations to be switched or diverted to alternative parts of the network in the event of disruptions to ensure continuity of services. **Response and recovery:** enabling a fast and effective response to, and recovery from, disruptive events. The effectiveness of this element is determined by the thoroughness of efforts to plan, prepare and exercise in advance of events. The report also establishes 7 resilience planning principles:	Components of resilience need to be considered across all aspects of an organisation. This means having the right skills, the right leadership and the right systems, as well as having a robust infrastructure. We term this 'resilience in the round'. It includes, but is not limited to, the following: **Operational resilience** - the ability of an organisation's infrastructure, and the skills to run that infrastructure, to avoid, cope with and recover from disruption in its performance; **Financial resilience** - the extent to which an organisation's financial arrangements enable it to avoid, cope with and recover from disruption; and, **Corporate resilience** - the ability of an organisation's governance, accountability and assurance processes to help avoid, cope with and recover from disruption and to anticipate trends and variability in all aspects of risk to delivery of services. Specifically, for Principle 2, a naturally resilient water sector, the following information is provided:

Source	Resilience principles	Supporting information
	Principle 1: Considering resilience in the round for the long term Principle 2: **A naturally resilient water sector** Resilient ecosystems and biodiversity underpin many of the key services provided by water companies. Promoting ecosystem resilience and biodiversity is a key part of the decision-making process for ensuring resilient services (where this is consistent with a company's role as providers of water and wastewater services). Principle 3: Customer engagement Principle 4: Broad consideration of intervention options Principle 5: Delivering best value solutions for customers Principle 6: Outcomes and customer-focused approach Principle 7: Board assurance and sign-off	In line with Principle 2, the environment underpins so much of the services water companies deliver. The 'water industry strategic environmental requirements' (WISER) from the Environment Agency and Natural England, and the PR19 'expectations and obligations' from Natural Resources Wales provide a framework for protecting and enhancing the environment. Companies will need to deliver environmental schemes where they have a legal duty to do so. And where, consistent with the company's role as providers of water and wastewater services, it is the best value way of delivering an outcome in line with customers' preferences and priorities and is affordable. Taking account of the impact on ecosystem resilience and biodiversity will be particularly important where a company's operations depend on ecosystems and the natural environment, for example, abstraction, treatment and discharges. Companies should also have regard to the wider costs and benefits of the resilience of their services to the economy and society. The natural capital approach provides an opportunity for the value of ecosystems to be better incorporated within the evaluation of resilience and, where appropriate, could be incorporated into the assessment of the impact of company activities.
Ofwat (2015a) Towards resilience: how we will embed resilience in our work	**Ofwat's Resilience Principals:** Principle 1 – a clear understanding of risk to services Principle 2 – action based on analysis of the risks Principle 3 – service providers ensuring resilience Principle 4 – customer views at the heart Principle 5 – resilience at the heart of the business Principle 6 – resilience as efficiency Principle 7 – partnership Principle 8 – the sector reporting transparently on its progress Principle 9 – a whole-life, 'total costs' approach Principle 10 – approaches delivering multiple benefits	The resilience objective is: (a) to secure the long-term resilience of water undertakers' supply systems and sewerage undertakers' sewerage systems as regards environmental pressures, population growth and changes in consumer behaviour, and (b) to secure that undertakers take steps for the purpose of enabling them to meet, in the long term, the need for the supply of water and the provision of sewerage services to consumers, including by promoting: (i) appropriate long-term planning and investment by relevant undertakers, and (ii) the taking by them of a range of measures to manage water resources in sustainable ways, and to increase efficiency in the use of water and reduce demand for water so as to reduce pressure on water resources.

Table C 3: Potential metrics to measure and track resilience in the water sector and the natural environment

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
Natural Resources Wales (2016) The State of Natural Resources Report (SoNaRR)	Broad factors operating across ecosystems: UK indicators for species abundance and distribution of priority species and other measures of diversity Extent of habitats Healthy ecosystems (inclusive of habitat condition and connectivity)				✔	✔

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
	Broad habitat and land-use summaries: Habitats Directive Article 17 for habitats and species. For example, for 'habitats' consideration of the following would be given: Range Area Structures and Function (condition and habitat pressures) Future prospects (including threats) For species, the following consideration would be required: Range Population Habitats for species Future prospects Water Framework Directive Objectives and Measures Glastir Monitoring and Evaluation Programme, metrics associated with: Biodiversity Climate change mitigation Freshwater Landscape and access Soil Woodland Natural Capital Committee Methodologies (i.e. natural capital accounting methodologies, using ecosystem services as 'units' for measurement) Prioritised Action Framework for Natura 2000 Sites SSSI monitoring and reporting Woodlands for Wales Indicators (23 indicators) Local and specific interest assessments: Methodologies published by the Resilience Alliance such as Toolkit for the Indicators of Resilience in Socio-ecological Production Landscapes and Seascapes (SEPLS) Resilience framework for resilience and tree health, based upon: Extent, condition, connectivity and diversity					

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
Wildlife and Countryside Link (2017) Blueprint for Water – Blueprint for PR19	Broad success measures listed in the main Blueprint for PR19 report included: Hectares of land in better stewardship and km of river length improved due to water company actions Percentage of drinking water safeguard zones where improvements in water quality are being seen Percentage of catchments with a long-term strategic wastewater plan Percentage sewerage capacity incorporating SuDS Total number of pollution incidents in each category each year, and a trend to zero pollution incidents. Percentage pollution incidents, where the company has a role, that are self-reported Per capita consumption in litres/household/day – dry year annual average / peak day multiple. Leakage per km of network (Ml/d/km) Proportion of metered/smart metered households (percentage of total households). Total water volume put into distribution (Ml/d) Percentage of the households eligible for social tariff that actually receive one. Percentage of households on a tariff or financial incentive scheme that rewards water saving Percentage of total abstraction from groundwater sources that are in poor quantitative status Percentage of total abstraction that is from surface water sources in water bodies where recent actual flows are below the Environmental Flow Indicator at high flows	Further information is found in the following documents: Blueprint for PR19 Environment Assessment Scorecard Scorecard Qualitative Analysis Details (Methodology for Qualitative Assessment of Business Plans)		Constraints of the Environmental assessment Scorecard included: Only material in the formal business plan and its summary or material specifically referenced from it was considered. Commitment strength and type was not considered in the assessment.	✔	✔
Ofwat (2017b) Resilience in the Round	The Asian Water Development Outlook (AWDO), developed by the Asian Development Bank, provides one of the first national and international sets of resilience metrics – the National Water Security Index. Incorporating eastern Asia and Australasia, the methodology compares and rates different aspects of water resilience, using common metrics, across countries. The index considers elements such as Social Capital and Adaptability, which may be more relevant to the UK.	Some forward-looking metrics will need to work in combination with more traditional, backward looking, performance metrics, such as mains burst frequency or interruptions to supply, to inform operational and corporate planning. Changes in the availability of skills and capacity in the labour market present potential	Forward looking metrics can be applied consistently and can be meaningful for customers.		✔	✔

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
	The Water and Wastewater Resilience Action Group (WWRAG) established a Task and Finish team on resilience metrics in late 2016. This cross-sector team developed a set of initial resilience metrics across water supply, wastewater, asset health and the environment. The key criteria used was to develop metrics which were forward looking, could be applied consistently and would be meaningful for customers.	resilience issues for water companies, supply chain and other partners. Energy & Utility Skills are now publishing a dashboard of key labour market metrics to help keep companies informed about trends in the labour market, so they can plan and manage appropriately. Hazards and pressures associated with these metrics include: • Drought • Water supply • Wastewater • Asset health • Environment				
HM Government (2016) National Flood Resilience Review	Extreme Flood Outlines test the resilience of key local infrastructure assets (such as energy, water, health, transport and telecommunications). To ensure that decisions about investment in flood defences are taken based on the best possible evidence, the following techniques are used: Mapping of Extreme Flood Outlines to test the resilience of Core Cities and other communities. Monitoring of improvements in resilience and the implementation of the temporary improvement plans for key local infrastructure.	Local detailed flood modelling (rivers and sea) can be used to support the design of resistant and resilience measures. Hazards and pressures associated with these metrics include flooding.			×	×
National Infrastructure Commission (2018) Preparing for a drier future: England's water infrastructure needs	An appropriate level of resilience is assessed by comparing the costs of proactive long-term resilience improvements, such as tackling leakage or providing new supply infrastructure, with the cost of these emergency responses (factored by the likelihood of them being needed in the period up to 2050) to maintain water supplies during a drought. The starting point is to assess the additional capacity that the system needs.	Hazards and pressures associated with these metrics include drought.			×	×
Defra (2016) Creating a great place for living:		Water UK is working to establish a Water and Wastewater Resilience Action Group to promote and enhance the				

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
Enabling resilience in the water sector		sector's resilience, and to develop a sector-wide strategic dashboard which should enable us and others to compare levels of resilience, now and in the future.				
UK NEA (2014) UK Natural Ecosystems Assessment	Mapping the relationships between ecosystem services and major sectors of the economy, such as agriculture or food manufacture, can help understand the economic impacts arising from any changes in our ecosystem services. The UK NEAFO has developed a Natural Capital Asset Check (NCAC) to help this process. It can be used to consider thresholds, trade-offs and the performance and resilience of ecosystems. It can be used to gain further insights into the properties of different ecosystem services and contribute to our understanding of how best to manage the natural world for the long-term benefit of society. The UK NEAFO uses existing classifications of ecosystems to assess our natural capital. These assessments assist decision-making as they consider thresholds, trade-offs and the long-term performance and resilience of our ecosystems. The Balance Sheet approach is both a process and a tool which addresses the complexity of real-world decision-making and trade-offs. It captures economic, ecological and social/deliberative perspectives in trade-off assessments. This not only incorporates efficiency, but also considers the distribution of gains and losses, resilience and carrying capacity aspects of sustainable management.		The trade-off assessments in the Natural Capital Asset Check process captures economic, ecological and social/deliberative perspectives.		✔	✔
Sustainability First (2016) Long-run resilience in the energy and water sectors: Are '20th century' approaches for securing resilience relevant for the citizens and consumers of the 21st?	In the water sector, there are currently no equivalent national metrics, although in the last price review every water company set clear targets for supply interruptions, and the water and sewerage companies set targets for the number of properties to be impacted by sewer flooding (as a proxy for wastewater resilience). Some companies publish their own internal measures, but these are not necessarily comparable with those of other providers. For	Water UK is currently working on a sector strategic dashboard which could help create a wider group of resilience measures. At a workshop for the International Centre for Infrastructure Futures and iBuild, it was noted that measurements of outcomes '…rely on the interactions of assets and		Metrics are just one of the tools that companies can use to secure resilience. Company culture and ethos also have an impact. The complexity of measuring resilience is likely to lead to a nuanced collection of metrics which can inform judgement rather than a single number.	×	×

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
	example, Anglian Water's business plan for PR14 contains some useful metrics by which they and their customers can assess their resilience (e.g. number of people supplied by a single water treatment works, number of pressure-managed controlled networks, number of free water audits etc). Customer satisfaction and value for money measures are used to track performance. Although these pick up some aspects of resilience, particularly in terms of short-term performance, on their own they may only give limited insight into some long-term resilience issues (particularly in terms of systems).	services from multiple infrastructure sectors. It is therefore no longer sufficient to monitor performance solely on an infrastructure by infrastructure basis.' Identifying the scope of the metrics used and the interdependencies between indicators is important. For example, it may be necessary to sometimes look at water and wastewater measures together to get the full resilience picture. Hazards and pressures associated with these metrics include water supply.		Some of the most revealing metrics may be qualitative, including views about customer service, rather than quantitative. Although metrics may be one helpful aid to resilience discussions, both inside and outside companies, getting these 'right' is unlikely to be an easy or a one-off process. An iterative approach is likely to be needed to respond to changed circumstances and to avoid unintended consequences.		
Ofwat (2017a) Delivering Water 2020: Our final methodology for the 2019 price review	Two of the common performance commitments focus on forward-looking resilience: the risk of severe water supply restrictions in a (1-in-200 year) drought; and the percentage of the population at risk of sewer flooding in a severe (1-in-50 year) storm.	Hazards and pressures associated with these metrics include water supply.	The two new resilience metrics, alongside the existing ones, enable customers and other stakeholders to better understand the resilience of the water and wastewater services provided by their water companies.	Requiring companies to have financial Outcome Delivery Incentives (ODIs) related to the two forward-looking resilience metrics are at relatively early stages of development and so lack historical and comparative performance data. Therefore, caution should be applied if relating financial ODIs to the metrics. Companies should only propose financial ODIs related to these metrics if they reflect the resilience challenges facing them, are supported by evidence and by their customers and do not involve ODI outperformance payments that overlap with funding received through cost allowances.	×	✔
Ofwat (2019) PR19 Initial Assessment of Plans: Summary	Yorkshire Water's systems-based approach to resilience incorporates:	Bespoke resilience performance commitments do not generally reflect companies' approaches to resilience or their asset			✔	✔

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
of Test Area Assessment	Clear mapping of interactions between the company's external and internal systems (within and outside of the company's control); and A comprehensive decision-making framework that embeds natural capital accounting. United Utilities uses qualitative and quantitative approaches to assess a wide range of risks associated with operational, financial and corporate resilience issues. The company also uses these approaches to develop options that include collaborating with third parties and promoting solutions that take advantage of, and work with, natural processes. South West Water also provides high-quality evidence of collaboration with stakeholders to develop efficient options and integrated systems around resilience. One example is its collaboration within the multi-stakeholder SIM4NEXUS research project to improve its understanding of the inter-relationships and interdependencies of water, energy and land management in the South West of England.	management strategies. For example, bespoke resilience performance commitments (such as, the percentage of population supplied by single supply system) could be used to complement common asset health commitments (which relate to asset reliability). This would mean that redundancy (for example, alternative sources of supply), resistance, and response and recovery mitigations could also be supported and monitored by performance commitments as part of companies' resilience strategies. But bespoke resilience performance commitments are rarely used in this way. Hazards and pressures associated with these metrics include water supply.				
Thames Water (2016a) Climate change adaptation reporting second round	In 2013, a gap analysis of Thames Water planning processes and level of preparedness was undertaken, against the Ofwat nine principles of resilience. This had a specific focus on four undesirable outcomes: Prolonged water supply interruption Contamination of water supply Third party damage (leading to, for example, a major sewer flooding incident) Major environmental pollution incidents Indicative metrics for assessing resilience to climate change and other hazards: Additional capacity protected from flooding (water) Additional population protected from flooding (waste) Improvement in security of supply index Net reduction in grid energy use per year	Resilience for each of the nine principles was assessed on a scale of 0 (principles not addressed) to 1 (principles fully addressed). The analysis suggested that good progress towards addressing climate resilience issues.			✔	✔

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?
	Area of impermeable paving removed					
South East Water (2015) Climate change adaptation reporting second round: South East Water	During the severe winter storms of 2013, South East Water were able to quantify and validate the level of resilience and adaptive capacity that their current infrastructure provided under a series of intense rainfall events and prolonged wet weather that was comparable with a 1 in 200-year level of severity. This has led to a better understanding of surface water and groundwater flooding in close proximity to assets and quantification of potential water quality issues that were built into future plans.	Hazards and pressures associated with these metrics include: Rainfall.	Since these events, South East Water's relationship with their energy suppliers has developed and a greater level of resilience has been built into emergency plans (e.g. identification of key strategic sites).		×	×

Ofwat (2015a) Towards resilience: how we will embed resilience in our work	A range of specific measures were suggested, including:
	• National Adaptation Programme indicators developed by the Adaptation Sub-Committee, relating to;
	  ○ Built environment;
	  ○ Infrastructure;
	  ○ Healthy and resilient communities;
	  ○ Agriculture and forestry;
	  ○ Natural environment;
	  ○ Business
	• Companies' performance commitments and outcome delivery incentives;
	• Company risk registers;
	• Stress testing; and
	• An independent review of the sector's resilience that could be updated periodically.
					✔	✔

AECOM (2016) Strategic Water Infrastructure and Resilience	The key metric of resilience for this project is the value of social, environmental and economic impacts that occur during water supply shortages (when normal water supply and environmental demand for water cannot be met).	These impacts can be mitigated by the implementation of strategic options that can help England 'withstand' and 'recover' from severe and extreme drought events. Therefore, an important sub-metric is water availability in terms of the magnitude and duration of water supply shortages that might occur under severe and extreme drought in England.			×	✔

Source	Metrics used	Supporting Information (including information on associated hazards and pressures)	Benefits	Limitations	Cross-cutting?	Recommended for use?

South East Water (2018) Environmental Resilience – PR19 Supporting Appendix 10	As part of South East Water's SWOT analysis, a number of objectives were identified which could be considered for the basis of metric development:
	• Building resilience into surface water catchments
	• Building resilience into groundwater catchments
	• Natural capital accounting, ensuring nature is valued in decision making
	• Ensuring abstractions are sustainable
	• Leakage and PCC reduction
	• Carbon accounting – Carbon accounting workbook, management by UKWIR
	  ○ Allocation of primary energy source
	  ○ Offset of carbon through landownership
	  ○ Embedded carbon
	• Protecting water quality
	• Educate current and future customers about water
	• Tackle demand for water
	• Tackle the level of greenhouse gases emitted
	• Protect wildlife and biodiversity
	• Protect heritage
	• Manage the risk of invasive, non-native species
			Reflects high level pressures faced across the water sector as a function of operating within, and depending upon, the natural environment.	Not strictly metrics, would require quantitative data to be collated.	✔	✔

Appendix D – Key stakeholders: Supporting information

This appendix provides supporting information for Section 6. Table D 1 provides detailed information regarding the key stakeholders with responsibilities for enhancing resilience.

Table D 1: Key stakeholders with responsibilities to enhance resilience

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
Amphibian & Reptile Conservation Trust[52]	ARC conserves amphibians and reptiles, and the habitats they depend on, to protect them for future generations. Several secondary benefits (climate change mitigation; contribution to health and wellbeing; maintaining the potential for scientific and medical knowledge; enhancing education and employment; and, amenity and recreational value) are also delivered.	• Managing catchments and land	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Angling Trust[53]	The Angling Trust lobbies governments, campaigns on environment and angling issues, fighting pollution, commercial over-fishing at sea, over-abstraction, poaching, unlawful navigation, local bans and broader threats to angling.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
British Canoeing[54]	British Canoeing is the national governing body for paddle sports in the UK. Protection of the environment is of paramount importance to British Canoeing, with works focused on invasive, non-native species, pollution etc.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?

[52] Organisational Website: https://www.arc-trust.org/benefits-of-our-work
[53] Organisational Website: https://www.anglingtrust.net/page.asp?section=30&sectionTitle=About+the+Angling+Trust
[54] Organisational Website: https://www.britishcanoeing.org.uk/about

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
			• Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
British Land[55]	The British Land Company is a property development and investment company in the United Kingdom. The firm became a real estate investment trust when REITs were introduced in January 2007.	• Managing catchments and land • Managing housing developments	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050?
Business in the Community[56]	Business in the Community aims to: create a skilled, inclusive workforce today and for the future; build thriving communities in which to live and work; and, innovate to repair and sustain the planet.	• Managing technological change	• Big Question 11: Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Canal and River Trust[57]	The Canal and River Trust manages a 2000-mile long 'green-blue ribbon' that connects hundreds of wildlife habitats and protects cultural heritage, thereby providing significant cultural ecosystem services. The Canal and River Trust also invests in the social value of local communities.	• Managing catchments and land • Partnership working	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Catchment Partnerships[58]	The Catchment Based Approach (CaBA) is an inclusive, civil society-led initiative that works in partnership with Government, local authorities, water companies, businesses and more, to maximise the natural value of the environment.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?

[55] Organisational Website: https://www.britishland.com/
[56] Organisational Website: https://www.bitc.org.uk/about-us
[57] Organisational Website: https://canalrivertrust.org.uk/
[58] Organisational Website: https://catchmentbasedapproach.org/about/

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
			• Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Committee on Climate Change[59]	The Committee on Climate Change advises the UK Government and Devolved Administrations on emissions targets and reports to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.	• Awareness raising	• Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
Defra[60]	Defra is responsible for safeguarding the natural environment, supporting world-leading food and farming industry, and sustaining a thriving rural economy. Defra has a broad remit, meaning they play a major role in people's day-to-day life, including the water we drink.	• Managing catchments and land • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?

[59] Organisational Website: https://www.theccc.org.uk/about/
[60] Organisational Website: https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/about

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
Department for Business, Energy and Industrial Strategy[61]	The Department for Business, Energy and Industrial Strategy is focused on building an economy that works for everyone, enabling businesses to invest, innovate and grow. Responsibilities relate to: Business; Industrial Strategy; Science, Research and Innovation; Energy and Clean Growth; and, Climate Change.	• Managing catchments and land • Managing technological change	• Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Developers	Developers have various responsibilities for improving water environment resilience, as demonstrated through the National Planning Policy Framework and associated Planning Policy Guidance for example[62].	• Managing catchments and land • Managing housing developments • Managing water supply and demand • Partnership working	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Environment Agency[63]	The Environment Agency works to create better places for people and wildlife and support sustainable development. Responsibilities include: regulating major industry and waste; treatment of contaminated land; water quality and resources; fisheries; inland river, estuary and harbour navigations; and, conservation and ecology. The Environment Agency is also responsible for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?

[61] Organisational Website: https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy/about
[62] National Planning Practice Guidance. Available online: https://www.gov.uk/government/collections/planning-practice-guidance [Last Accessed: 25.10.19]
[63] Organisational Website: https://www.gov.uk/government/organisations/environment-agency/about

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
			• Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Floodplain Meadows Partnership[64]	The Floodplain Meadows Partnership is an innovative project focusing on research, management, promotion and restoration of these special meadows in England and Wales.	• Managing catchments and land • Partnership working	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Forestry Commission / Forestry England[65]	The Forestry Commission is the government department responsible for protecting, expanding and promoting the sustainable management of woodlands. The Forestry Commission works with two agencies Forestry England and Forest Research.	• Managing catchments and land • Awareness raising	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
Green Alliance[66]	Green Alliance is an independent think tank and charity focused on ambitious leadership for the environment. Work is focused on low carbon futures, the natural environment, resource stewardship, political leadership and sustainable business.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Historic England[67]	Historic England are the public body which helps people care for, enjoy and celebrate England's historic environment. Historic England work with	• Managing catchments and land	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?

[64] Organisational Website: http://www.floodplainmeadows.org.uk/about-us
[65] Organisational Website: https://www.gov.uk/government/organisations/forestry-commission/about
[66] Organisational Website: https://www.green-alliance.org.uk/about.php
[67] Organisational Website: https://historicengland.org.uk/about/what-we-do/

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
	communities and specialists to share knowledge, skills and to inspire interest, care and conservation.		
Homes England[68]	Homes England is the public body that funds new affordable housing in England.	• Managing catchments and land • Managing housing developments • Managing water supply and demand	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Housing associations (e.g. Habinteg)[69]	Housing associations provide a variety of low-cost "social housing". For example, Habinteg is a registered social housing provider that owns and manages housing in multiple local authorities across England and Wales.	• Managing catchments and land • Managing housing developments • Managing water supply and demand	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Innovate UK[70]	Innovate UK is the UK's innovation agency, who drive growth by working with companies to de-risk, enable and support innovation. Support is available to businesses across all economic sectors, value chains and UK regions.	• Managing technological change	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Land agents	Land agents act as managerial employees who conduct business affairs of large estates, on behalf of the land owner / manager.	• Managing catchments and land • Managing water supply and demand	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?

[68] Organisational Website: https://www.gov.uk/government/organisations/homes-england
[69] Organisational Website: https://www.habinteg.org.uk/
[70] Organisational Website: https://www.gov.uk/government/organisations/innovate-uk/about

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
Land owners and land managers (agriculture)	Land owners and managers of agricultural land are required to comply with all relevant environmental laws, regulations and standards. However, land owners and managers are listed here in relation to the potential for them to act as a partner in collaborative initiatives, such as agri-environment schemes and the Environmental Land Management (ELM) scheme.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
Land owners and land managers (aquaculture/fisheries)	Land owners and managers of aquaculture / fisheries are required to comply with all relevant environmental laws, regulations and standards. However, land owners and managers are listed here in relation to the potential for them to act as a partner in collaborative initiatives, such as agri-environment schemes and the Environmental Land Management (ELM) scheme.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
Land owners and land managers (other e.g. investors)	Land owners and managers, such as investors, are required to comply with all relevant environmental laws, regulations and standards. However, land owners and managers are listed here in relation to individual organisations that purchase or sell land in response to price fluctuation, as an investment.	• Managing catchments and land • Partnership working	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Local Authorities (including Lead Local Flood Authorities (LLFAs), Local Planning Authorities	Local government is responsible for a range of vital services for people and businesses in defined areas.	• Managing catchments and land • Managing water supply and demand • Partnership working	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
(LPAs) and Highways Authority)			• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Local businesses	Local businesses should comply with all relevant environmental laws, regulations and standards. Local businesses are listed here in relation to the potential for them to act as a partner in collaborative initiatives.	• Partnership working	• Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Local Development Corporations	Local Development Corporations are created to facilitate development within a local authority. They are responsible for coordinating the investment and planning of development.	• Managing catchments and land • Managing housing developments • Managing water supply and demand	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Local Enterprise Partnerships[71]	Local Enterprise Partnerships decide priorities for investment in roads, buildings and facilities in their area.	• Managing housing developments • Partnership working	• Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Local Nature Partnerships	Local Nature Partnerships bring together local organisations, businesses and people who want to improve their local natural environment.	• Managing catchments and land • Partnership working	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?

[71] Local Enterprise Partnerships (LEPs) and Enterprise Zones. Available online: https://www.gov.uk/business/local-enterprise-partnerships-leps-and-enterprise-zones [Last Accessed: 25.10.19]

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
			• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Manufacturers of water-intensive appliances[72]	Whilst regulatory drivers are not currently in place regarding water efficiency of appliances, certain models now carry the Water Efficient Product Label and/or the Waterwise Recommended Checkmark.	• Managing technological change • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Marine Management Organisation (MMO)[73]	The MMO licenses, regulates and plans marine activities in the seas around England so that they are carried out in a sustainable way. This helps the government achieve its vision for clean, healthy, productive and biologically diverse oceans and seas.	• Managing catchments and land	• Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
National Parks England[74]	National Parks England are the association of the Authorities which look after the 10 National Parks in England and work to promote their needs.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Natural Capital Committee[75]	The Natural Capital Committee (NCC) is an independent advisory committee that provides advice to the government on the sustainable use of natural capital.	• Managing catchments and land • Managing water supply and demand • Managing technological change • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050?

[72] Organisational Website: https://www.energysavingtrust.org.uk/home-energy-efficiency/saving-water
[73] Organisational Website: https://www.gov.uk/government/organisations/marine-management-organisation
[74] Organisational Website: https://www.nationalparksengland.org.uk/
[75] Organisational Website: https://www.gov.uk/government/groups/natural-capital-committee

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
			• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Natural England[76]	Natural England is the government adviser for the natural environment in England, helping to protect England's nature and landscapes for people to enjoy and for the services they provide. Natural England are responsible for: 1. Promoting nature conservation and protecting biodiversity 2. Conserving and enhancing the landscape 3. Promoting access to the countryside and open spaces and encouraging open-air recreation 4. Contributing in other ways to social and economic well-being through management of the natural environment	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?
Ofwat[77]	Ofwat is the economic regulator of the water sector in England and Wales, Ofwat's role is to help the sector build trust and confidence with customers and wider society. Ofwat's three strategic goals are: 1. To transform water companies' performance for customers	• Managing catchments and land • Managing water supply and demand • Managing technological change • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050?

[76] Organisational Website: https://www.gov.uk/government/organisations/natural-england/about
[77] Organisational Website: https://www.ofwat.gov.uk/about-us/our-strategy/

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
	2. To drive water companies to meet long-term challenges through increased collaboration and partnership 3. For water companies to serve a wider public purpose, delivering more for customers, society and the environment		• Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Pharmaceutical companies	Pharmaceutical companies are required to comply with all relevant environmental laws, regulations and standards. Pharmaceutical companies are listed here in relation to the potential for them to act as a partner in collaborative initiatives relating to persistent chemicals linked to pharmaceuticals.	• Partnership working	• Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Property agents (e.g. Savills)	Property agents arrange the selling, renting or managing of properties or other businesses.	• Managing catchments and land • Managing housing developments	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
River Restoration Centre[78]	The River Restoration Centre is the national expert advice centre for best practice river restoration, habitat enhancement and catchment management. It provides a focal point for the exchange and dissemination of information and expertise.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Small-scale developers (e.g. Peabody, Igloo)	Small-scale developers have various responsibilities for improving water environment resilience, as demonstrated through the National	• Managing catchments and land • Managing housing developments	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?

[78] Organisational Website: https://www.therrc.co.uk/rrc

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
	Planning Policy Framework and associated Planning Policy Guidance for example.	• Managing water supply and demand • Partnership working	
The Rivers Trusts[79]	The Rivers Trust is the umbrella organisation for 60 local member Trusts who are dedicated to protecting and improving river environments for the benefit of people and wildlife.	• Managing catchments and land • Managing water supply and demand • Partnership working	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
The Royal Society for the Protection of Birds (RSPB)[80]	RSPB's work focuses on f the analysis of threats facing birds and the environment. Areas of focus include homes for nature and species recovery whilst continuing international work and facilitated partnership working and collaboration.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
The Wildlife Trusts[81]	The Wildlife Trusts is a movement made up of 46 Wildlife Trusts: independent charities with a shared mission to bring about living landscapes, living seas and a society where nature matters.	• Managing catchments and land • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?

[79] Organisational Website: https://www.theriverstrust.org/who-we-are/about-us/
[80] Organisational Website: https://www.rspb.org.uk/about-the-rspb/about-us/our-mission/
[81] Organisational Website: https://www.wildlifetrusts.org/about-us/vision-and-mission

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
UKWIR[82]	UKWIR is responsible for facilitating the shaping of the water industry's research agenda, developing the research programme, procuring and managing the research and disseminating the findings. UKWIR's ambition is to create a platform for research and innovation that meets the challenges of the water industry, involving key stakeholders to deliver real outcomes and benefits to the sector.	• Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Volume house builders (e.g. Bovis, Persimon)	Volume house builders tend to build many homes at a time, based on a limited library of home plans.	• Managing catchments and land • Managing housing developments • Managing water supply and demand • Partnership working	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
Water companies	Water companies are required to comply with all relevant environmental laws, regulations and standards.	• Managing catchments and land • Managing water supply and demand • Managing technological change • Partnership working	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050?

[82] Organisational Website: https://ukwir.org/eng/about-water-industry-research

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
		• Awareness raising	• Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Water Resource Planning Programmes (e.g. Water Resources East)	For example, the mission statement of Water Resources East is: 'To work in partnership to safeguard a sustainable supply of water for the East of England, resilient to future challenges and enabling the area's communities, environment and economy to reach their full potential'.	• Managing catchments and land • Managing water supply and demand • Managing technological change • Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050?

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
Water UK[83]	Water UK engages with companies and regulators to ensure customers receive high quality tap water at a reasonable price and that the environment is protected and improved.	• Partnership working • Awareness raising	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050? • Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
Wildfowl & Wetlands Trust (WWT)[84]	WWT protects wetlands and wildlife and is the UK's leading wetland conservation charity. WWT are pioneers in saving threatened wetland wildlife, a centre for excellence in conservation science and experts in wetland management and creation.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050?
Wildlife and Countryside Link[85]	Wildlife and Countryside Link (Link) is the largest environment and wildlife coalition in England,	• Managing catchments and land • Managing water supply and demand	• Big Question 1: How do we halve our abstractions by 2050? • Big Question 2: How will we achieve zero leakage in a sustainable way by 2050? • Big Question 3: How do we achieve zero interruptions to water supplies by 2050?

[83] Organisational Website: https://www.water.org.uk/about-water-uk/our-team/
[84] Organisational Website: https://www.wwt.org.uk/who-we-are
[85] Organisational Website: https://www.wcl.org.uk/

Organisation	Organisational responsibilities with respect to enhancing resilience	Relevant management measures for current and future risks to resilience	Relevant UKWIR Big Questions
	bringing together 54 organisations to use their strong joint voice for the protection of nature.	• Partnership working • Awareness raising	• Big Question 4: How do we achieve 100% compliance with drinking water standards (at point of use) by 2050? • Big Question 5: How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? • Big Question 6: How do we achieve zero uncontrolled discharges from sewers by 2050? • Big Question 7: How do we achieve zero customers in water poverty by 2030? • Big Question 8: What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? • Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment? • Big Question 10: How do we remove more carbon than we emit by 2050? • Big Question 11: How do we maximise recovery of useful resources and achieve zero waste by 2050? • Big Question 12: How do we achieve zero harmful plastics in the water cycle by 2050?
WWF[86]	WWF is the world's leading independent conservation organisation. Their mission is to create a world where people and wildlife can thrive together.	• Managing catchments and land • Managing water supply and demand • Partnership working • Awareness raising	• Big Question 9: How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?

[86] Organisational Website: https://www.wwf.org.uk/who-we-are

Appendix E – Interdependencies between sectors: Supporting information

This appendix provides supporting information for Section 3, detailing interdependencies between the water sector and the natural environment. Impacts and interdependencies between both sectors (natural environment and the water sector) were identified through consideration of the water cycle and an ecosystems approach. For each ecosystem service considered, commentary was provided as to the impacts and interdependencies identified. Table E 1 below summarises the impacts and interdependencies identified for each ecosystem service.

Table E 1: Ecosystem service impacts and interdependencies for the water sector and the natural environment

Ecosystem services	Description	Impacts and interdependencies
Provisioning Services		
 Crops	Cultivated plants or agricultural products harvested for human consumption.	For crops, elements such as disease/pest tolerance; fertile, stable soils; and good water quality are needed. Water for irrigation is also a fundamental requirement. **Impacts** • Outputs from delivering crops includes: chemicals (such as pesticides and nutrients from fertiliser) entering in to waterbodies from agricultural run-off; and soil erosion, leading to reducing stability and weathering and potentially the sedimentation and siltation of water. Similarly, owing to the water supply requirements for irrigation, water availability may be reduced. • The potential for a reduction in water availability can have a significant impact on the resilience of the water industry, particularly during summer months. This may result in the requirement to explore new sources of water supply. • The impacts on water quality and soil regulation are likely to be negative if not managed effectively. • Reduced water quality means increased water treatment requirements. • A reduction in water quality and quantity may affect assimilative capacity of watercourses receiving effluent from sewage treatment works. • Farming practices and land drainage techniques may result in reduced water availability as water is encouraged through the system at speed. **Interdependencies** • Requirements for irrigation affect resilience in the water industry as demand peaks in summer months (where farmers may not have their own water supplies) when the supply-demand balance for water companies is most critical, noting this may vary by water company service area. • Increased water treatment requirements (as a function of reduced water quality owing to chemicals and sedimentation/siltation) would increase the costs of treatment owing to the associated energy and chemical requirements. • Increased water treatment requirements would result in increased carbon emissions. Similarly, exploration of new sources of water may result in the use of techniques which have significant energy requirements (such as desalination) which further increases carbon emissions. • Carbon emissions would contribute to global climate change. • Climate change would influence future agricultural processes and productivity. • Exploration of alternative sources of water supply may potentially lead to unsustainable abstractions which may result in environmental degradation. **Taking the above into account, water quality, water supply and soil regulation are interdependencies.**
	Livestock includes animals raised for domestic or	For livestock and fodder, elements such as good quality soils, good water quality and nutrition are required. **Impacts**

Ecosystem services	Description	Impacts and interdependencies
Livestock & fodder	commercial consumption or use. Fodder is any foodstuff used to feed domesticated livestock.	• Outputs include animal wastes and the potential for soil degradation, leading to the sedimentation and siltation of water. These outputs are likely to impact upon water quality and soil regulation. • Farming practices and land drainage techniques may result in reduced water availability as water is encouraged through the system at speed. **Interdependencies** • Similarly, river quality may be impacted in terms of hydromorphology, which in turn increases pressure on abstractions, particularly where systems are already degraded. Subsequently, impacts of further abstractions are greater. • Reduced water quality (owing to chemicals and sedimentation/siltation) means increased water treatment requirements. • Increased water treatment requirements would increase costs owing to the associated energy and chemical requirements. • Increased water treatment requirements would result in increased carbon emissions. • Carbon emissions would contribute to global climate change. • Climate change would influence future agricultural processes and productivity. **Taking the above into account, water quality and soil regulation are interdependencies.**
 Capture fisheries	Aquatic organisms replenish naturally in both freshwater and marine environments. The capture of such organisms, particularly fish, provides an important food source for consumers worldwide.	Capture fisheries rely on good water quality, disease and pest resilience and wild species diversity. **Impacts** • Requirements for wastewater treatment in areas such as those designated as Shellfish waters will be higher (e.g. UV for bacteriological requirements) on coastal and estuarine discharges. • Dependent upon the methods used within capture fisheries, water quality may fall, as may wild species diversity as a result of overfishing. • A reduction in wild species diversity may increase the presence of invasive, non-native species. • Capture fishery productivity may be reduced as a result of invasive non-native species. • Low flows (irrespective of cause) will compromise the viability of capture fisheries and aquaculture (see below). **Interdependencies** • The water sector relies on good raw water quality and has duties in regards wild species diversity (as per the WFD etc.). • Both the water sector and commercial fisheries rely upon sufficient water supplies and are negatively affected by low flows. • Removal of invasive non-native species is costly to water companies and can impact upon the water available for transfer between catchments. This may mean that water companies have to explore additional sources of water which may have additional environmental and cost implications. For example, desalination demands significant energy and can result in significant carbon emissions, thereby impacting global climate regulation. • Global climate impacts and regulation have significant impacts of both sectors. Specifically, for fisheries and aquaculture, climate change impacts can include losses of production arising from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms. **Taking the above into account: Water quality, wild species diversity and disease and pest control are interdependencies.**
 Aquaculture	Aquatic organisms grown in controlled conditions in both freshwater and marine environments.	For aquaculture, please see above. Several chemicals including oxidants, coagulants, osmoregulators, algicides, herbicides, fish toxicants, antifoulants, therapeutants, disinfectants, anesthetics, agricultural pesticides, and hormones are used in aquaculture. As such, impacts to water quality are likely to be heightened, requiring additional treatment from water companies. Consideration should also be given to the implications that such chemicals may have on human health. Impacts on human health relate to human capital which is outside the scope of this project, which focuses on natural capital.

Ecosystem services	Description	Impacts and interdependencies
		Taking the above into account, water quality regulation, wild species diversity and disease and pest control are interdependencies, with water quality most likely being impacted to a greater degree here than for capture fisheries.
Wild foods	Many societies gather wild sources of food which replenish naturally across a variety of different ecosystems.	Whilst wild food growth, gathering and use provides benefits to the natural environment, the water sector is not considered to be dependent upon wild foods, with no significant interdependencies between sectors identified. **Despite this, it has been identified that the inputs needed to derive wild foods i.e. water quality regulation, soil quality regulation and disease and pest control, are fundamental to the water sector, as identified above.**
Timber	A range of ecosystems produce trees which can be harvested to provide a variety of wood products.	Timber production relies on several elements previously identified as being of importance to the water sector i.e. water quality regulation, disease and pest resilience and soil quality regulation. **Impacts** • Through timber production and subsequent loss of woodlands, wild species diversity, soil quality regulation, natural hazard regulation and local and global climate regulation may be affected. • Whilst water companies are responsible for protecting and enhancing wild species diversity across water environments, they would be unlikely to be affected by timber production and subsequent impacts on biodiversity. • The water sector is not currently considered to have significant impacts on timber production. However, water supply/demand deficits could result in conflict between the water and forestry sectors and may become more of an issue in the future. **Interdependencies** • Through loss of woodlands, carbon sequestration may be reduced, leading to a changing global climate. Climate change has direct impacts on water company operations and is considered in more detail below in 'global climate regulation'. **Whilst timber production relies upon several ecosystem services which have been identified as interdependencies, global climate regulation is considered to be the fundamental interdependency as detailed within 'global climate regulation' below.**
Energy	Ecosystems provide a variety of renewable energy sources, from harvestable biomass to hydropower. Fossil fuels are not considered to be ecosystem services as they are not dependent upon the living component of existing ecosystems, so any benefits are not derived from ecosystems*. Likewise, solar radiation and wind are not considered to be ecosystem services[87].	For energy to be captured, sufficient flows should be present i.e. in the case of hydropower, flows of water should be adequate. **Impacts** • Water companies may influence the ability of ecosystems to provide energy, for example in the case of over abstraction and hydropower. • Similarly, for water companies, flows of water are important for abstractions and can be altered during times of drought or flood. • These elements will be considered within services such as water supply and hazard regulation. **Interdependencies** **Taking the above into account, energy is not considered to be an interdependency.** * Whilst fossil fuels are not ecosystem services, they are considered to be part of natural capital and are considered to be natural capital assets.
Biochemicals/medicine	Many medicines, biocides, food additives, ethnobotanical plants, and biological materials are derived from ecosystems.	Whilst biochemicals/medicines have significant benefits to the natural environment and human health, the water sector is not considered to be dependent upon biochemicals/medicines, with no significant interdependencies between sectors identified. **Despite this, it has been identified that the inputs needed to derive biochemicals/medicine i.e. water quality regulation, soil quality regulation and disease and pest resilience, are fundamental to the water sector. Biochemicals/medicine have not been taken forward as an interdependency on this basis.**

[87] Wind and solar energy are not directly attributed to ecosystems and are considered to be environmental services, not ecosystem services.

Ecosystem services	Description	Impacts and interdependencies
Water supply (including drinking water)	Freshwater is essential for human life and occurs naturally in a range of habitats.	Both the natural environment and the water sector rely on streams, rivers and aquifers to supply water. **Impacts** • Water companies directly influence the supply of water across ecosystems as a function of abstraction and the discharge of treated effluent. In many rivers in south-east England, wastewater treatment provides a major source of flow, particularly in summer months. **Interdependencies** • Several regions across the UK are operating in water stress. Elements such as climate change and population growth are expected to exacerbate water stress in the future. • With water supply, consideration is given specifically to the quantity of water and continued flows. • For the natural environment, having a good base of flows in rivers and groundwaters is essential to supporting healthy ecology and creating environmentally resilient catchments that can respond to and recover from droughts. • Pollution events can mean that water is available yet cannot be abstracted as a function of poor water quality. Similarly, algal blooms will impact upon water supply. Water quality regulation is considered in greater detail below. • For water companies, a reduction in output from operational sources of water means alternatives would be sought, such as desalination, which is costly and has wider implications. These implications include being energy-intensive, emitting significant carbon emissions and therefore impacting global climate regulation and contributing to climate change. This in turn could potentially further reduce water supply. **Taking the above into account: water supply is considered to be an interdependency.**
Fibres and ornamental resources	A vast range of products are derived from plants and animals that are used as natural fibres in clothes or building materials, or as ornamental resources.	Whilst fibres and ornamental resources have significant benefits for the natural environment and human populations, the water sector is not considered to be dependent upon fibres and ornamental resources, with **no significant interdependencies between sectors identified**. Similarly, the water sector is not considered to directly impact the production of fibres and ornamental resources. Despite this, it has been identified that the inputs needed to derive fibres and ornamental resources i.e. water quality regulation, soil quality regulation and disease and pest resilience, are fundamental to the water sector.
Genetic resources	This includes the genes and genetic information used for animal and plant breeding and biotechnology.	Genetic resources depend upon wild species[88] diversity, for which the water sector has duties to protect (under the WFD etc.). **Impacts** • It is possible that water company activities could indirectly impact genetic resources, yet this would be through mechanisms such as altered water quality or quantity. • However, the water sector is not considered to be dependent upon genetic resources, with no significant interdependencies between sectors identified. • Dependent upon the origin of the generic resources, inputs needed to derive genetic resources i.e. disease and pest resilience, may be similar to some of the water sector's dependencies.
Regulating Services		
Local climate regulation	Ecosystems can influence the local climate through the level of evapotranspiration, surface albedo[89], and temperature regulation etc. Particular groups of trees or other vegetation can also	• Climate regulation is delivered by tree cover and streams/rivers providing shading and cooling respectively. Both the natural environment and the water sector are dependent upon local climate regulation and conditions. For example, localised cooling, shading and temperature regulation can have ecological/habitat benefits, and can enhance WFD objectives. Similarly, local climate regulation is essential for water company operations. Local climate may be increasingly well regulated in rural environments due to the proximity to natural capital assets (such as woodlands and rivers/streams etc.).

[88] Wild species are protected by a broad range of legislation such as The Habitats Directive 1992 (Special Areas of Conservation) and The Birds Directive 2009 (Special Protected Areas).
[89] Albedo is a measure of how reflective a surface is. It is a measure of the proportion of the incoming solar radiation that is reflected by the surface back into the atmosphere (Met Office).

Ecosystem services	Description	Impacts and interdependencies
	provide localised shading and temperature regulation.	• In urban environments, the presence of microclimates demonstrates localised climatic changes owing to environmental conditions. **Impacts** • Water company operations may influence local climate regulation where activities specifically impact the ability of an ecosystem to perform its function. For example, over-abstraction may reduce cooling from waterbodies. • Conversely, storage reservoirs (which are key for water sector resilience) may provide beneficial local climate regulation. • Local riparian tree cover may enhance climate change mitigation and adaptation through 'Keeping Rivers Cool'. **Interdependencies** It is worth noting that within the literature reviewed to date, local climate regulation is not considered to be of particular significance, with global climate regulation being referenced more frequently. However, whilst local climate regulation may not be an interdependency at present, local climate regulation may have an increasingly important role in the future, particularly in regards drought mitigation and climate change resilience. **Taking the above into account, local climate regulation is not considered to be an interdependency at present. However, it is accepted that this may change in the future.**
 Global climate regulation	Ecosystems play an important role in global climate regulation through sequestering and emitting greenhouse gases as well as contributing to the albedo effect, shading and cooling.	Global climate regulation requires natural capital assets (such as woodlands and oceans) to store and sequester carbon, as well as to regulate temperatures. Similarly, some ecosystems emit greenhouse gases. Global climate regulation services can therefore regulate the quantity of greenhouse gasses in our atmosphere and contribute to the management of climate change. Both sectors are impacted as a result of climate change. **Interdependencies** Article I. Climate change can influence the natural environment through ecological changes, such as species distribution. For the water sector, climate change can result in extreme events (as discussed below in hazard regulation), which impact operational activities. Article II. This is compounded by the need for water companies to find alternative water supply sources, which in turn exacerbates climate change owing to increased greenhouse gas emissions (such as desalination). This further affects ecological impacts associated with a changing climate, such as species distribution. It is likely that rural environments will have the greatest stock of natural capital assets that have the potential to regulate global climate change (depending on their condition). Article III. Similarly, the need to protect the water environment from pollutants contained within wastewater discharges (to meet increasingly tighter standards) also increases energy demand, which impacts global climate regulation. **Whist the water sector may not actively impact ecosystems which deliver global climate regulation services, the relationships between the two sectors when considering global climate regulation and climate change are so interlinked that this is considered an interdependency.**
 Hazard regulation	Ecosystems play a role in maintaining the integrity of land surfaces; maintaining soil cover and low suspended sediment loads in fluvial systems; retaining and storing water; and dissipating energy from coastal processes.	Hazard regulation requires elements such as soil stability, vegetation (inclusive of riparian buffers, for example), floodplains and resilient shorelines. Specifically, for hazard regulation in relation to drought, sufficient base flows, precipitation and temperature regulation are needed. **Impacts** • The outputs from hazard regulation include (in the case of flooding for example) benefits such as avoided or reduced damages across both sectors, e.g. prevention of habitat inundation and pollution of water quality through run-off containing sediment etc. • Hazard regulation in relation to drought will allow for continued water supply, supporting the vast systems which depend upon it. Effective management of drought prevents impacts relating to water quality and supply, human health, agricultural output and ecosystem health (inclusive of populations of invasive, non-native species). • Climate change is likely to negatively impact upon the ability of ecosystems to provide hazard regulation in relation to flood risk and drought.

Ecosystem services	Description	Impacts and interdependencies
		• During and following periods of drought, heavy rainfall can result in flash flooding. • In urban environments, point-source pollution may take the form of chloride from road de-icing salts, landfill leachates and/or industrial effluent. • In rural environments, diffuse sources of pollution, inclusive of inorganic fertilisers, may be more common. • Pollution events can mean that water is available yet cannot be abstracted due to poor water quality. Similarly, algal blooms will impact upon water supply. Water quality regulation is considered in greater detail below. • In the case of drought, in many rivers in south-east England, wastewater treatment discharges are a major source of flow, particularly in summer months. Similarly, such discharges may act to dilute pollution incidents. **Interdependencies** • Whilst the water sector is unlikely to directly influence the assets which deliver hazard regulation services, there are opportunities for enhancement through river and/or floodplain restoration projects (e.g. through WFD or WINEP requirements). For example, water company investment in catchments to improve water quality (which reduces treatment need) can provide hazard regulation if certain approaches such as riparian management are considered, benefitting both sectors. • Similarly, combined water storage options may also enhance flood regulation by drawing off peak flows. • In the case of drought, water company activities could be more likely to influence hazard regulation, as a function of unsustainable abstractions, for example. • Due to drought conditions and associated water supply, water companies would need to look for alterative water sources. This may result in unsustainable abstractions which may further exacerbate environmental degradation. Similarly, new sources of water (i.e. using desalination methods) can be energy intensive and associated with increased greenhouse gas emissions, thereby exacerbating climate change, a major contributing factor of more extreme weather events and impacts, such as drought and flood risk. • Hazard regulation services may be more prominent in rural environments where natural capital assets (such as river channels and floodplains) are less likely to have been altered and therefore could provide additional protection. • In urban environments, hazard regulation services may be reduced and/or compromised as a function of development. Similarly, hazards such as flood risk may be increased in urban areas owing to increased volumes of impermeable hard standing. • Similarly, reinstatement of hazard regulation services can be challenging due to the densely populated nature of urban environments and limited room to re-naturalise watercourses and create habitats, for example. **Taking the above into account, hazard regulation is considered to be an interdependency.**
 Air quality regulation	Ecosystems release chemicals to the atmosphere as well as extracting them, influencing many aspects of air quality.	Air quality regulation requires assets and systems that naturally filter air, such as vegetation. **Impacts** • Water company operations can result in negative air quality impacts. **Interdependencies** • Through rainfall, nutrients previously held within the air can be transported into water bodies. Increased nutrients in raw water can lead to blue green algal blooms which impact on the availability of water; resulting in increased water treatment costs and a significant overall environmental impact. • Nutrients are predominantly nitrates, which are less of an issue in ecological terms in freshwaters, where phosphates are the limiting factor that typically contribute to eutrophication when levels increase. Ecologically, nitrogen is more of an issue in coastal waters. • Algal blooms can result in a loss of oxygen and ultimately loss of life for aquatic organisms. Wild species diversity is therefore reduced (including some species, which provide natural filtering

Ecosystem services	Description	Impacts and interdependencies
		services, such as mussels), perpetuating air quality impacts across both sectors. • Algal blooms are likely to adversely impact water supply. Air quality may potentially be worse in urban environments, having subsequent impacts on water quality through the transportation of chemicals via rainfall. **Taking the above into account, air quality regulation is not considered to be an interdependency.**
 Water quality regulation	Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.	Both sectors are fundamentally reliant upon water quality regulation. For water quality regulation, assets which filter water naturally are required. Initial water quality (prior to filtering) should also be considered, with good raw water quality of importance. **Impacts** • The water sector directly influences water quality through treated and untreated wastewater discharges. • Wider land management practices have significant impacts on water quality regulation, such as introducing chemicals, pesticides, herbicides, fertilisers (in more rural environments) and heavy metals and chlorides (associated with urban environments, through highway run-off for example) into waterbodies. • Pollution events can mean that water is available yet cannot be abstracted as a function of poor water quality. Similarly, algal blooms will impact upon water supply. • In many rivers in south-east England, wastewater treatment discharges are a major source of flow, particularly in summer months. Similarly, such discharges may act to dilute pollution incidents. **Interdependencies** • Successful water quality regulation will support vital ecosystem functions and contribute to wild species diversity. • Similarly, for water companies, improved water quality means reduced treatment and associated costs, chemicals and energy, thereby reducing greenhouse gas emissions, elements of which could subsequently be transported into water bodies (see air quality regulation for more details). • Conversely, poor water quality regulation could result in adverse ecological impacts and an increased need for treatment, with associated disadvantages. As identified within 'hazard regulation', rural and urban environments have different water quality challenges. **Taking the above into account, water quality regulation is considered to be an interdependency.**
 Pollination	The distribution, abundance, and effectiveness of natural pollinators, such as bees, are directly dependent on ecosystems.	• For successful pollination, a suitable distribution, abundance and effectiveness of species that deliver pollination services is required. • Pollination is vital for the natural environment and across agricultural communities. • Whilst some pollination occurs through surface hydrophily, it is not considered that water companies are dependent upon pollination or influence it to a significant degree. • Pollination services may be more widespread across rural environments. However, urban gardens can afford significant benefits to pollination services. • Water companies may influence pollination services through land management practices on land they own and/or manage. **Taking the above into account, pollination is not considered to be an interdependency.**
 Disease and pest control	Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, destructive invasive species, and the prevalence of crop and livestock pests and diseases.	To facilitate effective disease and pest control, wild species diversity is required, comprising diverse resilient species. Management is also important with respect to accidental transportation and spread. Increasingly, water companies are being encouraged to consider cross-country water transfers as new sources of water supply, which could increase the risk of spreading invasive, non-native species. Disease and pest control allow for healthy ecosystems with continued wild species diversity. Where disease and pest control is compromised, wild species diversity can be undermined, with an increased abundance and distribution of invasive, non-native species. Where invasive, non-native species are identified, this can further lower the resilience of native species to disease and pests, therefore perpetuating adverse impacts.

Ecosystem services	Description	Impacts and interdependencies
		Impacts • There is the potential for invasive, non-native species to be transported and spread through water sector activities, although this is usually closely monitored by water companies. **Interdependencies** • The presence of invasive, non-native species affects water treatment processes, increases costs and reduces water availability, which has subsequent impacts on the natural environment. • Where invasive non-native species reduce water availability, water companies need look for alternative supplies, the issues with which are discussed above. • For example, desalination is associated with significant greenhouse gas emissions, which further contribute to a changing climate, a known factor for increasing the abundance of invasive, non-native species. **Taking the above into account, disease and pest control is considered to be an interdependency.**
 Noise regulation	Noise can have both a negative and positive impact on human well-being, depending on its magnitude and source (the sound of a waterfall for example may be considered positive, whereas the sound of traffic may be negative). Ecosystems play an important role in noise regulation, both in terms of contributing to and reducing noise.	Noise regulation can be provided by assets, such as woodlands, which create a noise barrier and reduce nuisance. **Impacts** • Water company treatment works can cause noise pollution that may impact upon local wild species diversity as a function of disturbance. However, mitigation measures are likely to be in place. • Noise regulation may be increasingly beneficial in urban environments yet is potentially more available in rural areas owing to assets such as woodland. **Interdependencies** • Whilst there are impacts associated with noise regulation and water sector activities, no interdependencies have been identified. **Taking the above into account, noise regulation is not considered to be an interdependency.**
 Soil quality regulation	Soils capture and release carbon, nutrients and water, detoxify pollutants, purify water, and suppress soil-dwelling pests and pathogens. The capacity of soil for regulation is determined by the interaction of its chemical composition, physical integrity and the structure and activity of soil biodiversity. Different soil types have different inherent regulating capacities.	Soil quality regulation has a role to play in the delivery of the following ecosystem services (as explored above): • Crops • Livestock and fodder • Wild foods • Timber • Biochemicals/medicine • Fibres and ornamental resources • Hazard regulation • Water quality regulation • Disease and pest control Soil quality is likely to differ across rural and urban environments. In rural environments, agriculture may result in soil degradation and chemical contamination. In urban environments, heavy metal pollution may be more common, for example. **Taking the above into account, soil quality is considered to be an interdependency.**
Cultural Services		
 Recreation	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.	Environmental quality often determines whether communities derive recreational value from the natural environment. **Impacts** • The activities of water companies can directly influence whether environments have recreational value. • Outputs from recreation include improved wellbeing and health, economic prosperity and the potential for environmental stewardship and/or degradation. • Outputs are influenced by water company activities. For example, water companies discharge sewage into freshwater and coastal bodies, which can affect WFD and revised Bathing Water Directive (rBWD) status respectively. This could affect the recreational benefits that visitors get from these sites.

Ecosystem services	Description	Impacts and interdependencies
		• In some instances, reservoirs form important recreational destinations. The accidental introduction of invasive, non-native species could result in adverse impacts on both the water sector and natural environment. • Angling and the management of angling sites has the potential to impact positively or negatively on aspects of the water environment that the water sector relies on. • There is also scope for positive impacts where recreational destinations offer a point of engagement with customers, which subsequently improves customer awareness and behaviour. • The benefits of recreation are highly spatially dependent and tend to be greater in densely populated urban areas where population is greater, and proximity to recreational sites is less likely. **Interdependencies** • The relationships identified for recreation in relation to the natural environment and the water sector are fairly linear in nature, i.e. water company operations directly influencing recreation value. However, in specific instances, such as the use of reservoirs for recreational purposes, there are activities (such as the accidental introduction of invasive, non-native species), which could have detrimental impacts to both the water sector and natural environment. **Taking the above into account, recreation is considered to be an interdependency as both sectors rely upon recreational activities being carried out in a responsible manner, to subsequently avoid adverse impacts/to promote protection and enhancement**
 Cultural & spiritual values	The diversity of ecosystems is one factor influencing the diversity of cultures and many religions attach spiritual and religious values to the natural environment. Many societies also place a high value on the maintenance of historically important heritage and landscapes and value the “sense of place” that is associated with recognised features of their environment.	The potential for cultural and spiritual value is considered to be the same across rural and urban environments. It should be noted that individuals may be willing to travel reasonable distances to remote rural areas to experience the tranquillity and spirituality that may not be available in urban environments. **Impacts** • The activities of water companies can influence whether environments have cultural and spiritual values. This could include cases where major new reservoirs proposed by water companies could alter landscapes and their cultural values. Other examples include the impact of water companies on wetlands and water-dependent habitats. • Many water companies preserve heritage (such as Abbey Mills pump house and Crossness steam engines). Public access is provided to such sites either on open days or all year round. **Interdependencies** • Interdependencies have not been identified in regard to cultural and spiritual values, with the relationships identified being mostly linear in nature. **Taking the above into account, cultural and spiritual values are not considered to be an interdependency.**
 Scientific & knowledge values	Ecosystems influence the types of knowledge systems developed by different cultures. They can also influence global knowledge systems as a source of scientific knowledge and discovery.	The potential for scientific and knowledge values is considered to be similar across rural and urban environments. **Impacts** • The activities of water companies can directly influence whether environments have scientific and knowledge values. **Interdependencies** • Interdependencies have not been identified in regard to scientific and knowledge values, with the relationships identified being fairly linear in nature. Further, scientific and knowledge values are considered to be part of intellectual capital, rather than natural capital which is the focus of this project. **Taking the above into account, scientific and knowledge values are not considered to be an interdependency.**

Ecosystem services	Description	Impacts and interdependencies
 Wild species diversity For the purposes of this project, wild species relates to native species.	Biodiversity is a supporting service since it underpins a number of provisioning, regulating, and cultural services. However, a number of studies suggest that the diversity of wild species is itself a service regardless of whether it provides a supporting role in the provision of any other services, and that people are willing to pay to protect the existence of wild species even if they do not directly benefit from any of the ecosystem services they support.	Wild species diversity has a role to play in the delivery of the following ecosystem services (as explored above): • Capture fisheries • Aquaculture • Genetic resources • Timber • Air quality regulation • Water quality regulation • Disease and pest control • Noise regulation It should be noted that water sector operations are influenced by associated environmental designations, such as Special Protected Areas and Sites of Specific Scientific Interest, for example. Some water companies also own land which they manage for biodiversity... Wild species diversity may be greater in rural environments as a function of broader habitat types. **Taking the above into account, wild species diversity is considered to be an interdependency.**
 Aesthetic Value	Ecosystems and the natural environment afford benefits to communities through aesthetically pleasing environments.	Whilst it may be anticipated that rural environments afford benefits to communities through aesthetically pleasing environments, cityscapes are also of significant importance. **Impacts** • It should be noted that many water company assets become protected sites (both statutory and non-statutory) and become part of the local landscape. Examples include Barn Elms wetlands and Essex and Suffolk Water's storage reservoirs which are designated Special Protected Areas for their habitat provision for birds. **Interdependencies** • As with recreation, cultural and spiritual values and scientific and knowledge values, interdependencies have not been identified in regard to landscape and aesthetic value, with the relationships identified being mostly linear in nature i.e. the water sector may impact and/or afford assets which deliver landscape and aesthetic value and are particularly impacted by associated environmental designations such as Areas of Outstanding Natural Beauty. **Taking the above into account, aesthetic value is not considered to be an interdependency.**

The effects of risks to resilience on people can be examined via an impact pathway approach which sets out the activity undertaken by one of the sectors, its impact on resilience and its effect on people. Figures E 1 to D 2 provide examples of an impact pathway approach applied to the interdependencies that were identified.

It should be noted that the examples provided are not exhaustive and there are no certainties that the effects and impacts will arise as a result of activities identified, Figures E 1 to D 2 are simply examples.

Figure E 1: Impact pathway approach for water supply

Water Supply (including drinking water)

Activity
- Abstraction and discharge of treated effluent.

Impact
- Impacts upon the supply of water (for example, in many rivers in south-east England, wastewater treatment provides a major source of flow, particularly in summer months).

Effect
- Water supply is fundamental for public health. Shortages could result in health impacts (morbidity and mortality).

Where water supply is limited, secondary impacts on people may arise:

Activity
- A reduction in output from operational sources of water means alternative sources would need to be sought.

Impact
- For example, desalination is energy-intensive, emitting significant carbon emissions and therefore impacting global climate regulation and contributing to climate change.

Effect
- Societal implications of climate change include impacts on public health, living conditions and infrastructure.

Impact
- Alternatively, over-abstraction may result in environmental degradation such as reduced water quality and habitat loss.

Effect
- Environmental degradation (as a result of over abstraction) may result in impacts on cultural ecosystem services and the benefits people derive from spending time within the natural environment.

Figure E 2: Impact pathway approach for global climate regulation

Global Climate Regulation

Activity
- Water companies' operational activities may be impacted by extreme weather events which are associated with climate change. Water company responses will be dependent upon the nature of the event.

Impact
- Environmental impacts are unknown owing to the uncertainty regarding water company impacts.

Effect
- Irrespective of the water company response, impacts to operational activities are likely to have impacts on customers with the potential for public health impacts.

Effect
- Where responses have impacts on the environment (such as with emergency abstractions and desalination (as a function of requiring new sources of water)), this may result in impacts on cultural ecosystem services and the benefits people derive from spending time within the natural environment. This effect is further exacerbated by the greenhouse gas emissions emitted from high-energy processes such as desalination.

It should be noted that changing frequency and severity of extreme weather events as a result of climate change (including drought and flooding), will have impacts on morbidity and mortality, with significant economic damages.

Activity
- Water companies require increased energy for sewage treatment works in order to meet increasingly tight water quality standards.

Impact
- Water treatment processes increases the the quantities of greenhouse gas emissions, exacerbating climate change.

Effect
- Social implications of climate change include impacts on health, living conditions and infrastructure.
- Environmental degradation (as a function of climate change) has associated impacts on cultural ecosystem services, reducing the benefits people derive from the natural environment.
- Changing frequency and severity of extreme weather (including drought and flooding) will have impacts on morbidity and mortality, with significant economic damages.

Figure E 3: Impact pathway approach for hazard regulation

Hazard Regulation

Activity
- In the case of drought, in many rivers in south-east England, wastewater treatment discharges are a major source of flow, particularly in summer months.

Impact
- Such discharges may act to dilute pollution incidents and reduce environmental impacts.

Effect
- Water supply is fundamental for public health and the dilution of pollution events could help reduce morbidity and mortality.
- Protection of cultural ecosystem services and the benefits people derive from spending time within the natural environment.

Activity
- Effective management of drought.

Impact
- Prevents impacts on ecosystem health (inclusive of water quality and supply).

Effect
- Protection of human health; continued agricultural output (and associated public health and financial benefits); and, continued protection of cultural ecosystem service benefits for enjoyment of people.

The impacts and effects of river/floodplain restoration projects is similar to that of combined water storage which may enhance flood regulation by drawing off peak flows.

Activity
- River/floodplain restoration projects.

Impact
- Environmental effects will be dependent upon the activity, yet could relate to catchment-scale initiatives which improve water quality or reduce flood risk.

Effect
- Benefits to people will be dependent upon the measures implemented yet could include improved affordability of water bills (owing to a reduced need for water treatment).
- Restoration of rivers and floodplains may encourage wildlife. As wild species diversity plays a role in the delivery of several ecosystem services, the benefits to human populations are significant and wide ranging.
- Reduced economic damages from flood risk.

Figure E 4: Impact pathway approach for water quality regulation

Water Quality Regulation

Activity
- Water company explored new sources of water supply (as a function of drought conditions).

Impact
- Water treatment processes increases the the quantities of greenhouse gas emissions, exacerbating climate change and further impacting water supply.

Effect
- Impacts on public health; reduced agricultural output (and associated public health and financial implicatrions; and, deterioration of cultural ecosystem service benefits.

Activity
- Unsustainable water abstractions.

Impact
- Environmental degradation.

Effect
- Reduced benefit from cultural ecosystem services.

Activity
- Land management and partnership catchment management.

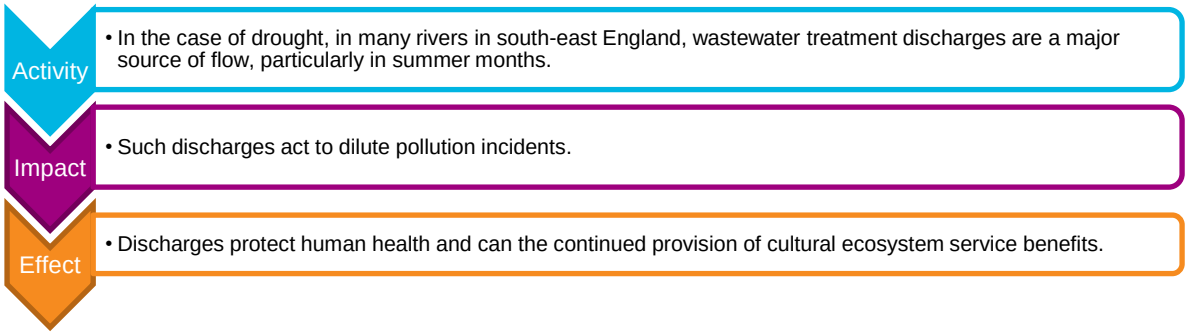
Impact
- Improved water quality.

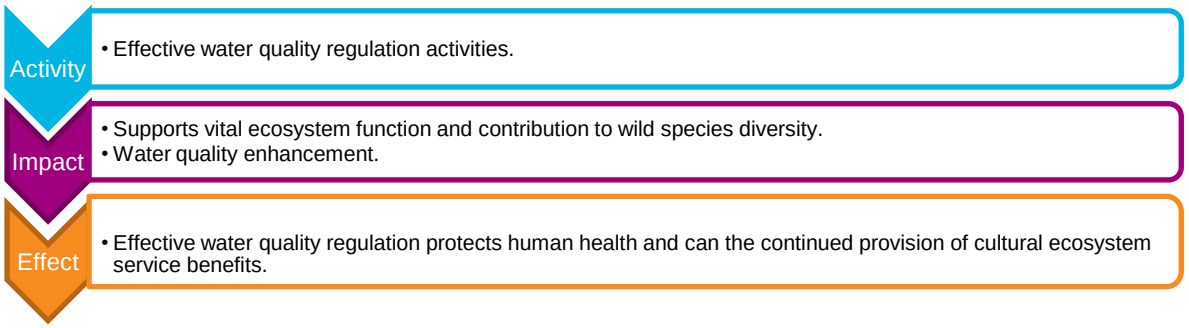
Effect
- Protection of human health, potential for reduced water bills as a function of reduced wastewater treatment, protect human health and can the continued provision of cultural ecosystem service benefits.

Activity
- During flooding events, combined water storage options utilized by water companies may enhance flood regulation by drawing off peak flows.

Impact
- Reduced peak flows decrease the risk of several impacts associated with flooding, including: Severely damaged infrastructure; Habitat inundation; and Mobilization of pollutants.

Effect
- Benefits of reduced peak flows to people include reduced risk of mortality and morbidity, as infrastructure is protected, and water quality is maintained. People will also benefit from cultural ecosystem services, as a result of reduced risk of habitat inundation.


Activity
• In the case of drought, in many rivers in south-east England, wastewater treatment discharges are a major source of flow, particularly in summer months.
Impact
• Such discharges act to dilute pollution incidents.
Effect
• Discharges protect human health and can the continued provision of cultural ecosystem service benefits.


Activity
• Effective water quality regulation activities.
Impact
• Supports vital ecosystem function and contribution to wild species diversity.
• Water quality enhancement.
Effect
• Effective water quality regulation protects human health and can the continued provision of cultural ecosystem service benefits.

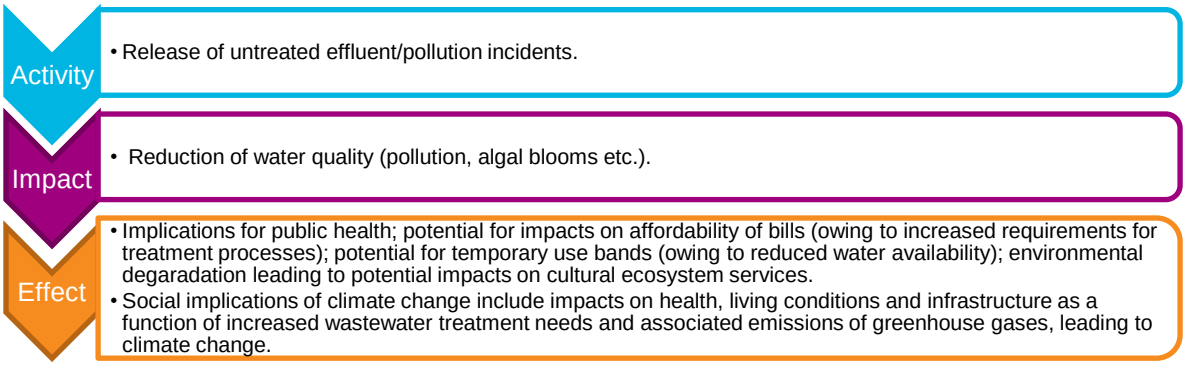

Activity
• Release of untreated effluent/pollution incidents.
Impact
• Reduction of water quality (pollution, algal blooms etc.).
Effect
• Implications for public health; potential for impacts on affordability of bills (owing to increased requirements for treatment processes); potential for temporary use bands (owing to reduced water availability); environmental degaradation leading to potential impacts on cultural ecosystem services.
• Social implications of climate change include impacts on health, living conditions and infrastructure as a function of increased wastewater treatment needs and associated emissions of greenhouse gases, leading to climate change.

Figure E 5: Impact pathway approach for disease and pest control

Disease and Pest Control

Activity • Management of invasive, non-native species.

Impact • Prevents accidental transportation and spread of invasive, non-native species.

Effect • Protects environmental resilience of native species and wild species diversity and the continued provision of cultural ecosystem service benefits.

Activity • Cross-country water transfer as a new supply of water.

Impact • Could increase the risk of spreading invasive, non-native species, comprising wild species diversity.

Effect • Undermines the continued provision of cultural ecosystem service benefits.

Where invasive non-native species reduce water availability, secondary impacts on people may arise:

Activity • For example, a reduction in output from operational sources of water means alternative sources would need to be sought, the issues with which are discussed above.

Impact • For example, desalination is associated with significant greenhouse gas emissions, which further contribute to a changing climate, a known factor for increasing the abundance of invasive, non-native species.

Effect • Societal implications of climate change include impacts on public health, living conditions and infrastructure.

Figure E 6: Impact pathway approach for soil quality regulation

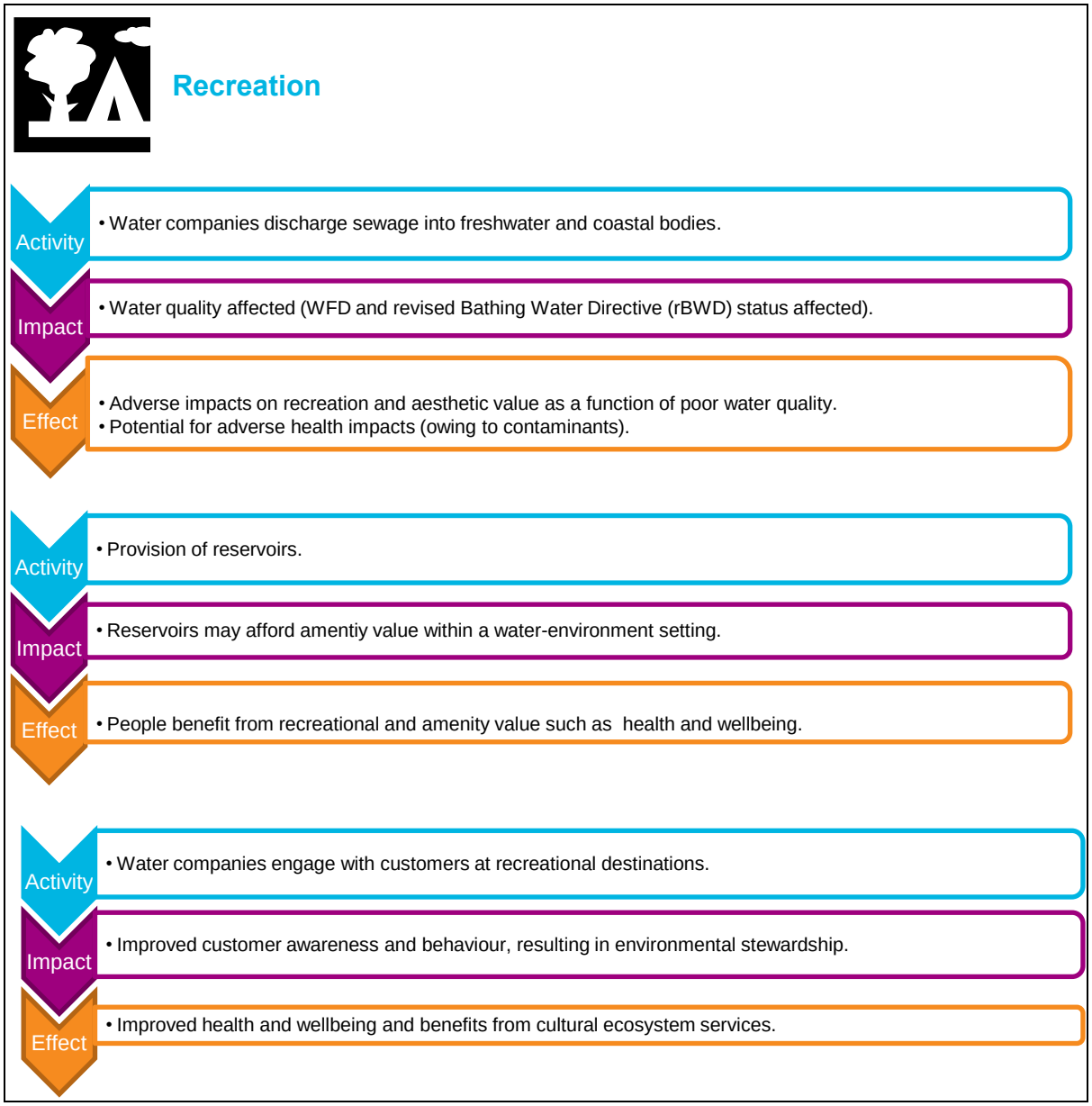
Soil Quality Regulation

Soil quality regulation is essential for the delivery of several ecosystem services, as listed below. Owing to the vast number of linkages that soil quality regulation has across the two sectors, it is not considered feasible or an efficient use of resource to consider each one of these in turn. This is particularly the case when considering the objective of this Appendix, which is to highlight the effects on people as a function of water sector activity. As a result, the significant and wide-ranging benefits provided as a function of soil quality regulation to human populations include:

Effect

- Agricultural productivity and nutrition.
- Protection from hazards such as flooding and drought thereby minimizing impacts associated with morbidity, mortality and economic damages.
- Protection of water quality and associated public health benefits.
- Control of disease and pests and associated public health benefits.

Figure E 7: Impact pathway approach for recreation[90]



[90] It should be noted that if discharges are appropriately designed and operated then this should not have any environmental repercussions and effects on people.

Appendix F – Current and future risks to resilience: Supporting information

This appendix provides supporting information for Section 7, presenting the findings from the evidence reviewed to identify current and future risks to resilience.

Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents

- The UK CCRA identifies that action is being taken to reduce adverse pressures such as pollution incidents and to increase the extent of protected marine sites. The steps are expected to enhance the resilience of marine ecosystems to climate change. However, it will be necessary to continuously monitor and assess whether additional actions will be necessary in the future.
- Blueprint for Water – Blueprint for PR19 identifies that pollution continues to be the biggest problem facing the freshwater environment.
- In addition to the pollution pressures from agriculture, around one quarter of rivers are not in good ecological health due to sewage pollution point and diffuse sources. Wastewater treatment networks face challenges regarding capacity, particularly during peak flows in wet weather periods, which has the potential to cause pollution incidents. Climate change and population growth will increase this risk.
- The Global Risk Report (2019) identifies biodiversity loss and ecosystem collapse as the 8th most likely and 6th most severe impact in regards impact.
- The Government's 25 Year Environment Plan identifies the following targets under 'Reducing Pollution':
  - Minimising the risk of chemical contamination in our water.
  - Ensuring we continue to maintain clean recreational waters and warning about temporary pollution.
- Similarly, the 25 Year Environment Plan has a target of minimising (by 2030) the harmful bacteria in designated bathing waters.
- Three of the UK Water Industry Research (UKWIR) Big Questions relate to this risk theme[91], as follows:
  - How will we deliver an environmentally sustainable wastewater service that meets customer and regulator expectations by 2050? The areas that this Big Question covers includes:
    - Developing a resilient wastewater service that has the ability to cope with the impacts of growth and climate change
    - Developing sustainable treatment technologies
    - Maintaining and protect biosolids quality
    - Playing a part in controlling any emerging substances of concern to the environment
  - How do we achieve zero uncontrolled discharges from sewers by 2050? The areas that this Big Question covers includes:
    - Reducing sewer blockages

[91] UKWIR is currently working on the approach to answering the three 'Big Questions' referenced.

Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents

- Reducing overflows (escapes) at rising mains and pumping stations
- Achieving integrated sewerage catchment management
- Addressing sewer infiltration, excess surface water flows including flows from developments
- Playing a part in wider flood management
- Supporting the industry's 21st Century Drainage programme of work

- How do we achieve zero harm from plastics via our operations and activities by 2050? The areas that this Big Question covers includes:
  - Evaluating contributions of harmful plastics to the water cycle
  - Establishing the source and effective control measures to remove plastics

– The WISER document highlights the following expectations of water companies in relation to enhancing the environment.

- Water body status (Water Framework Directive)
  - Measures to prevent deterioration in current water body status
  - Measures to improve water body status
  - Work with stakeholders and Catchment Based Approach (CaBA) partnerships to explore integrated solutions at a catchment scale.

- Biodiversity and ecosystems
  - Measures that contribute to meeting and or maintaining conservation objectives of Natura 2000 sites (Special Areas of Conservation (SAC) & Special Protection Areas (SPA)) and Ramsar sites
  - Measures that contribute to meeting and/or maintaining Favourable Condition targets for SSSI
  - Measures that contribute to priority habitat and species outcomes as well as other biodiversity actions and measures to enhance ecosystem resilience on water company owned land or in the catchments within a water company's area of operation
  - Measures that contribute to the conservation objectives of Marine Conservation Zones (MCZ)

- Urban waste water
  - Measures to protect newly identified sensitive areas
  - Measures to improve wastewater treatment where population thresholds are exceeded
  - Maintain sewers to demonstrate sewer leakage to ground is minimal, especially in Source Protection Zones.

- Chemicals
  - Measures to prevent deterioration (includes load standstill measures)
  - Measures to achieve compliance with environmental quality standards (EQS)
  - Work with business customers and catchment partners to explore alternatives to end of pipe treatment solutions.

Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents

– The Kent Spatial Risk Assessment for Water (2014) identifies:

- That there is an increased risk of failure of physio-chemical elements of WFD status as a result of urban diffuse pollution, increased soil erosion and degradation and lower summer river flows and more frequent summer hydrological droughts.
- The risk of reduced land stability affecting infrastructure as a function on increased soil erosion and degradation.
- The risk of worsening condition of aquatic habitats and species including eutrophication as a function of: increased soil erosion and degradation; lower summer river flows and more frequent summer hydrological droughts; and, limitations on wastewater discharges to river system.

This Risk Theme is considered to be a joint risk.

Climate change

– The Global Risk Report (2019) identifies the failure of climate change mitigation and adaptation as the second most likely risk and second most severe in regards impact.

– The Government's 25 Year Environment Plan has a target to tackle the effects of climate change which is considered to be the most serious long-term risk to the environment given higher land and sea temperatures, rising sea levels, extreme weather patterns and ocean acidification, which harms marine species.

– The UK Climate Change Risk Assessment (CCRA) (2017) identifies that climate change presents a substantial risk to the UK's native wildlife and to the vital goods and services provided by the natural environment to people.

– The UK CCRA identifies three key objectives set by the Forestry and Woodlands Policy Statement (2013):

- Protecting the nation's trees, woodlands and forests from increasing threats such as pests, diseases and climate change.
- Improving their resilience to these threats and their contribution to economic growth, people's lives and nature.
- Expanding them to increase further their economic, social and environmental value.

– The UK CCRA identifies that risks from climate change are heightened because the natural environment is already stressed as a function of historic and on-going pressures including pollution, habitat loss and fragmentation, the continuing drainage of wetlands and unsustainable use of soil, water and marine resources. These pressures constrain the natural resilience of species and

Climate change

ecosystems and their ability to adjust and adapt. There is therefore a risk that climate change will lead to further species declines and habitat degradation.

– Water management policies established by the European Climate Adaptation Platform Climate-ADAPT (Climate ADAPT, n.d)[92] identify that climate change directly impacts water resources in terms of both water quality and water quantity. Similarly, the role water management plays in ecosystems, socio-economic activities and human health is highlighted. Climate change is expected to worsen the impacts of already existing stresses on water as changes in precipitation, combined with rising temperatures, will cause significant changes in the quality and availability of water resources.

– Defra's National Policy Statement for Water Resources Infrastructure (2018) identifies that climate change mitigation is essential to minimise the most dangerous impacts of climate change. These impacts include an increased risk of drought and flooding, drier summers and warmer wetter winters, more intense rainfall events and rising sea levels.

– Natural England's Climate Change Risk Assessment and Adaptation Plan (2015) identifies that some habitats, particularly woodlands, wetlands and blanket bog are important carbon sinks and play a vital role in the management of carbon dioxide. Good habitat management, together with new habitat creation and restoration can provide cost-effective means of reducing greenhouse gas emissions, Natural England has an essential role in delivering and supporting this.

– Southern Water's Climate Change Adaptation Reporting: Second Round Reports (2015) identified several secondary, indirect impacts as a result of climate change:

  - Redistribution of populations (both residential and tourist) as a result of temperature increase or water stress
  - Changes in agricultural practice as a result of higher temperatures and a longer growing season
  - Increase in algal growth and invasive species disrupting water quality
  - Effects of higher temperature on treatment processes (water and wastewater)
  - Effects of higher temperature on operation and life expectancy of electrical and other equipment
  - Potential loss of power caused by more extreme events
  - More extreme wetting/drying cycles leading to ground movement and consequent structural failure
  - Transport and logistical difficulties caused by extreme weather conditions
  - Changes in staff working practices arising from higher temperatures

– Priority risks to Natural England's objectives, as stated within Natural England's climate change risk assessment and adaptation plan (2015) (NE612), are as follows:

  - Threats to conservation and recovery of priority threatened species and habitats
  - Threats to the condition of protected species (Sites of Special Scientific Interest (SSSI), National Nature Reserves, Marine Protected Areas and Natura 2000 sites)
  - Threats to the conservation and enhancement of landscape character
  - Threats to sustainable land and sea management

[92] ADAPT is a partnership between the European Commission and the European Environment Agency.

Climate change

- Threats to the protection of the natural environment though incentive schemes
- Threats associated with working with partners and local communities
- Threats to our delivery of planning and sustainable land use responsibilities
- Threats to access and engagement work

– The Thames WRMP identifies the following impacts of climate change on their business:

- Water distribution: Underground pipe network affected by changes in wetting/drying soil
- Water usage: Changes in the pattern of customer demand
- Water treatment: Reduced volume/lower quality of water for treatment and risk of flooding to operational sites
- Wastewater to sewer: Increased flooding/surcharge
- Wastewater treatment: Increased risk of inundation of operational sites
- Water abstraction: Reduction in water available for abstraction
- Effluent discharge: Reduced river flows in summer to dilute effluent discharges.

– The Water Industry Strategic Environmental Requirements (WISER) document also identifies the impacts of changing weather patterns and severe weather, such as freeze-thaw. The WISER document expects water companies to thoroughly assess the vulnerability of the water supply system to non-drought water supply hazards such as freeze-thaw impacts.

– The Global Risk Register (2019) identifies extreme weather events as the top risk (by likelihood) and third most significant in regards impact.

1) One of the UK Water Industry Research 'Big Questions' relates to Climate Change[93]:

- How do we remove more carbon than we emit by 2050? The areas that this Big Question covers the following objectives:
  - Establish where and how we can store energy
  - Optimise energy generation and address energy waste
  - Seek out novel materials to use in construction and rehabilitation.

This Risk Theme is considered to be a joint risk.

[93] UKWIR is currently working on the approach to answering the 'Big Question' referenced.

Natural hazards (drought and flood risk) including economic resources to prepare for and address risks

- The Government's 'Keeping the country running: natural hazards and infrastructure' guidance (2011) identifies that natural hazards can disrupt infrastructure.
- The Global Risk Report identifies man-made environmental disasters as the sixth most likely risk assessed (2019) and the ninth most severe in regards impacts. Natural disasters were ranked third most likely and fifth most severe in regards impacts.
- Blueprint for Water – Blueprint for PR19 identified that the economic, social and environmental risks posed by drought are severe. This is particularly the case in the south east, where population growth and climate change will impact already stretched supplies.
- The Southern Water WRMP identifies that all droughts are different and that planning for one type of drought condition (i.e. the worst drought on record) may mean that the designed supply system is not as resilient as possible i.e. there are different types of drought, with different lead-in conditions and low rainfall duration and extent which may threaten supplies to a greater extent.
- The Water Supply and Resilience and Infrastructure Environment Agency advice to Defra (2015) identifies that severe drought would cause significant deterioration in the environment. Appropriately planned water supply resilience solutions will reduce the frequency and impact of drought measures on the environment during drought conditions, thereby benefitting the environment.
- Within the Government's 25 Year Environment Plan, there is a commitment to:
    - Work with nature to protect communities from flooding, slowing rivers and creating and sustaining more wetlands to reduce flood risk and offer valuable habitats, potentially offering an area of partnership working.
    - Reducing the risk of harm to people, the environment and the economy from natural hazards including flooding, drought and coastal erosion by:
        - Making sure everyone is able to access the information they need to assess any risks to their lives and livelihoods, health and prosperity posed by flooding and coastal erosion.
        - Bringing the public, private and third sectors together to work with communities and individuals to reduce the risk of harm.
        - Making sure that decisions on land use, including development, reflect the level of current and future flood risk.
        - Ensuring interruptions to water supplies are minimised during prolonged dry weather and drought.
        - Boosting the long-term resilience of our homes, businesses and infrastructure.
        - Updating the national flood and coastal erosion risk management strategy, looking to strengthen joint delivery across organisations.
        - Promoting natural flood management as an important role in flood and coastal risk management.
        - Consider how Lead Local Flood Authorities, water and sewerage companies, highways authorities and other risk management authorities work together to manage surface water flooding. Improving existing arrangements for managing surface water flooding, and the outcomes delivered by Lead Local Flood Authorities and other risk management authorities, including water companies.

Natural hazards (drought and flood risk) including economic resources to prepare for and address risks

– The Kent Spatial Risk Assessment for Water (2014) identified the risk of increased need for flood defence infrastructure investment owing to a risk of greater depth and extent of river, surface water and tidal flooding. Similarly, the report identifies that coastal settlements are at medium or high risk as a function of coastal erosion.

This Risk Theme is considered to be a joint risk.

Political or regulatory reform

1) The SoNaRR identifies socio-political changes (evolution and development of legislation, regulation and policy) especially in policies and incentive mechanisms to be an indirect driver of the use and management of natural resources and ecosystems.

2) The SoNaRR also highlights that indirect drivers affecting the use and management of natural resources and ecosystems in Wales includes socio-political changes (evolution and development of legislation, regulation and policy) especially in policies and incentive mechanisms.

– Political uncertainty, particularly relating to BREXIT, results in future uncertainty relating to funding for infrastructure, investment in research and environmental regulation for example. The South East Water WRMP identifies that BREXIT is likely to have an impact which is currently not quantifiable.

3) Two of the UK Water Industry Research 'Big Questions' relate to regulatory reform[94]:

- What is the true cost of maintaining assets and how do we get this better reflected in the regulatory decision-making process? The objectives of this Big Question include:
    - Understand how to manage and maintain ageing assets in an effective and affordable way
    - Efficient asset optimisation and operation
    - Keep our costs as low as possible and deliver an affordable service
- How do we ensure that the regulatory framework incentivises efficient delivery of the right outcomes for customers and the environment?
    - Finding new ways of involving customers in our business planning process
    - Ensuring the costs and benefits of service and environmental improvements are appropriately assessed

– Ofwat's Resilience Task and Finish Group - Final Report (2015) suggests that it is unclear as to whether the current structure of the sector and the form of economic regulation encourages legitimate resilience investments to be made.

This Risk Theme is considered to be a joint risk.

[94] UKWIR is currently working on the approach to answering the two 'Big Questions' referenced.

Socio-economic factors such as population growth

- Each water company has identified population growth as a risk within their Water Resource Management Plans (WRMPs). For example, Southern Water has estimated that during the next 25 years, an additional 181,000 properties will be built in their operating region, with population growth at 19%, thereby increasing water demand significantly, with the requirement to secure sufficient water supplies to meet this demand.
- In addition to population growth, behavioural change is an important socio-economic consideration. The Southern Water WRMP identifies that changing lifestyles including the trend for smaller households and people living on their own is also adding to the pressure on resources because water use (i.e. for washing machines, dishwashers and gardening) is shared among fewer people.
- The State of Natural Resources Report (SoNaRR) 2016 identifies that direct and indirect drivers affect the use and management of natural resources and ecosystems in Wales including demographic changes (population, age structure and consumption patterns) and cultural and behavioural changes (knowledge, attitudes and purchasing preferences can influence ecosystems).
- Defra's 'Creating a great place for living: Enabling resilience in the water sector' (2016) identifies that by 2050, the population in England is forecast to grow by over 10 million people, with a large part of this growth occurring in areas where water is already scarce. This population growth also puts pressures on the sewerage network.

This Risk Theme is considered to be a joint risk.

Unsustainable abstraction, abstraction reform and changing abstraction licences

1) The South East Water WRMP identifies that water companies are vulnerable to future regulatory and legislative changes such as uncertainty around abstraction reform and changes to water quality standards.
2) Similarly, the Southern Water WRMP identifies that one of the biggest challenges facing water companies is the need to meet new European legislation which could significantly reduce the amount of water we can abstract from the environment.
3) The Environment Agency regulates abstraction by issuing licences which set out how much and how often organisations can take water from the environment.
4) These licences are being reviewed as part of the WFD. If rivers, groundwater and streams are felt to be under pressure, 'sustainability reductions' can be put in place to reduce the amount of water which can be abstracted.
5) Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies abstraction licences as a mid-term shock.
6) One of the UK Water Industry Research (UKWIR) Big Questions relates to this risk theme[95], as follows:

[95] UKWIR is currently working on the approach to answering the three 'Big Questions' referenced.

a) How do we halve freshwater abstractions in a sustainable way by 2050? The following will be considered:

- Resilient water resources that cope with, and recover from, disruptions as well as anticipate trends and variability in order to maintain our supplies
- Eliminate water wastage
- Maximise use of potential new sources of drinking water (e.g. desalination, final effluent re-use, rainwater harvesting)

This Risk Theme is considered to be a joint risk.

Agricultural intensification/damaging fishing practices

– The UK National Ecosystem Assessment identifies that the intensification of farming can result in increasing flood risk and loss of wildlife.

– The UK Climate Change Risk Assessment identifies that action is being taken to reduce adverse pressures such as damaging fish practices and to increase the extent of protected marine sites. The steps are expected to enhance the resilience of marine ecosystems to climate change. However, it will be necessary to continuously monitor and assess whether additional actions will be necessary in the future.

– The Government's 25 Year Environment Plan identifies that farming can be a powerful force for environmental enhancement. However, currently it generates too many externalities such as emissions from livestock and pollution from fertilisers and pesticides. Overall, farming is now the most significant source of water pollution and of ammonia emissions into the atmosphere in the UK. It accounts for 25% phosphate, 50% nitrate and 75% sediment loadings in the water environment, which harms ecosystems[96].

– The 25 Year Environment Plan also states that Integrated Pest Management (IPM) should be at the heart of an in-the-round approach, using pesticides more judiciously and supplementing them with improved crop husbandry and the use of natural predators. By making IPM central to the approach, wider investment in research and development will be encouraged.

– The WISER document highlights the following expectations of water companies in relation to enhancing the environment.

- Sustainable fisheries
  - Screen abstractions and outfalls to prevent the entrainment of eels and salmon
  - Address barriers to the passage of fish

– The Kent Spatial Risk Assessment for Water (2014) identifies that:

- There is the potential for agricultural opportunities as a function of climate change.
- There is a risk of agricultural degradation or loss of agricultural land quality as a result of increased soul erosion and degradation and greater depth and extent of river and tidal flooding.

[96] The impact of agriculture on the water environment: summary of the evidence, Defra, 2014

- There is a risk of losing agricultural land (Grades 1-3) through increased coastal erosion.

This Risk Theme is considered to be a joint risk.

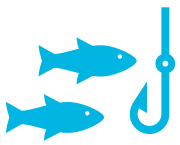
Declining water environment quality including known deterioration (nitrate, phosphorus, metaldehyde) and other risks (combined sewer overflows and emerging substances)

– The South East Water WINEP identifies that raw water quality in several groundwater catchments is at risk of decline. Of specific concern is nitrate in chalk aquifers and chlorides in coastal chalk aquifer blocks.

– The Aggregate Assessment of Climate Change Impacts of the Goods and Benefits Provided by the UK's Natural Assets (2015) identified five existing risks to the provision of clean water, as follows:

- Nutrient enrichment and eutrophication
- Combined sewer overflows
- Dissolved organic carbon
- Specific pollutants, priority substances and 'other' chemical pollutants
- Over-abstraction and saline intrusion.

This Risk Theme is considered to be a joint risk.



Ageing infrastructure/asset failure (with associated cost implications) and leakage

– Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies:

- Leakage and ageing infrastructure as long-term stressors on the water sector. Asset failure and dam failure are identified as long-term shocks.
- Extreme vandalism and unrest and hoax calls as short-term shocks to the water sector. Terrorist or cyber-attacks and data fraud/theft, in addition to nuclear incidents are identified as longer-term shocks.

– One of the UK Water Industry Research 'Big Questions' relates to ageing infrastructure/asset failure[97]:

- How will we achieve zero leakage in a sustainable way by 2050? In relation to this 'Big Question', UKWIR states the following:

[97] UKWIR is currently working on the approach to answering the 'Big Question' referenced.

- ‘Achieving the target of zero leakage is extremely ambitious, one that cannot be achieved with existing processes, techniques and equipment, even if used in much greater quantities than at present. If zero leakage is ever to be a realistic target, and one that can be achieved sustainably, we will need a large amount of research and development in this area. This will need to cover many different aspects of leakage and leakage management. The timescale for achieving this target is 2050, which means that potentially almost anything is possible, and the research should not be constrained by the limitations of existing methods and equipment’.

– The Resilience Task & Finish Group identifies that there is a need for modern infrastructure which has enough capacity to solve issues for future generations.

– United Utilities’ ‘Measuring Resilience in the Water Sector’ identifies ageing infrastructure as one of the five key challenges facing the sector.

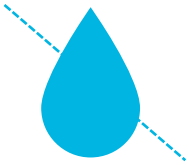
This Risk Theme is not considered to be a joint risk and relates to the Water Sector.

Urbanisation, urban creep and land-use change

– Anglian Water’s ‘A systems approach to resilience shocks and stresses’ (2018) identifies urban creep, rising urbanisation and land-use change and coastal erosion as long-term stressors.

– The Global Risk Report (2019) identifies that urbanisation not only concentrates people and property in areas of potential damage and disruption, it also exacerbates those risks— for example by destroying natural sources of resilience and increasing the strain on groundwater reserves. The risks of rising sea levels are often compounded by storm surges and increased rainfall intensity, intensifying impacts will render an increasing amount of land uninhabitable.

This Risk Theme is considered to be a joint risk.



Water shortage

– The Water Industry Strategic Environmental Requirements (WISER) document identifies that as demand rises and climate changes, bringing periods of hotter and drier weather, the long-term risk of severe water shortages is rising.

– Defra’s National Policy Statement for Water Resources Infrastructure identifies that having the right flow in our rivers and protecting groundwater levels is essential to support healthy ecology and enhancing natural resilience to drought. The impacts of climate change and the growing demand for water are putting added pressure on this availability.

– The Global Risk Report identifies that water crisis (societal) is the 9th most likely risk and 4th most severe in regards impact.

– The South East WRMP identifies that water companies in the south of England may operate in areas of water stress, wherein current (or future) household demand for water is a high proportion of the current effective rainfall that is available to meet demand.

– There is often a high reliance on groundwater which presents challenges to water companies during extended periods of low rainfall. The Environment Agency has identified that some of these aquifers are over-abstracted and fail to meet the requirements of the Water Framework Directive, meaning the sustainability of some of the abstractions are uncertain. In situations such as this, the following approach may be required:

  - Better assessment of extreme drought events
  - Improving our network connectivity to make the best use of resilience sources of supply
  - Developing a more diverse mix of sources of supply to reduce over-reliance on one particular type or source.

– The Water Supply and Resilience and Infrastructure document (2015) identifies that large parts of society, industry and commerce are currently exposed to the risk of emergency water restrictions at a likelihood in the order of 1% every year. The future risk of emergency water restrictions is likely to increase due to a combination of growth pressures and changes to droughts associated with climate change, unless water companies and other business invest in resilience. The consequence of emergency water restrictions has the potential for sever economic, societal, reputational and environmental impacts, particularly in large conurbations. It is possible that the societal impacts of such restrictions could include break-down of social cohesion and serious impacts on public health.

1) One of the UK Water Industry Research 'Big Questions' relates to Water Shortage[98]:

   - How do we achieve zero interruptions to water supplies by 2050?

2) The Kent Spatial Risk Assessment for Water (2014) identified that lower summer river flows and more frequent summer hydrological droughts could result in increased competition for available surface water.

This Risk Theme is considered to be a joint risk.

Water efficiency in households e.g. washing machines, water meters

Across the water sector, it is argued that new housing developments may fail to integrate water efficiency measures.

The Government's 25 Year Environment Plan has the target of stipulating high environmental standards for all new builds with the aim that new homes will be built in a way which reduces demands for water, energy and material resources, improves flood resilience, minimises overheating and encourages walking and cycling.

This Risk Theme is considered to be a joint risk.

Affordability and vulnerability of customers along with changing customer expectations

[98] UKWIR is currently working on the approach to answering the 'Big Question' referenced.

- One of the UK Water Industry Research 'Big Questions' relates to affordability and vulnerability[99]:
  - How do we achieve zero customers in water poverty by 2030? The objectives for this Big Question include:
    - Consider alternative charging structures and tariffs and their impact on affordability
    - Understand the future pressures that may lead to water poverty
- The Southern Water WRMP identifies that customers expect more cost effective and efficient services than ever before, at a price they can afford.
- Ofwat's Resilience Task and Finish Group - Final Report (2015b) identifies that greater engagement with customers is needed to understand their expectations on service levels and to enable a more active role for customers in building resilience.
- The same report also identifies that customers, communities and social considerations are often overlooked and that the general public play an important role in helping to build resilience. It is considered that significant opportunities exist in this area for shaping future investment proposals, changing behaviours to increase resilience, and community-level action to deliver protection. An important enabler to unlock this opportunity is to build understanding and raise awareness amongst the public; ensuring they are better-informed and able to participate fully in decisions.
- Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies inequality/income disparity as a mid-term stressor.
- United Utilities' 'Measuring Resilience in the Water Industry' (2017) identifies 'affordability' as one of the five key challenges facing the water sector.

This Risk Theme is not considered to be a joint risk and relates to the Water Sector.

Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)

- Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies financial crisis and growth vs. recession to be a long-term stressor.
- The Global Risk Report (2019) identifies asset bubbles in major economy to be the 10th most likely risk.
- The Kent Spatial Risk Assessment for Water (2014) identified that there is an increased risk of wastewater treatment costs as a function of lower summer river flows and more frequent summer hydrological droughts. Similarly, increased costs may result as a risk of limitations on wastewater discharges to river systems.
- Ofwat's Resilience Task and Finish Group - Final Report (2015) identifies that many factors are implicated in water resilience, inclusive of economic scarcity where social resources are required to successfully adapt to water scarcity.

This Risk Theme is considered to be a joint risk.

[99] UKWIR is currently working on the approach to answering the 'Big Question' referenced.

Security risks e.g. cyber security

- Ofwat's Resilience in the Round final report (2017b) identifies that: Future threats to the sector are likely to increase in frequency, interconnectivity and unpredictably (World Economic Forum Global Risk Report 2017). These range from climate change and extreme weather events, to cyber security threats and a rapidly changing labour market.
- Defra's 'Creating a great place for living: Enabling resilience in the water sector' (2016) identifies that the water sector needs to maintain resilience to a range of pressures in the short- and long-term inclusive of attacks on computer systems.
- Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies fire events as a short-term shock.

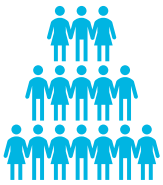
This Risk Theme is not considered to be a joint risk and relates to the Water Sector.

Biosecurity/pest and disease management (including invasive, non-native species)

- The Government's 25 Year Environment Plan makes a commitment to developing plans to reduce the risk from all high priority pathways for invasive non-native species (INNS) introduction into England.
- The UK Climate Change Risk Assessment (2017) identifies the following objective set by the Forestry and Woodlands Policy Statement (2013) in relation to biosecurity:
  - Protecting the nation's trees, woodlands and forests from increasing threats such as pests, diseases and climate change.
- Blueprint for Water – Blueprint for PR19 identified that additional work is needed to ensure the risks of invasive non-native species for the environment and water companies are avoided.
- Invasive non-native species can also increase flood risk and soil erosion, whilst posing a serious risk to water company assets.
- Within the 25 Year Environment Plan, a target of enhancing biosecurity to protect wildlife and livestock and boosting resilience of plants and trees is included, and will be achieved by:
  - Managing and reducing the impact of existing plant and animal diseases; lowering the risk of new ones and tackling invasive non-native species
  - Ensuring strong biosecurity protection at our borders, drawing on the opportunities leaving the EU provides
  - Working with industry to reduce the impact of endemic disease
- The WISER document highlights the following expectations of water companies in relation to enhancing the environment.
  - Prevent deterioration by reducing the risks of spread of INNS and reducing the impact of INNS

- Reduce the impacts of INNS, where INNS is a reason for not achieving conservation objectives or good status
- Understand pathways of introduction and spread of INNS

This Risk Theme is considered to be a joint risk.



Changing labour market and skills shortage

– Resilience in the Round identified that 'Future threats to the sector are likely to increase in frequency, interconnectivity and unpredictably (World Economic Forum Global Risk Report 2017). These range from climate change and extreme weather events, to cyber security threats and a rapidly changing labour market'.

– Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies skills shortages as a short-term stressor.

This Risk Theme is not considered to be a joint risk and relates to the Water Sector.

Digital revolution benefits, potential for and over-reliance on technology and associated risks e.g. system failure

– Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies the digital revolution as a long-term stressor.

– The Global Risk Report (2019) identifies critical information infrastructure breakdown as the 8th most significant risk regarding impact.

– The Resilience Task & Finish Group identifies that information and communication technologies are needed to make our current infrastructure smart enough to adapt to change.

– The SoNaRR 2016 identifies that indirect drivers including technological changes (mechanisation and use of chemicals can influence landscape, habitats and productivity) affect the use and management of natural resources and ecosystems in Wales.

– The Environment Agency's Final Water Resources Planning Guideline (2016) identifies that future demand will be subject to many influences including changes in technology and practices for leakage detection and repair.

This Risk Theme is considered to be a joint risk.

Public health and Infectious diseases (people and animals)

1) Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies:

   - Infectious diseases as a long-term shock.
   - Lifestyle change, rising chronic/lifestyle diseases as a long-term stressor.

– Within the 25 Year Environment Plan, a target of enhancing biosecurity to protect wildlife and livestock and boosting resilience of plants and trees is included, and will be achieved by:

   - Managing and reducing the impact of existing plant and animal diseases; lowering the risk of new ones and tackling invasive non-native species.
   - Working with industry to reduce the impact of endemic disease.

– The WISER document highlights the following expectations of water companies in relation to enhancing the environment.

   - Bathing waters
     - Measures to achieve at least sufficient class
     - Measures to prevent deterioration in class
     - Event monitoring of storm overflows impacting on bathing waters
     - Measures to achieve good/excellent class
   - Shellfish waters
     - Measures to prevent deterioration in current water body status
     - Measures to achieve shellfish water protected areas objectives
     - Event monitoring of storm overflows impacting on shellfish waters
   - Drinking Water Protection Areas (DrWPA)
     - Catchment measures to prevent deterioration in water quality and to reduce the need for additional treatment
     - Catchment measures to improve water quality to reduce the level of existing treatment

2) One of the UK Water Industry Research 'Big Questions' relates to Public Health[100]:

   a) How do we achieve 100% compliance with drinking water standards (at point of use) by 2050?

      - Information relating to this 'Big Question' is as follows: Drinking water quality is of key importance to public health, and the provision of safe drinking water has been recognised as one of the greatest technological and public health advances of the last century. The current system of delivering safe water to consumers in the UK is based upon significant investment in infrastructure and performs at an excellent standard at a very low cost. However, the future challenges of climate change, energy efficiency, population growth, and an aging infrastructure mean that the traditional ways of providing safe water may need to change.

This Risk Theme is considered to be a joint risk.

[100] UKWIR is currently working on the approach to answering the 'Big Question' referenced.

Water company dependency on other sectors (i.e. telecoms and power failures)

– The Environment Agency's Water Supply and Resilience Infrastructure report (2015) identifies that while many businesses plan their future needs, there is no strategic sectoral planning for the risks associated with water for energy security, agriculture, industry, commerce and private water supplies reliant on direct abstractions.

– Anglian Water's 'A systems approach to resilience shocks and stresses' (2018) identifies[101]:

  - Supply chain failure as a short-term shock
  - Resource scarcity (e.g. fuel) and severe energy price change to be short-term stressors
  - Telecoms and power failures as a short-term shock.

– AECOM's Strategic Water Infrastructure and Resilience Project summary report (2016) identifies that there are many examples of events that have disrupted water supplies in England in the past, including storms causing loss of power supplies and communications.

This Risk Theme is not considered to be a joint risk and relates to the Water Sector.

[101] The Water Supply and Resilience Infrastructure Report identifies that shocks are considered to be disruptive events which impact the ability to provide a high-quality service. Stresses are chronic conditions which weaken the function of the organisation or system long-term.

Appendix G – Managing risks to resilience through collaboration: Supporting information

This appendix provides supporting information for Section 8, on managing resilience risks.

G.1 Current and Future Risk Management Measures[102]

Table G 1 summarises the management measures for current and future risk to resilience.

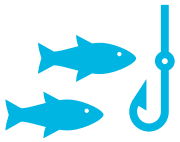
Table G 1: Current and Future Risk Management Measures

Risk Theme	Opportunities to manage risk
Environmental degradation including soil degradation, habitat loss, ecological status of water bodies and pollution incidents	**Current** • Working with land managers to improve soil structure and health can improve carbon sequestration, and reduce pesticide and fertiliser application, thus improving biodiversity. • More onus on soil health, which is important for productivity as well as ecosystem services (especially groundwater recharge, protection of raw water quality and flood risk management). • There is great interest and opportunity in improving soil management in the UK. Good soil management such as no-till farming presents the opportunity to reduce sedimentation, improve infiltration, sequester carbon, reduce artificial inputs and improve biodiversity. • Education, information and training in agricultural colleges and universities to target sustainable change coupled with agri-environment incentivisation and more realistic fines for harmful practices. • Many of the solutions exist yet need to be mainstreamed in professions.
	Future • Promote more effective land management schemes to increase the quality and extent of habitats and to manage soils effectively. • The 25 Year Environment Plan should provide the framework for addressing these risks, but real investment in natural capital and a robust, consistent approach to this is needed.

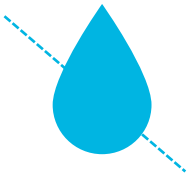
[102] Risk themes are provided in order of the frequency in which they were identified as a top five current risk by survey respondents.

Risk Theme	Opportunities to manage risk
Climate change 	**Current** • Catchment resilience in the form of adaptive management to reconnect floodplains. This could take the form of managing, enhancing and connecting habitats to provide resilience to drought and flooding. This may include the adoption of two stage channels, slowing the flow, and working with landowners to manage nutrient and chemical inputs into surface and groundwater sources. This could build on 'other user resilience', including rainwater harvesting, water efficiency, and the use of grey water systems to reduce water demand when it is less likely to be available, such as during the summer period. • Better management of peat habitats to secure existing major carbon stores and to reduce risks to raw water quality. • Education, information and training to reduce impact. • Reduction in emissions to reduce the risk, with benefits for both society and businesses.
	Future • Catchment resilience, in the form of adaptive management to reconnect floodplains, and managing and enhancing connecting habitat to provide resilience to drought and flooding. This may include the adoption of two stage channels, slowing the flow, and working with landowners to manage nutrient and chemical inputs into surface and groundwater sources. This could build on 'other user resilience', including rainwater harvesting, water efficiency, and the use of grey water systems to reduce water demand when it is less likely to be available, such as during the summer period. • The impacts of climate change can be managed by water company: climate adaptation strategies, WRMPs, corporate risk register (to identify and manage interdependencies with other utilities) etc.
Natural hazards (drought and flood risk) including economic resources to prepare for and address risks 	**Current** • Better, integrated land management policies, such as managing run-off. • Understanding the possible impact of natural hazards both environmentally and operationally for water companies is critical to understand the systems and therefore what the opportunities are to better manage risks. • Where natural hazards can be avoided (as opposed to unavoidable hazards such as volcanoes) approaches are part of the action on climate change.
	Future • Build a more resilient 'natural' environment to manage water and run off. • Large-scale improvement of soil management (agricultural), especially peatlands, (whether near-natural or currently given over to agriculture or forestry) to increase water storage capacity. This reduces flood peaks and runoff-related water quality issues during times of high rainfall and supports infiltration and maintenance of base flows during dry periods. • There should be a focus on working with natural processes to reduce reliance on costly engineered schemes.

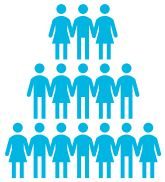
Risk Theme	Opportunities to manage risk
Political or regulatory frameworks (current or reformed)	**Current** • The key short-term resilience risk to the water sector is the current economic regulatory framework, driving costs down rather than focusing on driving value up, resulting in rising charges. • There needs to be a national, government-led initiative to tackle water efficiency (encompassing water labelling and building standards). Political and Regulatory frameworks need to recognise water that is currently too cheap. A modest raise in bills would not be catastrophic and would serve to allow the industry to invest more consistently in infrastructure. • Strong policy measures and managing provision of housing/ infrastructure based on impacts. • Better promotion of Farming Rules for Water, and measures that build on them. In addition, enforcement of baseline regulation is required, with a focus on Environmental Land Management (ELM) scheme to deliver a means of tackling difficult issues such as inadequate slurry storage. There should be an enhanced focus on wetland habitats through the Environment Bill & delivery of the 25 Year Environment Plan. It is important link to freshwater habitats in terms of hydrology, water quality and species. • Education, information and training to better inform all ministers and advisers and embedding the concerns to empower prioritisation. **Future** • Strong policy measures and managing provision of housing/ infrastructure based on impacts. • Regulators to be properly resourced, trained, allowing them to be clear on what their responsibilities and role entails. There is currently confusion over roles and responsibilities.
Socio-economic factors such as population growth	**Current** • Education, information and training to reduce impact. **Future** • Changes in societal norms should be considered in the future in addition to population growth.
Unsustainable abstraction, abstraction reform and changing abstraction licences	**Current** • Unsustainable abstraction can be managed through licensing. • Changes to abstraction licence are critical – risks can be identified and manged by taking a holistic view. Is a change in abstraction the best overall environmental solution or is there a risk that abstraction reduction or change in one catchment leads to solutions with a greater overall environmental impact in another catchment?

Risk Theme	Opportunities to manage risk
	Future • Significant stakeholder interest in chalk streams suggests reduced abstraction would be beneficial, protecting habitats and reducing conflict. Environmental enhancement in the interim (as per Southern Water's S21 Agreement on the Test & Itchen) will serve to provide longer-term resilience to the habitats, and targeted water efficiency schemes in areas served by chalk rivers & aquifers will reduce demand. Better data & modelling may allow less rigid abstraction regimes than historic seasonal or monthly limits, and investment in rainwater harvesting will ease pressure in times of peak demand – It should be considered whether this can be facilitated by the water industry in the most critical areas, e.g. working with developers. • Research to ensure better water management is promoted across stakeholders and supply chain partners. • There is a danger of diminished resources being (further) unevenly spread as a result of market dominance and control of supply.
Agricultural intensification/damaging fishing practices 	**Current** • ELM (and other funding means including the water industry), to more effectively facilitate landscape-scale collaboration, for benefits 'greater than the sum of their parts'. • Education, information and training in agricultural colleges and universities to target sustainable change coupled with agri-environment incentivisation. • Relates to patterns of consumption and addressing unsustainable land use and activity at sea and on the sea bed. Evidence is that food production is itself being undermined by land degradation and nature's decline. Solutions lie in proper stewardship of soil, water and land and spreading of the skills this involves.
Declining water environment quality including known deterioration (nitrate, phosphorus, metaldehyde) and	**Current** • Legislative and appropriate funding mechanisms for the agriculture sector, in addition to the development of non-chemical alternatives. • Introducing legislation to stop the use of harmful pesticides, fertilisers etc. or at least ensure that the external costs of using these products are covered by those who use them.

Risk Theme	Opportunities to manage risk
Other risks (combined sewer overflows and emerging substances) 	**Future** • Historic groundwater pollutants can possibly be mobilised in the future through changing land use and development. In some areas, nitrate concentrations are predicted to continue to rise into the future. This is partly due to legacy effects, but also due to more recent leaching. Here we have an opportunity to work with farmers (the dominant source of nitrate leaching) to find a catchment solution. Cover crops offer a great opportunity to tackle nitrate leaching but also provide natural flood management, biodiversity, water resources and air quality benefits. There are also opportunities to work with partners to investigate solutions to provide better management of surface water to prevent pollution incidents, and to support research into new and emerging pollutions such as micro plastics and persistent chemicals linked to pharmaceuticals.
Ageing infrastructure/ asset failure (with associated cost implications) and leakage 	**Future** • Better understanding through modelling, monitoring, and citizen science, in order to prioritise investment. • New investment (by the industry as well as developers, etc.) to better future-proof, especially in terms of waste water capacity. • Increasing use of natural techniques e.g. treatment wetlands to supplement built infrastructure. • The proposed UKWIR project – 'Asset Health Indicators - Forward Looking Metrics' looks to set a common action for the water sector to provide a commitment to work to develop robust forward-looking asset health metrics and provide greater transparency of how asset health indicators influence operational decision-making • Investment.
Urbanisation, urban creep and land-use change 	**Current** • There are sustainable forms and patterns of physical development, urban greening and restoration of natural and semi natural features which can be deployed as part of reversing land degradation and fragmentation. **Future** • From a catchment perspective urbanisation presents risks for water quality, water resources (both direct and indirect), flood risk management and biodiversity. These multiple risks however, present multiple opportunities to mitigate the risks. Many of the solutions for mitigating the impact of urbanisation will have multiple benefits, such as sustainable drainage systems (SuDS), green roofs, and rain gardens. Therefore, water companies have an opportunity to work collaboratively with others such as flood risk managers, NGO's and local businesses to joint fund solutions. There are also opportunities to engage with the growing urban population to be part of the solution through collective action. • Ensure tight planning regulations and punitive powers to resist growth - reduce the incentivisation of 'development' by short term economic gain.

Risk Theme	Opportunities to manage risk
Water shortage 	**Future** • Earlier use of customer communications to reduce consumption, but also to raise awareness of the value of water more broadly (for knock-on benefits such as reducing blockages by un-flushable items, informing consumer choices on appliances, etc.). • More investment in habitat enhancement including in-river restoration measures and climate change adaptation/resilience measures, to increase the resilience of freshwater habitats (and therefore water resources) to low flows.
Water efficiency in households e.g. household appliances, water meters 	**Current** • Water use and understanding personal use will be key to driving down consumption. Opportunity to join with other organisations to highlight and educate people about the volumes involved with direct activities and the link back to the environment. **Future** • We should invest today to deal with long term risks, however the current regulatory structure does not support this if it were to increase customer costs.
Affordability and vulnerability of customers along with changing customer expectations 	**Current** • Risks around some groups of vulnerable customers could be managed with an increased range of variable tariffs.

Risk Theme	Opportunities to manage risk
Financial crisis (i.e. a lack of resources to successfully manage risks such as water shortages and environmental degradation)	**Future** • Financial crisis creates pressure to keep customer bills low, yet investment is needed to increase sustainability. Ofwat processes/mechanisms need to facilitate investment, e.g. the innovation fund is welcomed. Approaches like EnTrade are valuable, enabling cost-effective achievement of water industry needs. Opportunities to jointly fund initiatives such as agri-environment schemes and supply-chain initiatives (such as Coca Cola & Jordans) should be explored. A move to natural capital accounting is important to demonstrate wider benefits of investment (to both Ofwat and customers). Reward tariffs warrant greater consideration to enable customers more opportunity to reduce costs. Water efficiency schemes specifically focusing on vulnerable customers would do the same.
Security risks e.g. cyber security	**Current** • More resource is required to maintain security (cyber and physical) to enable systems to remain active.
	Future • Reduce reliance on digital systems and train and empower people to be able to step in.
Biosecurity/pest and disease management (including invasive, non-native species)	**Future** • Prevention of raw water transfer between catchments. • Management of invasive, non-native species using controls such as rust fungus on Himalayan Balsam. • Management of recreation risk and waste management between catchments. • The ability to anticipate trends and risks based on scenarios resulting from climate and nature breakdown.

Risk Theme	Opportunities to manage risk
Changing labour market and skills shortage 	N/A
Digital revolution benefits, potential for over-reliance on technology and associated risks e.g. system failure	**Future** • Reduce reliance on digital systems and train and empower people to be able to step in. • We should re-consider the view that technology will solve everything. Technology can help, such as clean engine technology and manufacturing, but it can also obscure simple existing ways and practices to solve existing problems and avoid them being problems in the future. For example, proper stewardship of soils and rivers may not need to involve new technology and inventions. Technology can help but can also be a distraction from perfectly good practices which may have fallen out of favour.
Public health and Infectious diseases (people and animals)	**Future** • Earlier identification and anticipation of threats.

Risk Theme	Opportunities to manage risk
Water company dependency on other sectors (i.e. telecoms and power failures)	• N/A

G.2 Additional risk management opportunities identified in the survey

Questions 7 and 9 provided the opportunity for survey respondents to provide additional information on risk management opportunities for current and future risks, as provided below.

G.2.1 Current Risk Management Opportunities

- There is a statutory requirement (the Environment Bill) to create (plan and deliver) a spatially-mapped Nature Recovery Network to inform action to bring about nature's recovery, which will include:
  - Informing decisions on planning (both strategic planning, e.g. local plans, and individual developments);
  - Directing agri-environment funding under a new ELM scheme;
  - Providing connectivity for species to move between sites in response to pressures including climate change; and,
  - Identifying the activities needed for a given area that will deliver most for biodiversity (primarily) and other ecosystem services (in addition).
- One response suggested that the Local Nature recovery Strategies and Nature Recovery Networks provide a means for protecting and enhancing natural capital assets and whether water companies could influence the development of these resources through involvement in Local Nature Partnerships. Natural capital approaches were identified as a technique to undertake more wide-ranging assessment of impacts.
- Natural capital was also identified as an approach to change the fundamental management and funding of water. The current system which is based on the public water system (abstraction, supply, use, treatment and discharge) was considered no longer fit for purpose.
- At the catchment-level, adopting an integrated ecosystems approach was recommended. Similarly, it was recommended that it is ensured that future agricultural land management schemes are developed to address environmental issues at a catchment level, rather than national level.
- Within the survey responses it was argued that the environmental and financial regulatory regime is inadequate to deal with current risks. It was subsequently argued that: infrastructure is physically failing; water company management systems are built to fail; enforcement is woefully inadequate; and the environment continues to decline in scale and quality.
- Implementing and funding present regulatory requirements e.g. Water framework Directive by required deadlines
- Systems thinking is needed to ensure sufficient consideration is given to assets and the relationship with the wider environment they operate in. This includes the natural environment and a greater understanding of the reliance and impact on natural capital. Natural capital should be invested in alongside manufactured/financial capital.
- It should be ensured that short term investment does not compromise long term goals. Roadmaps to ensure resilience are required.
- It will be important to understand the interdependencies across systems which can be exposed to stresses and shocks such as extreme events.
- A more proactive, less reactive approach to risks and shocks is required compared to a reactive approach. This will allow better prediction and management of risks and shocks.
- Sectors (and companies within sectors) working collaboratively facilitates an opportunity to help minimise environmental damages and water shortages (also considered to be a future risks and opportunity).

- Better use of digital platforms affords an opportunity to manage information and risks in real time (also considered to be a future risks and opportunity).
- Risk management should be informed by better science to inform decision making, through providing credible evidence (also considered to be a future risks and opportunity).
- Partnership working should be led through a combination of local and strategic solutions to managing risks (also considered to be a future risks and opportunity).
- More flexible permitting would allow risks to be managed more dynamically (also considered to be a future risks and opportunity).
- It was suggested that the water company requirement to connect new developments should be reconsidered, allowing water availability to be appropriately considered within national planning policy.
- Additional funding for local community groups and eNGOs was suggested as an area of future consideration.

G.2.2 Future Risk Management Opportunities

- The role of natural capital accounting was identified as a fundamental element of long-term decision-making processes.
- The use of regional and national planning to improve the resilience of infrastructure is considered to be an area of opportunity.
- It was suggested that most opportunities for managing risks are down to political will, as opposed to not knowing how to approach risks. Opportunities are therefore identified around educating the electorate as to the problems we face.
- Due to the interdependencies of both the environment and the utilities sector, the role of natural hazards (such as drought and flood events and the changing frequency and duration and severity of events) will have an impact on future resilience risks.
- Lack of investment in future infrastructure may be a large future risk with increased levels of leakage.
- Reform of the water sector, including greater weight for investment in long-term sustainability measures is required. Rebuilding sewage networks; greater investment in catchment management, natural flood management and agricultural land use/management change are essential. Creating a wastewater treatment system that does not overflow during rainfall events is fundamentally important. Engineering better storage, as well as managing demand and efficiencies is critically important to allow abstractions from environmentally sensitive areas e.g. chalk aquifers, to be reduced.
- Ensure better integration with variety different plans and departments at the catchment level through properly resourced catchment partnerships.
- Alignment of the time frames between different plans, for example Water company business plans, River Basin Management Plan, Flood Risk Management Plan, Nature Recovery Networks, housing targets etc.
- A national water quality monitoring network (Environment Agency, water companies) supported by qualified and resourced citizen scientists.