Method Statement: Resilience Framework

November 2022

Title	Method Statement: Resilience Framework
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For the full library of WRSE Method Statements, please visit wrse.org.uk/library.

A consultation on the WRSE Method Statements was undertaken in Autumn 2020 – the consultation details can be viewed on the WRSE engagement hq platform at https://wrse.uk.engagementhq.com/method-statements.

An additional consultation on the Resilience Framework has also been undertaken – the consultation response can be found at https://www.wrse.org.uk/media/qybbxsqw/resilience-framework-response-to-feedback-03-august-2020_final.pdf.

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Executive summary

Water Resources South East (WRSE) is developing a multi-sector, regional resilience plan to secure water supplies for the South East until 2100.

We have prepared Method Statements setting out the processes and procedures we will follow when preparing all the technical elements for our regional resilience plan. We have consulted on these early in the plan preparation process to ensure that our methods are transparent and, as far as possible, reflect the views and requirements of customers and stakeholders.

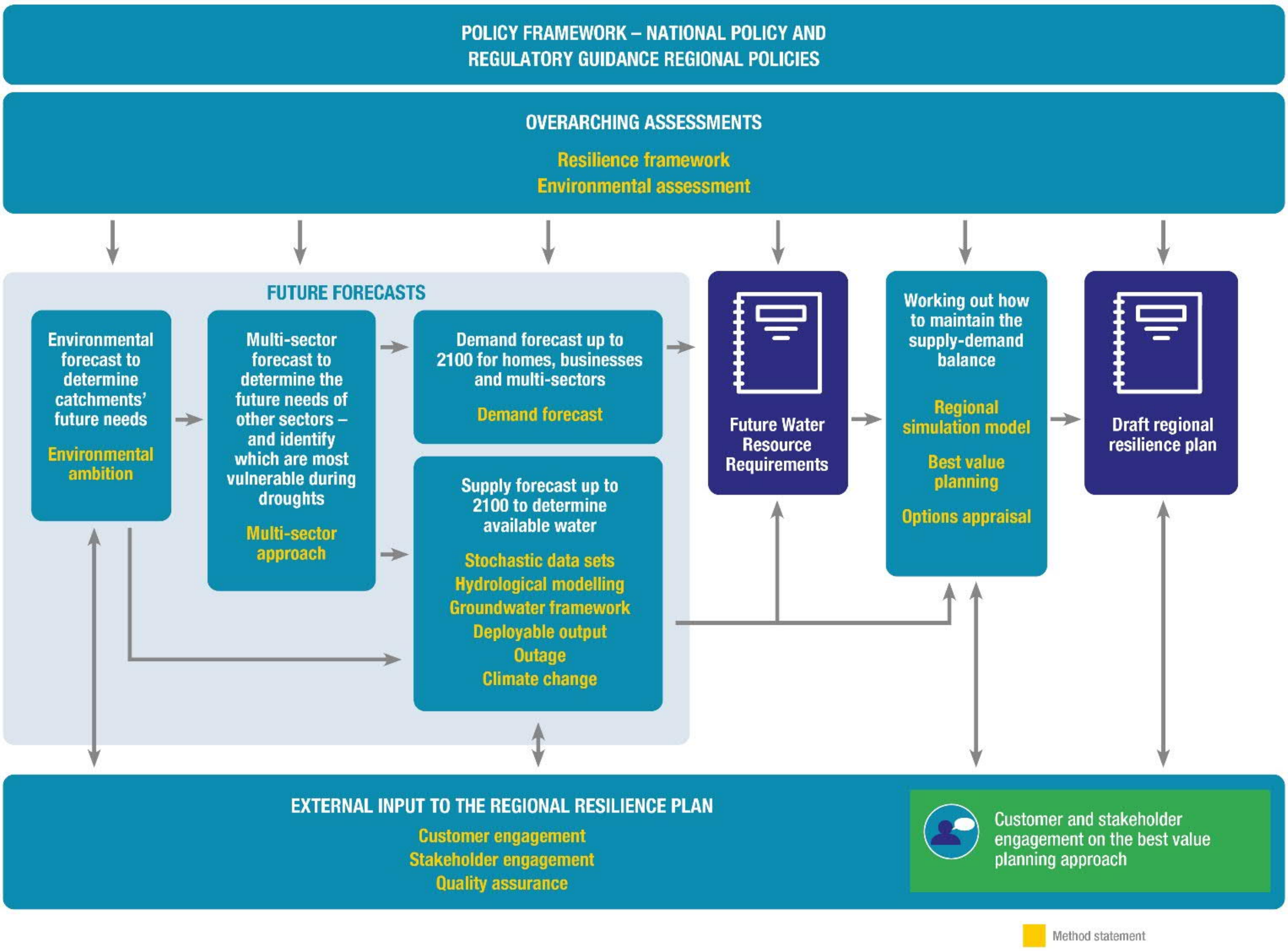
Figure ES1 illustrates how this resilience framework Method Statement will contribute to the preparation process for the regional resilience plan.

To make sure our plan is resilient to future shocks and stresses – both the ones we can forecast and those we can't – we're going to develop and test our plan against a new resilience framework. This will allow us to assess options in terms of greater resilience to short-term shocks and long-term trends, as well as for cost, best value and impact on the environment.

This is a new framework which we have already published for consultation (WRSE Securing resilient water resources for South East England) but our method statement sets out how we have developed it, and how we will use it to assess the resilience of our regional resilience plan.

A specific framework is needed because there are a number of important aspects of `water resource resilience' that are not currently covered by more conventional assessments (and which tend to be economic and environmental -led). We also need to move away from a planning approach that has concentrated on a single 'hazard' – a shortage of water caused by droughts – to one that looks at the resilience of non-public water supplies, the environment and our society and economy more generally.

Figure ES1: Overview of the Method Statements and their role in the development of the WRSE regional resilience plan



The Resilience Framework Technical Report Consultation Document and the summary of the response to the consultation can both be found in the document library on the WRSE website.

1. Introduction

This Method Statement outlines the final framework approach that Water Resources South East (WRSE) has implemented to allow us to incorporate the concept of 'resilience' into our regional planning process. This framework helps to move us from a focus on securing public water services and managing the risk of droughts, to securing wider resilience across a series of connected water systems.

We recognise that the water resource systems across the South East of England are complex, multi-sector and interlinked, and that risks associated with drought events cannot be viewed in isolation if we are able to address the challenges and identify the opportunities that exist within the domain of water resources within our region. We also understand that future shocks and stresses are uncertain, and the way in which we plan to invest in improvements to our water resource systems needs to reflect that in order to be resilient in themselves.

The framework described within this document is therefore intended to allow us to evaluate and quantify 'resilience' so that we can incorporate the concept into our wider best value planning of water resources for the south east. We consider this is an important step towards a wider, more integrated understanding of water resources planning.

For more information on WRSE and its members, the development and purpose of the regional plan and how it fits into the national picture, please visit wrse.org.uk.

2. Feedback on our approach

As laid out in our document: 'Securing resilient water resources for South East England – our response to feedback on our resilience framework', we collated responses on our initial draft framework and have reflected them where appropriate within this document. The key changes we have made as a result of that consultation can be summarised as follows:

- We have carried out a full, systems mapping exercise of the key systems associated with water resources in the south east and ensured that the metrics we have used to measure resilience reflect the most important interactions between those systems.
- We have considered the south-east economic and social system as underlying the other three key systems and looked at how relevant feedback loops might affect our framework. That process specifically identified metrics relating to customer response during drought, and engagement with catchment management, which have been incorporated into the scoring metrics.
- We have clarified how the resilience framework fits in with and interacts with the rest of the best value decision making framework, particularly in relation to environmental value criteria, and we have enhanced the role of supporting catchment services in the resilience framework.
- Links to the national resilience assessment and Cabinet Office definitions of resilience have been made clearer and more explicit. The role of response and recovery is clearly identified, and the ability of investment programmes to evolve and incorporate innovation has been strengthened.
- The interactions with 'shortfalls' in the baseline system resilience, including parts of the public water supply system where there are known or suspected resilience issues, and catchment and soil health deficits for the water environment, have been made clearer.
- The water quality metric has been enhanced to include both the resilience of water resource options themselves, and the impact that changes might have on wider catchment water quality.
- We have implemented a carefully controlled process for managing subjective metric scoring to ensure, as far as is practical, that assessments are consistent and unbiased. This has been subject to an assurance review.
- We have avoided the need for metric or option weighting, with all benefits scaled according to an options contribution to a relevant regional deficit. Inputs relating to hazards and shock events other than drought have been clearly identified within the metrics.

3. Summary of the framework

The first question that arises is 'what do we mean by *resilience* in this context'? There are a multitude of possible definitions and responses to this, and, in line with the National Infrastructure Commission, we have adopted this as a concept rather than a specific definition. In concept:

'Resilience is about the ability to continue to function effectively in the face of future challenges. The requirements to achieve it change over time, as challenges alter.'[1]

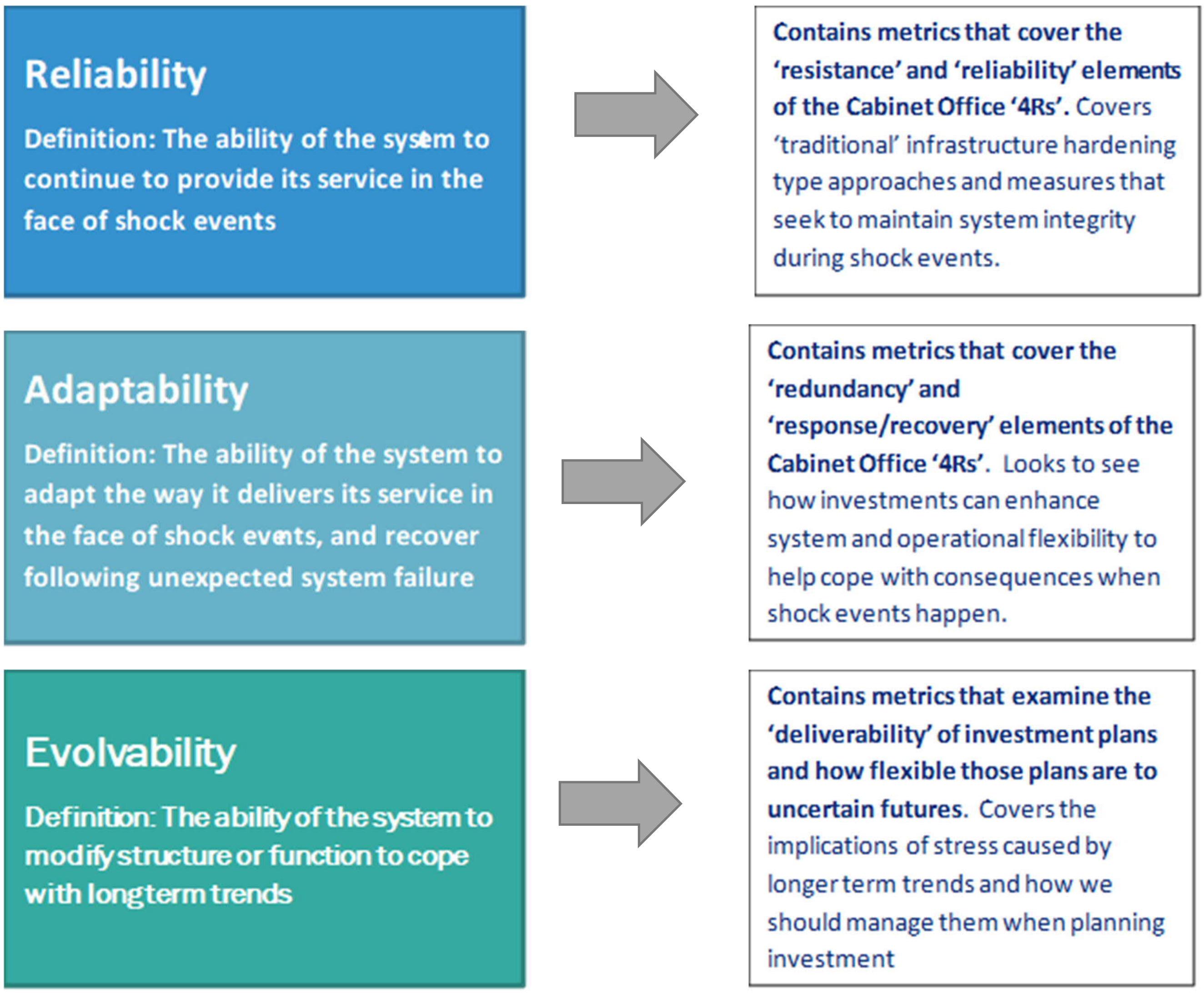
Whether or not a system can be considered to be functioning depends on whether or not it is able to provide the service that we desire from it. We explore the concept of service and how it relates to resilience later in this section.

Our resilience framework is based on the three key attributes of *reliability, adaptability,* and *evolvability.* These describe how our systems are able to cope both in the face of 'shock' events (transient events such as drought or pandemic that can act to disrupt the function of the system) and future 'stresses' (trends that affect the functioning of the system). These attributes have been modified from the framework proposed by Boltz and Brown's 'Resilience by Design' approach[2], and one of the authors of that paper has been involved as an expert reviewer throughout the framework development.

We have chosen this method because it incorporates the required 'resilience in the round' approach recommended by Ofwat, and the 4R's recommended by the Cabinet Office to understand the resilience of existing systems and extends this to include an assessment of how resilient our investment plans themselves are to future uncertainties. A summary of the three attributes and how they relate to the best practice recommended by the Cabinet Office and Ofwat is provided in the figure below.

[1] National Infrastructure Comission, 2019 Resilience Study Scoping Report

[2] Boltz, F., N.L. Poff, C. Folke, N. Kete, C. Brown, S. Freeman, J. H. Matthews, A. Martinez and J. Rockström. 2019. Water is a master variable: solving for resilience in the modern era. Water Security 8: 1000483. https://doi.org/10.1016/j.wasec.2019.100048



In our case it is important to note that the WRSE resilience framework sits within the wider 'Best Value' decision making framework. Within that framework, all of the value criteria described in the figure below are evaluated and considered when the decisions are being made about the preferred regional plan. That means value criteria such as carbon reduction, and the day-to-day condition of the environment are contained elsewhere within the best value decision making framework (the environment framework in that case). Similarly, societal resilience in the form of cost burden and economic considerations are evaluated elsewhere in the best value decision making framework.

The framework presented here concentrates on the ability of regional water resource systems to respond to shocks and manage long term stresses that might affect our ability to invest in and improve that response. Factors such as natural capital, biodiversity net gain, carbon emissions and affordability are not included in this resilience framework as that would mean they are double counted within the best value framework.

Covered by this framework

As well as the over-arching concept and definitions of the three resilience attributes, there are two further key concepts that inform our resilience framework.

Systems approach.

In accordance with accepted best practice, our approach to resilience is *systems based*. That is, we evaluate the resilience of the systems of interest as a whole, with a view as to understanding how well they can continue to provide the required service in the face of shock events and long-term stresses. In this case there are three primary systems of interest: the public water supply (PWS) system, the water environment (environment) system and the non-public water supply (non-PWS) system (i.e., other sectors that use water from sources other than the public utilities). We have undertaken a detailed process of systems mapping to identify how these systems interact with each other and how they interact with the wider south east regional socio economic system, and used this understanding when developing our scoring metrics (see below) and the approach to implementation described in the next section.

Scoring metrics.

The three core attributes (reliability, adaptability and evolvability) of the resilience framework are not specific enough to allow us to measure them directly, so we apply a number of *metrics* that allow us to evaluate the resilience of the existing systems and proposed investment plans. These metrics have been identified through a process of *systems mapping* and are deigned to allow us to quantify the impact that potential options for regional investment might have on the resilience attributes for each system.

Our resilience framework therefore looks at the three systems and examines how well different water resource programmes that are being considered by WRSE might help those systems provide the resilient service that we want from them, as summarised in the figure below.

What is the SYSTEM?	What does it (typically) include?	What is the *service* we want?
Public water supply	Operation, infrastructure and supply chain associated with abstraction, treatment, and bulk network distribution, plus the nature of water demand on the system	Secure supplies that maintain availability to customers irrespective of hazards that might affect water resources
Non-Public Water Supply (other Sectors)	Management and infrastructure for abstraction and economic activities that rely on that water (crops, industrial processes etc)	Predictably available water resources that support relevant social and economic activities
Water environment	Catchments, including soils and hydrological processes, along with water bodies and their ecology	Catchments and water bodies that are able to help maintain water quality and ecology during and after shock events

We carried out *systems mapping* to understand how these three interact within the south east regional context ('system of systems') and make sure we are measuring all those metrics that describe the relevant interactions

We defined the service we want to understand how different options and investments help avoid failure of the service (i.e. promote resilience). We measure this through our option metrics

In summary, our resilience framework is designed to allow us to:

- Define the three systems that we need to consider, and understand how they interact within the wider south east context.

- Define the service that we desire from these three systems and the attributes of resilience that we consider will help to maintain this service over the long term.
- Understand how all of the water resource options that we have identified as being potential investments for the regional Plan can contribute to our three resilience attributes, in the context of the three systems that we have identified.
- Identify metrics through which we can score the resilience contribution of each option and potential investment portfolio, based on the systems mapping that we have undertaken in the context of the wider south-east region.
- Evaluate the benefits that the plan has on the baseline regional resilience (the ‘resilience shift’), in terms of the number, type and extent of known pre-existing resilience issues that are addressed by the planned water resources enhancements.

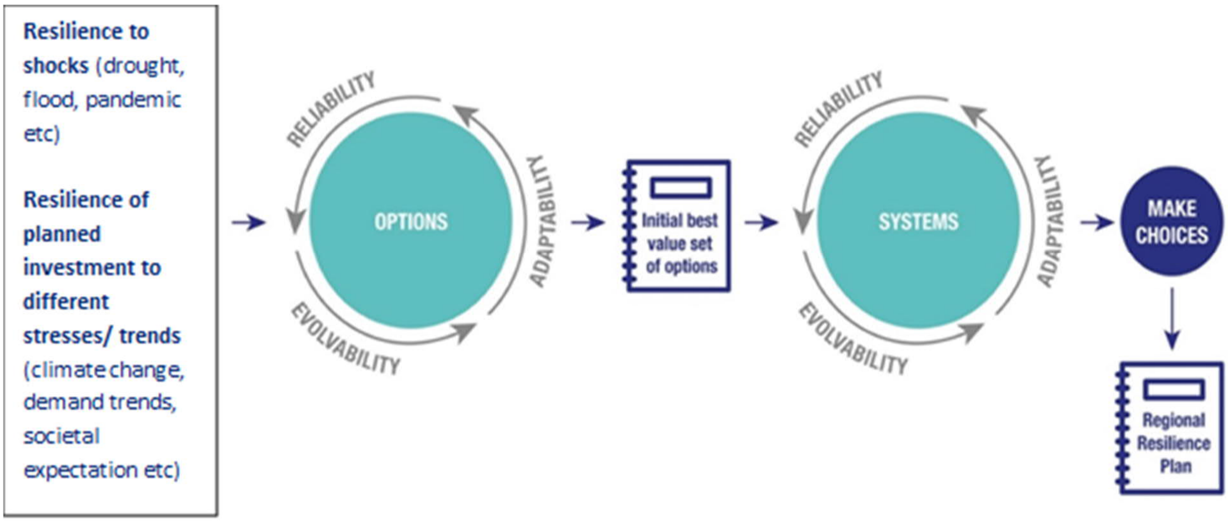
4. How we have applied the framework

Concept and purpose of the framework application

The resilience framework was designed to allow WRSE to consider how all the options, schemes and strategies that have been identified as potentially contributing to water resources in the region might affect the resilience of the PWS, non-PWS and water environment systems. Not all options/schemes will affect all aspects, but the metrics have been designed to ensure that all reasonable benefits have been captured, and the scoring system is designed to allow different options, strategies and schemes to be compared on a reasonably consistent basis. It is meant to be comparative, not absolute, and we recognise that there will be more variability for some metrics. That is an expected outcome of the framework, i.e. it helps us understand how and where the regional plan can affect the resilience of water resources in the region.

Because the framework is designed to score resilience in a consistent, comparable way, we can use it to compare the overall resilience of potential water resource programmes that we identify during the best value decision making process. The framework is essentially applied in two stages:

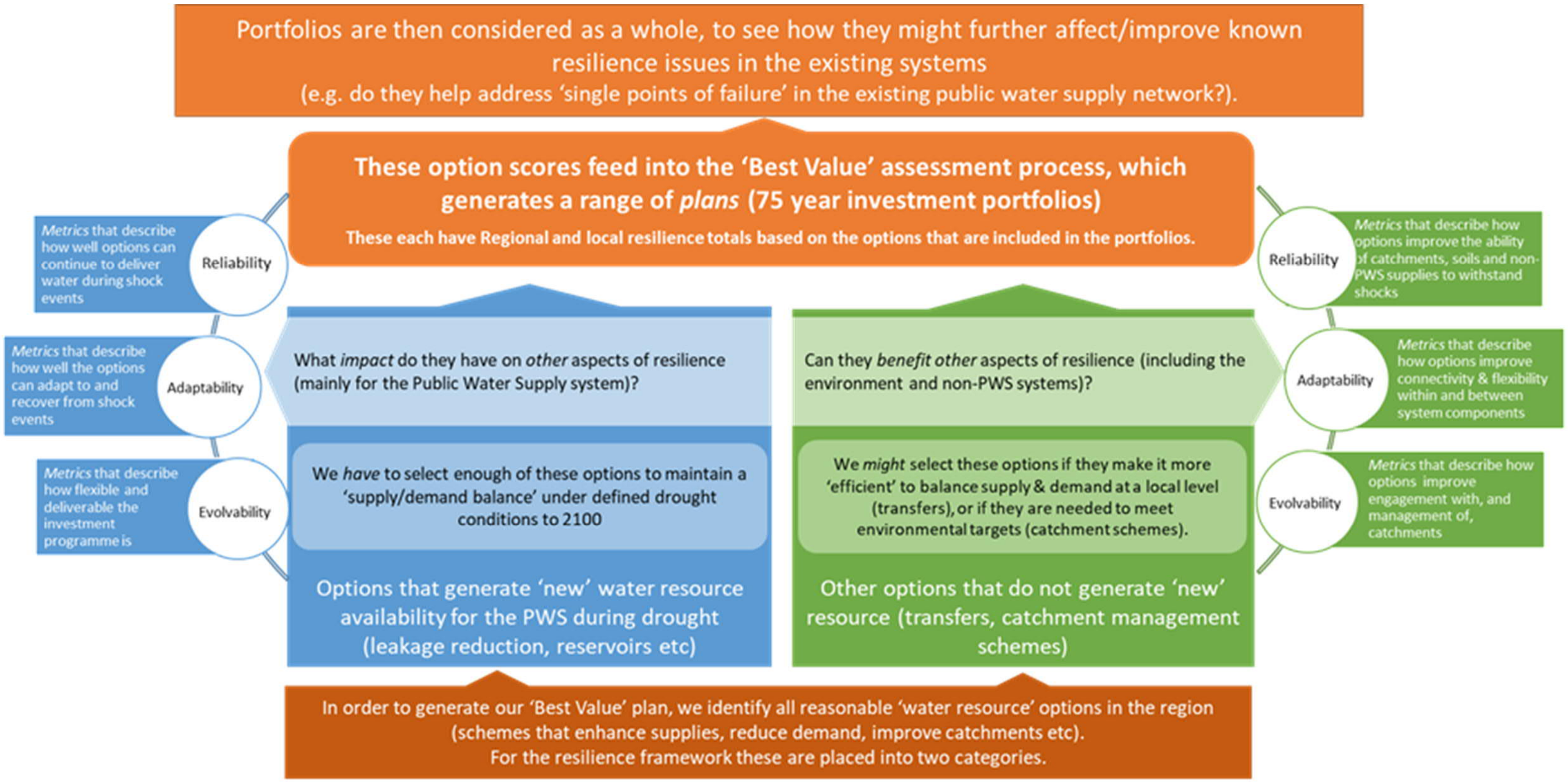
1. As a scoring method for individual options that the regional plan could consider to address its identified water resource needs
2. At a 'portfolio' level (i.e. as a whole across the proposed investments within a water resource programme and the existing systems) once a range of potential plans have been identified. This is summarised in the figure below.



One of the main points that we had to account for in the framework was that the majority of options have been designed to address a specific requirement, primarily related to drought resistance (supply/demand benefit) or environment (enhancing natural capital, biodiversity net gain etc), but those options also have a potential impact on our resilience metrics, and this could occur across more than one system. We also had to account for options that either directly, or as a result of their nature, helped to address existing resilience deficits within the *existing* PWS, non-PWS and environment systems. For example, a catchment management scheme may be designed to enhance water quality specifically for PWS supply capability, but in doing so it might also help to improve known soil health issues in the catchment and help promote public involvement in the catchment, which, in turn, enhances customer co-operation during drought events.

The framework addresses this by compartmentalising and scoring individual options prior to the generation of candidate best value water resource programmes, and then by evaluating those programmes against existing known system issues, as shown in the Figure overleaf.

Summary of the process used to generate resilience scores for candidate water resource programmes



5. How we have measured resilience for options and programmes

As indicated above, the performance of options (covering demand management strategies, supply options, transfers and catchment schemes) in relation to resilience is scored through the use of metrics. Further metrics are then scored once candidate investment programmes have been identified. Details of the scoring process and guidance are provided in the Technical Appendix to this Method Statement.

These metrics were identified and then refined through an extensive process of systems mapping, which identified the key contributors to water resource resilience, and the interactions between the systems. This systems mapping is described in the WRSE report 'WRSE Resilience Phase 2: Multi-Sector and Systems Approaches'. A summary of all of the resulting metrics that were identified, separated according to the benefitting system and the type of resilience effect that they have, is provided below. To clarify, the metrics themselves are indicated by the 'R1, R2, R3..' type descriptors below. The sub-headings (e.g. 'uncertainty of performance') have been included purely to give a high level conceptual description of the nature of the metrics contained in that sub-heading

Overall metric summary table

System attribute	RELIABILITY	ADAPTABILITY	EVOLVABILITY
System Indices	UNCERTAINTY OF PERFORMANCE	TIMING AND WARNING OF EVENTS	FLEXIBILITY AND DIVERSITY OF OPTIONS
Metric	**R1** PWS △ Uncertainty of supply/demand benefit	**A1** ★ PWS Expected time to failure (PWS)	**E1** PWS △ Scalability and modularity of interventions
Metric	**R2** ★ N-PWS ENV Breaches of flow and level proxy indicators	**A2** ★ PWS N-PWS ENV Duration of enhanced drought restrictions	
System Indices	ABILITY TO PERSIST WITH PLANNED FUNCTIONS	ABILITY TO RESPOND TO AND RECOVER FROM UNEXPECTED FAILURES	DELIVERABILITY OF PLANNED CHANGES
Metric	**R3** ★ PWS ★ △ Risk of failure due to physical hazards	**A3** ★ ★ PWS △ Operational complexity and flexibility	**E2** PWS △ Intervention lead times
Metric	**R4** PWS Availability of additional headroom	**A7** PWS △ Customer engagement with demand restrictions	**E3** PWS △ Reliance on external bodies to deliver change
System Indices	RESILIENCE OF SUPPORTING SERVICES	SYSTEM CONNECTIVITY AND EASE OF SYSTEM RECOVERY	MONITORING AND MANAGEMENT OF CHANGE
Metric	**R5** ★ PWS N-PWS ★ △ Catchment / raw water quality risks	**A5** ★ PWS △ PWS system connectivity	**E4** PWS Flexibility of planning pathways
Metric	**R6** ★ ENV Capacity of catchment services	**A4** PWS WRZ connectivity	**E5** N-PWS ENV Collaborative landscape management
		A6 N-PWS ENV Inter-catchment connectivity	
Metric	**R7** ★ PWS Risk of failure of supporting service due to exceptional events		
Metric	**R8** ★ N-PWS ENV △ Soil health		

Metric applied to:
- PWS Public water supply
- N-PWS Non-public water supply
- ENV Environment

★ Evaluated for the baseline system as well as for investment options

Metric calculated by:
- Semi-qualitative subjective scale
- Calculated (at option and portfolio level)
- Calculated (only as part of portfolio)

In accordance with the overall concept, the approach to scoring has been carefully designed to allow the resilience impacts of options to be simply added together without any need for subjective weighting to generate an overall score for each investment portfolio. At the same time, it is important that the resilience scores generated for different portfolios can be compared on a consistent basis. These objectives have been achieved through the application of two over-arching principles to the scoring process:

1. All metrics are described according to the same 5-point scale approach, ranging from 'notably less resilient (2 points below an average), through to 'notably more resilient' (2 points above average). There is a variety of ways in which metrics have been scored, from quantitative to semi-qualitative, as detailed in the technical appendix, but the key point is that impacts are all scored on a comparable basis.
2. The *impact* that individual options have on the overall metric scoring across the region is scaled according to the size of benefit they provide to the relevant key regional need. For example, if a water supply option can contribute 100Ml/d to an overall regional supply/demand deficit of 1,000Ml/d, then its *impact* value for a given metric (e.g. R1) is equal to its metric score * 100/1000. Using this 'scaling approach' means that all option impacts can be added in a consistent way to generate overall resilience scores for regional investment programmes.

These two principles mean that any potential investment programme that is being considered within the best value decision making process can be compared on a meaningful basis, against any other programme according to a single overall attribute score, which is equal to the sum of the impact values from options and strategies in that programme. Each of the resilience attributes (reliability, adaptability and evolvability) has this single overall attribute score for each programme, and the contribution of any individual scheme/option is visible based on the impact value it has for each metric.

The actual process for scoring resource options, demand management strategies and catchment schemes has been carefully managed and assured to address the risk of bias or misinterpretation when scoring has been carried out. This process is described in the relevant assurance report. The key elements can be summarised as follows:

- For water company supply schemes, relevant metrics were all initially evaluated by the WRSE team on a generic basis according to type (e.g. desalination plant feeding a system with limited/no storage). The generic scores were then challenged in an open workshop format across all companies and amended where appropriate logical/conceptual cases were made and accepted. The WRSE team then met with water companies on an individual basis to define 'bespoke' scores for individual schemes, mainly for larger options. Again, this was carried out on a challenge/accept basis, where changes to the generic scoring were only accepted by the WRSE team where appropriate logical and conceptual representations were made.

- For demand management strategies, relevant metrics were scored centrally by the WRSE team, based on the type of demand management initiatives contained within that strategy.
- Catchment and soils enhancement schemes (metrics R6, R8, E5) were evaluated according to the amount of movement that they provided towards the desired standard, according to the 5-point scale described above. This was done by the WRSE team using the baseline assessment as described in the next section.
- Additional programme level benefits (metrics R4 and A4) were evaluated using the investment model. For the draft regional plan the portfolio level metric assessments were not included for metrics R2, A1, A2, A6 and E4, while A5 was only used as part of assessment of the benefits of plans in addressing baseline resilience hotspots.

6. Evaluating impacts on baseline resilience issues

The resilience framework was not only designed to allow an evaluation of the level of resilience associated with the 'new' water resource that is provided by water resource options and demand management strategies. The existing PWS, non-PWS and environment systems were evaluated to understand where there may be deficiencies in the existing systems in relation to the metrics covered by the framework. This is important because the investments proposed by the regional plan can affect these pre-existing issues, and the assessment of how proposed regional investment programmes might affect these existing issues is an important part of the programme level scoring process. Baseline assessments were therefore carried out on the following aspects of the existing systems:

- For the PWS systems, interviews were held with all water companies to understand where there are likely to be concerns in the base year (2025) within their existing networks relating to metrics R3 (vulnerability to physical shocks), R5 (water quality risks), R7 (vulnerability to other exceptional events), A3 (system flexibility and complexity) and A5 (system connectivity). These interviews were used to generate a geographically based 'hotspot' assessment, similar in nature to the approach used in long term wastewater management planning. The initial regional 'candidate' portfolios were then reviewed to determine which schemes and combinations of schemes have the potential to feature in the final Regional Plan. These were then reviewed against the 'hotspot' assessment to understand where scheme combinations might benefit the existing supply system and enhance the overall resilience score for those portfolios that contain such beneficial scheme combinations.
- For the environment system the work carried out on catchment strategies for the environmental framework was used to determine where those strategies might benefit existing catchment resilience issues. This generated the scores for metric R6. Similarly, a regional assessment was carried out to determine the soil quality for all major catchments, and the potential benefits that catchment management schemes could have on areas of degraded soils. This generated the scores for metric R8.
- Although discussions were held with non-PWS system (multi-sector) representatives and important qualitative understanding was taken from those discussions, the outputs were not sufficiently detailed to allow a quantitative baseline impact assessment in the same way as the PWS and environment systems.

7. Next steps

An initial version of this document was consulted upon between 1st August 2020 to 30th October 2020 and comments received during this time have been incorporated in this version.

We have also reviewed this document against the final WRPG and supplementary guidance notes issued by the regulators.

If any other further relevant guidance notes or policies are issued then we will review this Method Statement to see if it needs to be updated.

When we have finalised our Method Statement, we will ensure that we explain any changes we have made and publish an updated Method Statement on our website.

Appendix 1: WRSE Updated Resilience Technical Appendix

Introduction

The purpose of this document is to provide clear guidance and advice for practitioners or stakeholders seeking to technically understand the Resilience Framework as part of the best value modelling process. This will ultimately ensure that the resilience framework is applied consistently and as intended by WRSE.

This document is related to the WRSE Resilience Method Statement (2021). The method statement is intended to provide a detailed description of the resilience conceptual model we are using and why we have selected it. In addition, the method statement provides an overview of our engagement relating to the resilience framework, highlighting how we have incorporated feedback in iterations of the framework. Practitioners or organisations reading this document should read the method statement document first.

This document covers the following sections:

1. Introduction: Provides an overview of the document purpose and structure as well as its relationship to other documents.
2. Background: Provides an overview of WRSE's definition of resilience and overall approach to resilience.
3. Guidance for organisations: Provides an overview of the key information for different organisations and where it is located in the report.
4. Metrics – provides an overview of the resilience framework and a schedule of all metrics, including definitions / descriptions. This section also describes the scoring approach for each metric.
5. Amalgamating metric scores – this section provides summary guidance for amalgamating individual metric scores to produce attribute level scores.

- Appendix A: Aggregation of metrics for EBSD modelling – this appendix provides a detailed description the mathematical approach to scoring, scaling and aggregating metrics for each of the three resilience attributes for the PWS system.
- Appendix B: Detailed metric scoring guidance – this appendix provides detailed guidance for scoring individual metrics.
- Appendix C: Mapping to other Resilience Frameworks – this appendix provides detailed guidance on mapping to other frameworks.

Background and Systems Mapping

We have been developing our resilience framework to support the best value regional plan since late 2019.

In our approach to the development of the resilience framework, we have used the following working definition:

> *Resilience is the ability of a system to reliably maintain, recover, adapt and evolve system performance in face of shocks and trends that would disturb it.*

In addition to this, our ambition for resilience spans water across the whole south east. This is something we articulated in our consultation on the draft resilience framework in the summer of 2020. In the consultation we also emphasised that achieving this ambition requires a perspective which is broader than public water supply (PWS) alone. Therefore, the WRSE conceptual framework for resilience addresses water in the context of the four following main systems:

- Society and economy
- Multi-sector e.g. agriculture, industry.
- Public water supply system
- Environment (which underpins and supports the other systems)

As we developed the resilience framework, we have mapped the interconnections and interdependencies of these systems. In doing this, we chose to refine the scope of our outlook on resilience to focus more specifically on the resilience of water supply services in relation to these systems. We have therefore adjusted the list above to the following, which has formed the basis of the framework of metrics we describe in Section 4 of this report.

- Public water supply system (PWS)
- Non-public water supply system (non-PWS)
- Environment system

The high-level systems mapping that was carried out to evaluate the relationships and measurement metrics that are appropriate for the Resilience Framework against the south east regional system and PWS system are replicated in Figure 1 and Figure 2. A more comprehensive version of the system maps, providing detail on systems in the environment, multi-sector systems and more information on the PWS, is available in the report 'WRSE Resilience Phase 2: Multi-sector resilience and systems approaches'. Figure 1 shows value creation and transfer across the systems. The orange lines indicate value flows that could be measured in terms of the six capitals framework. The blue lines are also multi-capital flows, but are coloured blue to indicate that the principal value is the provision of water. Black lines indicate the relevance of the resilience framework to the system. System resilience enables the system to maintain health and deliver its function in delivering valuable outputs. Figure 2 provides a high level PWS system map. Arrows indicate influence of upstream nodes on downstream nodes. The gold node is the key system function which is the supply demand balance. The yellow nodes represent outcomes to the social and economic system. The red node represents regional coordination.

Figure 1 Systems Mapping of the Water Resources Related Value Chain Across the South East of England

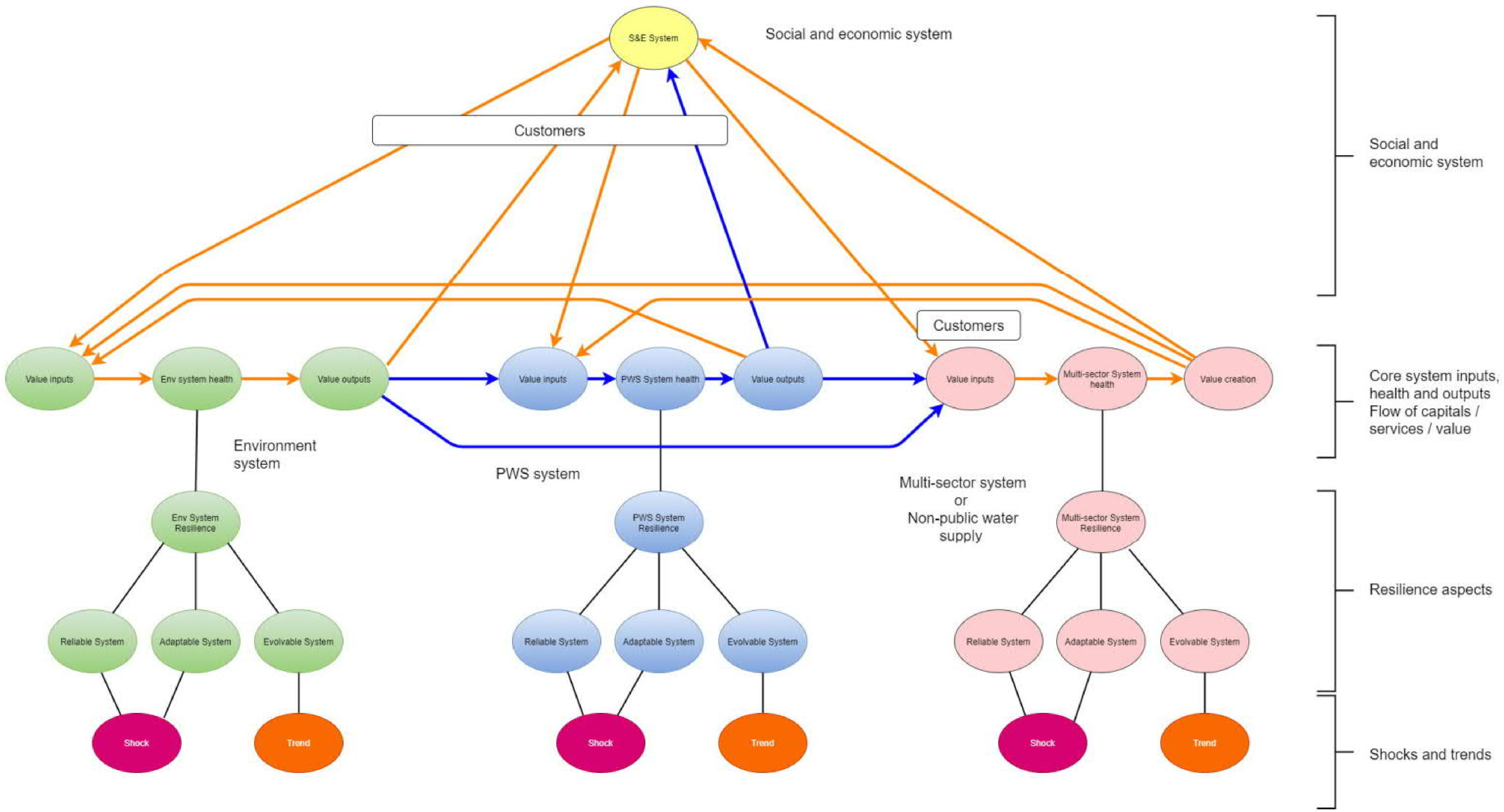
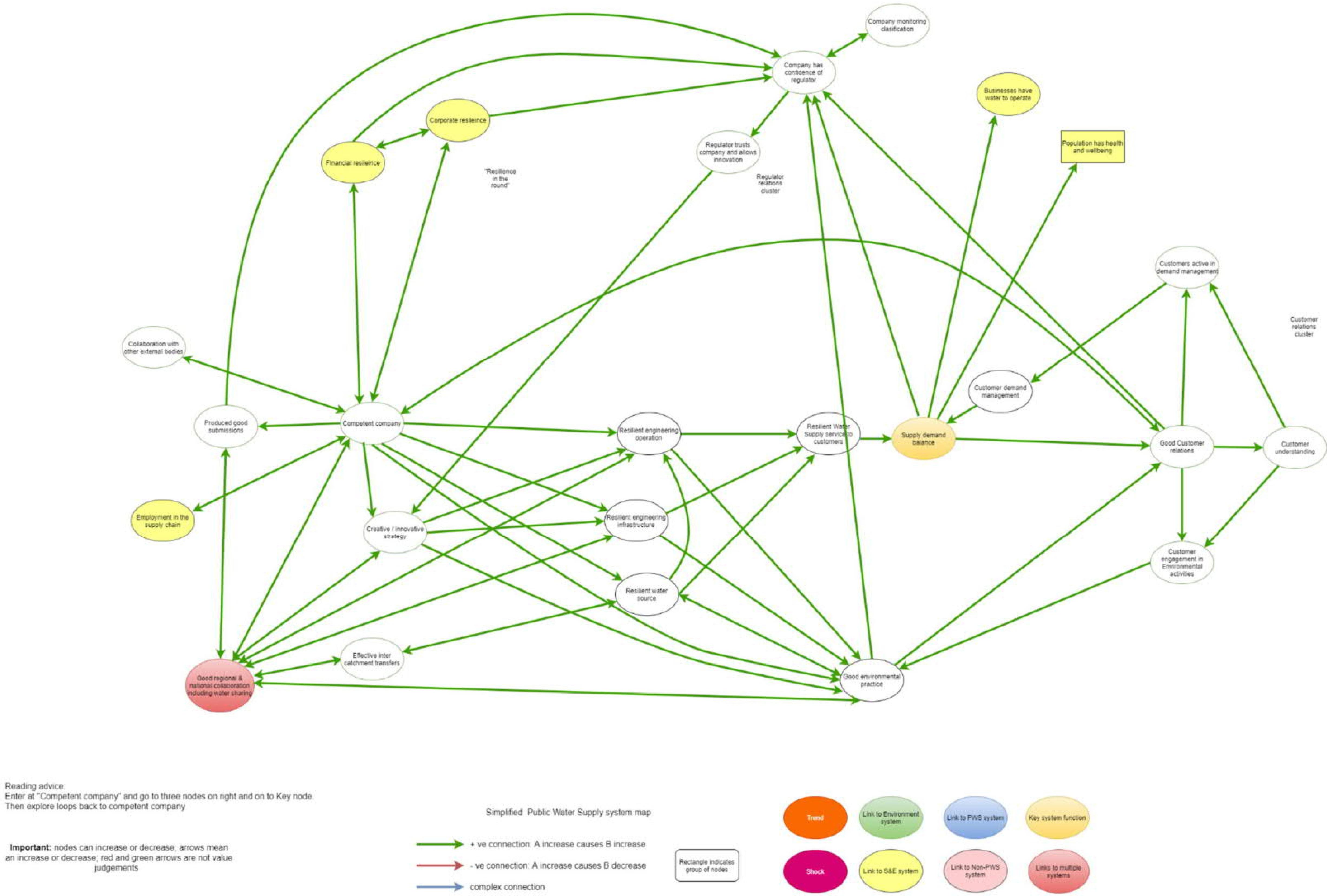


Figure 2 High Level Systems Map of the Public Water Supply System



As described in the main Resilience Framework method statement, the south east regional 'social and economic' system has not had resilience metrics or scores identified, rather the system mapping was used to identify the interaction between systems in the context of the south east regional 'system of systems'. The approach and relevant analysis are described in report 'WRSE Resilience Phase 2: Multi-Sector and Systems Approaches'. An integrated tool was used in the systems mapping, and node and connection analysis was carried out based on a fully linked 'system of systems'. The complexity of the network developed in that tool is illustrated in Figure 3 below.

Figure 3 Replication of the Full Integrated Systems Map Developed for WRSE

This map shows all of the PWS, multi-sector and environment system nodes and connections that were mapped and integrated for the Phase 2 analysis

This mapping was used to check the applicability and comprehensiveness of the metrics that had been developed for Phase 1. From this process, additional metrics relating to soil health, catchment planning and customer responsiveness to drought interventions were identified as being relevant and required for the WRSE Regional Plan.

Metric Scoring and Assessment Guidance

In order to evaluate and quantify the resilience impacts of the different investment portfolios that can make up the Regional Plan, it is necessary to score the benefits using 'metrics'. This section provides an overview of where key information and guidance relating to the description, scoring and amalgamation of metrics is located in this document. These components form the technical elements of the Resilience Framework.

Concept, Schedule and Description of metrics

- A full schedule of metrics, including descriptions, is provided in Table 1 in Section 4: Metrics
    - Metrics relevant to the public water supply (PWS) system are indicated with a blue ellipse on Table 1 and are described in Table 2
    - Metrics relevant to the environmental system are indicated with a green ellipse on Table 1 and are described in Table 3.
    - Metrics relevant to the non-public water supply system are indicated with a pale pink ellipse on Table 1 and are described in Table 4.

Metric scoring

- Guidance for the scoring of metrics, including scales for subjectively scored metrics is provided in Appendix B.
    - Subjectively scored metrics are identified in Section 4: Metrics.

Developing scores for the 3 resilience attributes

- The detailed approach and methodology for generating scores for each of the three resilience attributes is provided in Section 5: Amalgamating metric scores and Appendix A.

Evaluation of Options Primarily Benefitting PWS

- These organisations had to consider the metrics in Table 2 in Section 4: Metrics.
    - If there are elements of the scheme which relate to the environmental system organisations will need to consider Table 3 also.

Evaluation of Options Primarily Benefitting Non-PWS Water users

- These organisations had to consider the metrics in Table 4 in Section 4: Metrics.
    - If there are elements of the scheme which relate to the environmental system organisations will need to consider Table 3 also.

Note: In some cases, metrics are repeated across tables. This is because they are relevant to assessment in the context of more than one of the systems.

For further detail on the development of the resilience framework and how we have incorporated feedback from our engagement activities into our approach to resilience please refer to the main method statement.

Metrics

Overarching concept and hierarchy

The framework we have developed to assess and characterise the resilience of our three systems of interest (PWS, NPWS, Environment), is designed according to the following logical model and hierarchy. Figure 4 below outlines the framework elements, actions needed and descriptions.

In addition to this, it is worth noting that the 'Attributes' and 'Groupings' elements of the framework are relevant across all of the WRSE external systems (PWS, Non-PWS and Environment). Some 'Metrics' may be relevant across different systems, however not all metrics are relevant to each system. The relevant metrics for each system are shown on Tables 1,2,3,and 4.

Attributes

Figure 4 below outlines the three resilience attributes of the framework.

Figure 4 Summary of the Three Attributes that form the Resilience Framework

Reliability

Definition: The ability of the system to continue to provide its service in the face of shock events

For the PWS system, this is the ability of the water supply system to continue or re-start operating as planned in the face of shock events

PWS example: good quality, confined groundwater source that is protected from pollution events and is not vulnerable to drought or climate change.

Adaptability

Definition: The ability of the system to adapt the way it delivers its service in the face of shock events, and recover following unexpected system failure

For the PWS system, this is the ability of the water supply system to change operations to continue service in the face of shock events and recover after unexpected failures

PWS example: a cross company bulk supply transfer that can be easily mixed with the existing network water quality and provides backup capacity in the event of an emergency

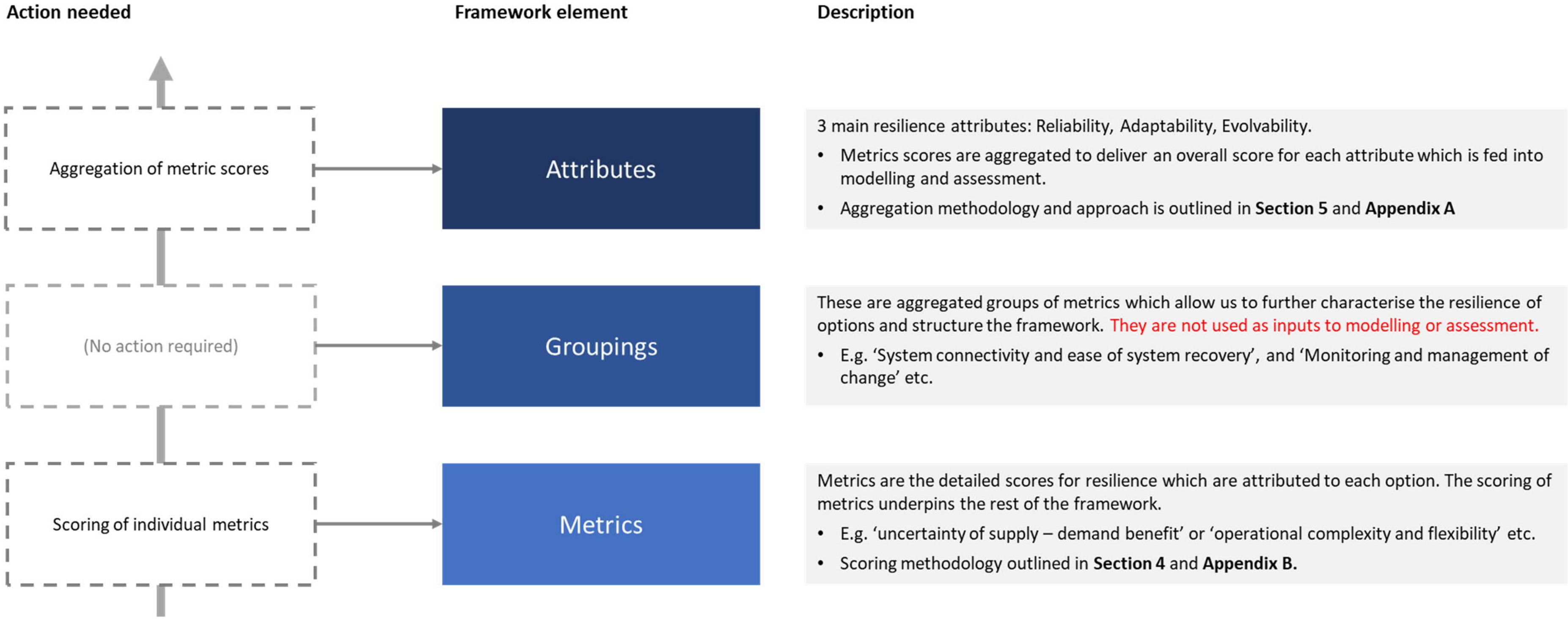
Evolvability

Definition: The ability of the system to modify structure or function to cope with long term stresses or trends

For the PWS system, this is the ability to deliver and adapt water supply investments in the face of uncertain futures and changing trends

PWS example: a smart metering based demand management strategy that contains staged plans for behaviour change and reducing customer wastage, with backup elements to address any shortfalls against targets

Figure 5: Framework concept



Metrics

There are the following general observations to consider regarding the metrics of the resilience framework:

- Most metrics used for the PWS system are only applicable to it, although there is a small amount of overlap with metrics for other systems.
- The metrics used for Non-PWS and Environment are largely common across both systems.
- Note: For the environmental system there are a large number of metrics associated with SEA, biodiversity net gain and carbon emission that are included in the WRSE Best Value modelling but do not form part of this *operational resilience* framework.

All of the metrics in the framework, across all of the systems, can be characterised according to 3 main categories of assessment method:

1. Metrics that require evaluation at the option (intervention) level and require a guided but subjective semi-qualitative assessment:
    - These metrics are indicated with an orange box on Table 1 and orange shading in Tables 2,3,4 .
2. Metrics that require evaluation at the option (intervention) level but can be objectively analysed through modelling or use of existing data sets.
    - *In a number of cases the evaluation is only required for strategic level options, and the metric is re-calculated at a latter stage for the investment portfolio as a whole.* These metrics are indicated with a salmon pink box on Table 1 and salmon pink shading in Tables 2,3,4 .
3. Metrics that are evaluated at the portfolio level only.
    - These metrics are indicated with a blue box on Table 1 and blue shading in Tables 2,3,4 .

★ Starred metrics are evaluated for the baseline system as well as options/portfolios. This is because the benefits from options/portfolios are either calculated based on the degree of change from the baseline, or there are synergistic opportunities for the option/portfolio to address identified resilience concerns in the baseline system. .

The outline descriptions of the metrics, grouped according to system, are provided in Tables 2 to 4 below.

Table 1 Overall metric table

System attribute	RELIABILITY		ADAPTABILITY		EVOLVABILITY	
System Indices		UNCERTAINTY OF PERFORMANCE		TIMING AND WARNING OF EVENTS		FLEXIBILITY AND DIVERSITY OF OPTIONS
Metric	**R1** PWS	Uncertainty of supply/demand benefit	**A1** PWS	Expected time to failure (PWS)	**E1** PWS	Scalability and modularity of interventions
Metric	**R2** N-PWS ENV	Breaches of flow and level proxy indicators	**A2** PWS N-PWS ENV	Duration of enhanced drought restrictions		
System Indices		ABILITY TO PERSIST WITH PLANNED FUNCTIONS		ABILITY TO RESPOND TO AND RECOVER FROM UNEXPECTED FAILURES		DELIVERABILITY OF PLANNED CHANGES
Metric	**R3** PWS	Risk of failure due to physical hazards	**A3** PWS	Operational complexity and flexibility	**E2** PWS	Intervention lead times
Metric	**R4** PWS	Availability of additional headroom	**A7** PWS	Customer engagement with demand restrictions	**E3** PWS	Reliance on external bodies to deliver change
System Indices		RESILIENCE OF SUPPORTING SERVICES		SYSTEM CONNECTIVITY AND EASE OF SYSTEM RECOVERY		MONITORING AND MANAGEMENT OF CHANGE
Metric	**R5** PWS N-PWS	Catchment / raw water quality risks	**A5** PWS	PWS system connectivity	**E4** PWS	Flexibility of planning pathways
Metric	**R6** ENV	Capacity of catchment services	**A4** PWS	WRZ connectivity	**E5** N-PWS ENV	Collaborative landscape management
			A6 N-PWS ENV	Inter-catchment connectivity		
Metric	**R7** PWS	Risk of failure of supporting service due to exceptional events				
Metric	**R8** N-PWS ENV	Soil health				

Metric applied to:

- PWS Public water supply
- N-PWS Non-public water supply
- ENV Environment

★ Evaluated for the baseline system as well as for investment options

Metric calculated by:

- Semi-qualitative subjective scale
- Calculated (at option and portfolio level)
- Calculated (only as part of portfolio)

Key Note on PWS Option and Portfolio Scoring

It should be noted that PWS development options form four distinct groups for the purposes of assessment:

1) Options that provide a 'supply/demand' benefit. These options are scored against all metrics *except* R6, R8 and A4. The score is evaluated for the scheme elements that are required to *generate* the benefit (supply DO, or demand reduction), and general score on a 5 point scale depending how resilient they themselves are. If the scheme is separated into stages of development, then the associated DO is assigned to each stage. The scheme needs to be scored overall according to the point of output – in most cases the 'weakest link' will dictate the score, but where there are storage elements (e.g. feed into a reservoir) then this can be mitigated. Where there are 'resilience' bulk transmission schemes that are enabled by water resource options (i.e. they are only possible once the associated resource is built), then these are evaluated as additional benefits (based on the existing system resilience problems that they address) and *added* to the DO scheme scores (e.g. if the DO scheme scores a 3 against R3, but there is an associated pipeline supply that addresses an existing very significant 'hotspot' problem, then the cost of the pipeline scheme can be added and the R3 score for the DO option is increased to a '5').
2) Intra regional transfer schemes. These are not scored, but instead provide a benefit against metric A4 – i.e. they enhance the connectivity of the PWS system across the south east.
3) Options that provide primarily environmental benefits (e.g. catchment management). These score primarily against metrics R6, R8 and E5, and generally add to the overall score of a portfolio, increasing by up to +2 points. Where they do have a notable DO benefit then they *also* score against the other metrics, as described for the other supply/demand balance schemes above
4) 'Resilience only' options that do not provide a supply/demand benefit, but address known problems in the baseline resilience for either the PWS or non PWS systems. These reflect the value of the underlying 'hotspot' problem that they address (assessed for metrics R3, R5, R7, A3 or A5), generating additional benefits of +1 or +2 to that metric.

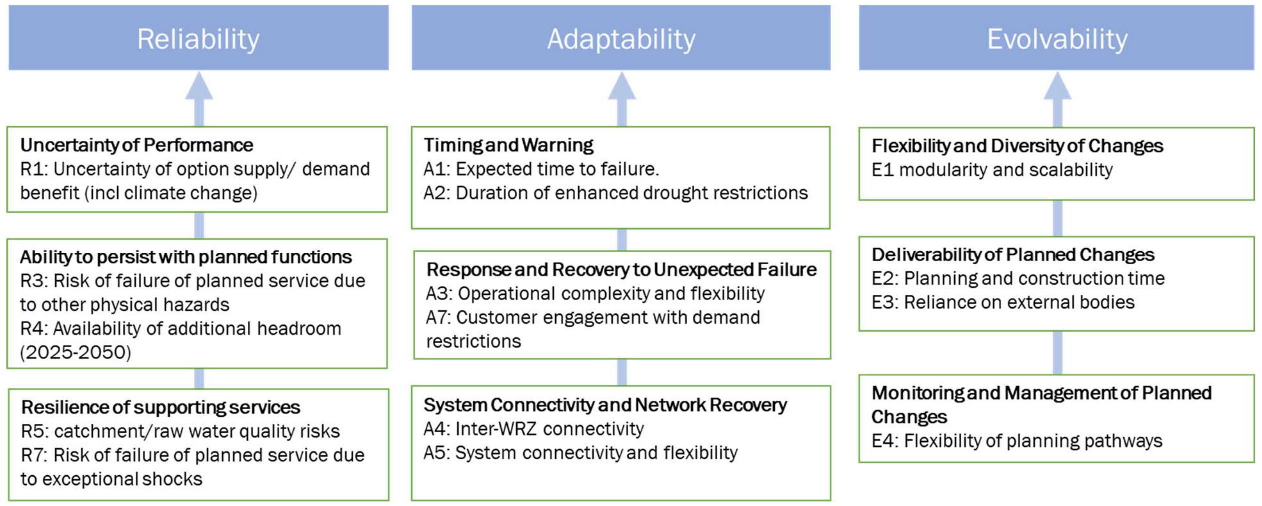
The portfolio level benefits are calculated where appropriate (R2, R4, A1, A2, E4) through the WRSE process, either using the Regional System Simulator (RSS), or the EBSD optimisation model.

Key Note on Environmental and non-PWS Scoring

As described in Section 5, these are assessed as beneficial metrics, either as an additional benefit provided by PWS options that are primarily intended to generate supply/demand (drought) improvements, or, more commonly, as schemes that are intended to deliver environmental enhancements. This means that the scoring is generally evaluated as 0 (no impact) through to +2. This is equivalent to the PWS approach, as they are scaled according to the area or river length etc that is not achieving the required state in the baseline, so a +2 will generally relate to a change from the default, poor condition to a ';'good' condition for that metric. See Section 5 for more information on how metrics are amalgamated and how we have ensured that benefits are comparable across metrics.

Table 2 PWS Metric descriptions

[A summary of the metrics that support the PWS system is shown in advance of the table, followed by the metric description and assessment colour coding]



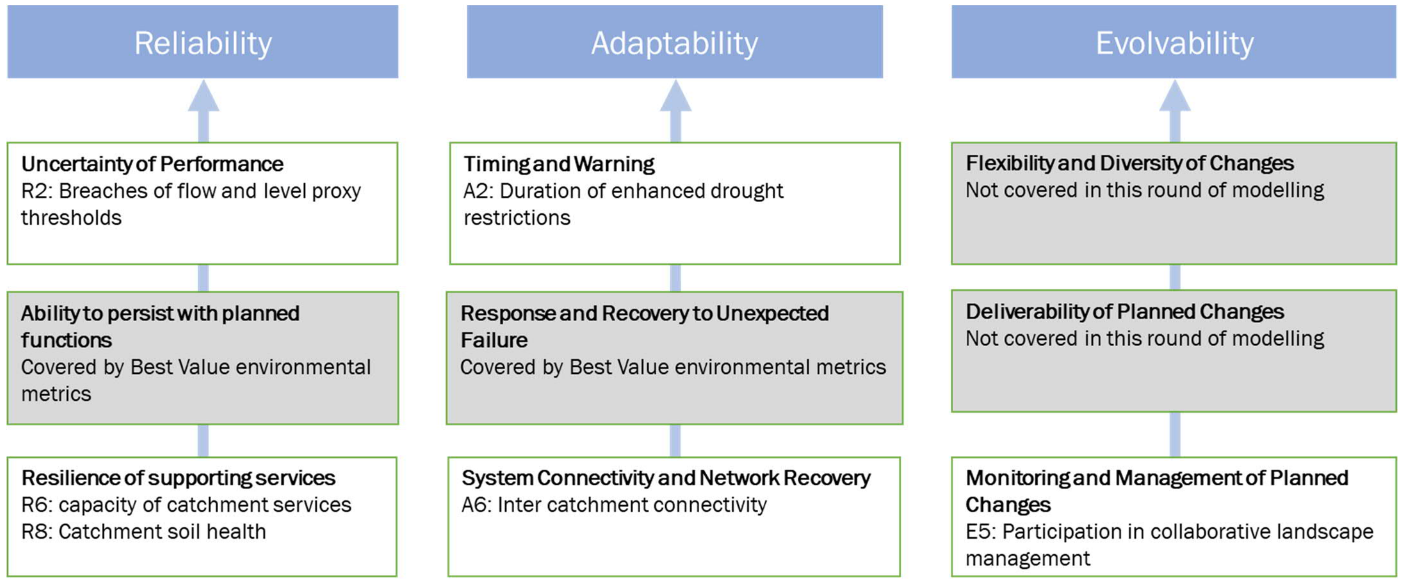
Metric	Scoring	Description	Scoring Approach
R1: Uncertainty of options supply/demand benefit	Modelled data Option and Portfolio level	Baseline uncertainty in yield or reduction in demand from DM options. In the interests of simplicity this should be the combined uncertainty taking into account underlying factors (hydrological modelling etc) and climate change 90% confidence interval at 2050. N.B. this does not represent double counting with Target Headroom in the investment planning, as there is no allowance for option uncertainty in the Target Headroom included in the EBSD Real Options modelling.	For each option a 90% confidence interval range is evaluated and the range fed back as guidance to companies. They then assign a 1-5 score for each option. .
R3: Risk of failure of planned service due to other physical hazards	Subjective Scales	Relative risk of loss of service due to a physically based shock event that is likely to occur when availability of water resources is already stressed (e.g. during drought, freeze/thaw etc). This includes hazards such as flooding, extreme weather - excessive cold, ice, snow, or heat, fire, terrorism / vandalism, geotechnical instability. Need to consider availability of storage and planned redundancy of assets that are designed to mitigate exposure, although it is important to note that potential for network and operational workarounds is covered by A5 below. Need to account for routine and planned recovery measures e.g. back-up power generation.	5 point scale relative to the current 'typical' exposure and vulnerability of available options (1 = notably at risk, 2=higher than typical risk, 3=typical, 4=lower than typical risk, 5 = notably less at risk). Consider key vulnerable points, passive storage and availability of routine re-start capability. See Appendix B for further information. The resilience of demand management measures will be primarily related to the vulnerability of the measures contained in the strategy to variations in weather (hot weather and freeze/thaw).
R4: Availability of additional headroom	Modelled at Portfolio/System Level Only	Based on EBSD modelling. Indication of the amount of 'incidental' surplus generated by interventions (the plan still seeks to balance, but there will be periods of surplus).	Used as a modifier to the sum of the individual scores from other metrics for a given EBSD model portfolio output. Applies a percentage uplift to the score based on the calculation as detailed in Appendix A
R5: Catchment & raw water quality risks	Modelled data Option and Portfolio level	Risk represented by transient water quality events occurring in the catchment beyond those that are adequately covered by outage (e.g. high colour/turbidity/metaldehyde affecting multiple sources during runoff events, algal blooms causing widespread treatment problems). Represents the net impact that the option has on the risk to service – if this causes benefit or detriment to the existing risk for abstractors during shock events then this should be included in the scoring assessment. This can be mitigated by option components, but only where these represent 'failsafe' elements that mean outages>24	5 point scale based primarily on DWSP catchment risk assessment without control measures (1= notable increase in risk, 3 = 'typical', 5 = notable decrease in risk). Demand measures score in the neutral category (3) by default. Although this is a quantified metric based on catchment risk assessment scores, the standard DWSP approach allows flexibility between companies, so guidance is required - See Appendix B for further information. Where an option changes the raw water quality risk within a catchment (e.g. catchment management scheme) then these can score according to the difference that they make (generally none, +1 or +2; in theory it could be

		hours or contamination entering the network are highly unlikely (e.g. bankside storage with intake protection).	negative but in practice it is very unlikely that options will be shortlisted that have a strong detrimental impact on water quality).
R7: Risk of failure of supporting services due to exceptional events	Subjective Scales	Evaluation of the nature of the services and supply chain that support the treatment and distribution network associated with the option to determine if they are particularly resilient or vulnerable to exceptional events, such as: • cascading/long duration regional power outage events • long duration communications loss - cyber attack/solar flare/ space weather/ telecoms failure • Supply chain loss - materials shortages e.g. chlorine, fuel, strikes, commodity price change • Human resource loss – Epidemic/ pandemic, civil unrest, skills crisis, national strike • Rapid behavioral change – e.g. recent COVID conditions.	5 point scale relative to the current 'typical' exposure and vulnerability of available supply options (1 = notably at risk, 2=higher than typical risk, 3=typical, 4=lower than typical risk, 5 = notably less at risk). Consider key vulnerable points, passive storage and availability of routine re-start capability. See Appendix B for further information. Demand management measures may be vulnerable to this metric, depending on their nature (e.g. measures vulnerable to behaviour change due to societal changes such as pandemics).
A1: Expected time to failure	Modelled data Option and Portfolio level	*Only calculated for full portfolios during the second stage. Uses the baseline system simulator run to set the initial time between full and 'failed' resource state, by WRZ. Impacts expressed as a percentage change from this.*	Metric calculated as mean time from resource state = 100% to resource state failure under critical events. Percentage change from this calculated across the same events. Each WRZ is then given a score of 1-5 according to the range of outputs of % change (impacts on WRZ timing). A score of 3 means no significant change. Needs a granularity check – each band must represent at least a 5% change or else the difference is not considered to be significant. (N.B. although the effect of a scheme at the WRZ level may be small, this is accounted for when the scaling factor is applied in the summation calculation – see Appendix A)
A2: Duration of enhanced drought restrictions	Modelled data Option and Portfolio level	*Long term statistically expected duration (days/annum) with Drought Orders/Permits and NEUBs in place. This is only modelled at the system level when portfolios have been generated.*	System simulator (Pywr) output. Scored band 1-5 in the same way as the expected time to failure above (including the significance check, where each band must represent at least a 5% change). In this case the impact is only likely to be apparent once portfolios have been constructed – see Appendix A for scaling and calculation.
A3: Operational complexity and flexibility	Subjective Scales	A measure of the net impact that an option has on the complexity of operation of the abstraction, treatment and distribution infrastructure, which affect the ability of public water supplies to be reconfigured to cope with unexpected consequences of shock events.	5 point scale relative to the current 'typical' situation (notably complex, complex, typical, less complex, notably less complex). Base on aspects such as reliance on multiple institutions, connectivity and the ability to move water around the network, experience of operation and other factor - See Appendix B for further information. Demand management will tend to score neutrally (i.e. a 3).
A4 Inter-WRZ connectivity	Capacity	A measure of the capacity of new inter-Water Resource Zone (WRZ) connections that are made as part of the portfolio.	Absolute capacity of the transfer only. Identified at the portfolio level
A5: PWS system connectivity	Modelled data Option and Portfolio level	*Population effectively provided with an alternative water supply where a notable 'single point of failure' risk was previously in place. In this case the 'SPOF' can relate to network or treatment constraint, and can apply where there is more than one feed to a given area, but where the loss of either asset would result in failure.*	The option is scored according to the distribution input benefitting – i.e. where a baseline 'hotspot' is addressed. Scoring will therefore normally either neutral or positive, so the range is normally 0 to +2 (see Appendix 1 for application), although could be negative (-1 or -2) in some circumstances (e.g. where a transfer from one company to another creates a vulnerability).
A7: Customer engagement with demand restrictions	Subjective Scales	This metric reflects the benefits of mutual social obligation – a social contract – between customers and the company. Where customers perceive companies to be acting on the basis of mutual social obligation – doing the right thing – in controlling leakage, enforcing demand management and restoring the environment, then they will have a positive sense of mutual social obligation to do the right thing themselves. This metric reflects the	This is an additive benefit associated with different demand management strategies, so scores 0, +1 or +2 . depending on how well they engage customers, for example through media and influencing campaigns. There are some aspects of demand management that may have a lesser benefit, such as water efficient labelling with minimum standards (customers may feel that they have already 'done their bit) and rising block tariffs, which

		contagion effect of action in one part of the system to another via the perception and association of issues in the perspective of the customer. It is anticipated that such engagement can enhance the receptiveness of customers to calls for restraint, Temporary Use Bans and Non-Essential Use Bans during drought events, which help to manage the shocks associated with drought conditions.	monetise the social contract and will tend to mean that customers are less responsible to what they may see as a service failure.
E1: Modularity and scalability	Subjective Scales	Ability of proposed interventions to be implemented on a modular or scalable basis (i.e. can they be planned and constructed on a staged basis that can be expanded at a later date to address the under-achievement of benefits or mitigate the risk of investment 'white elephants').	5 point score based on the overall flexibility. A score of 1 represents an initiative that can only realistically be a single sizescale with no flexibility (e.g. reservoir or certain approaches to national water labelling). A score of 5 represents a scheme that can be implemented on a fully staged, modular and extendable basis. See Appendix B for further information
E2: Intervention lead times	Modelled data Option and Portfolio level	*Lead time to plan and then implement option.*	Total planning and construction/implementation time for the option/intervention. All options are evaluated and separated into 5 equal sized bands (DO weighted) to provide a 1-5 score.
E3: Reliance on external organisations	Subjective Scales	Evaluates the risk that the intervention could be halted by external challenge, or relies on other institutions to implement and maintain policies to support the intervention. It should be noted that this generally refers to third parties (e.g. not partners in a joint development or bilateral trades) and represents risks above and beyond 'normal' planning processes.	5 point scale ranging from no risk (5) through to significant likely challenge but under well understood statutory planning arrangements (3) through to schemes that rely on new forms of co-operation between multiple, potentially conflicting institutions (1). See Appendix B for further information
E4: Flexibility of planning pathways	Modelled at Portfolio/System Level Only	Assessed at the end of Stage 2 only, once adaptive pathways have been identified. Represents the ease and availability of pathway changes available under the adaptive plan. The assumption here is that the fewer the number of decision points that are required and the less the economic difference between the branches of the plan, the easier it will be to manage adaptations (i.e. large, frequent changes in pathways are detrimental).	Can only be assessed once the adaptive planning alternative strategies are known. Evaluated based on the difference in NPV between the different pathways and the frequency/lead in time between pathway decision points.

Table 3 Environmental metric descriptions

[A summary of the metrics that support the Environment system is shown in advance of the table, followed by the metric description and assessment colour coding]

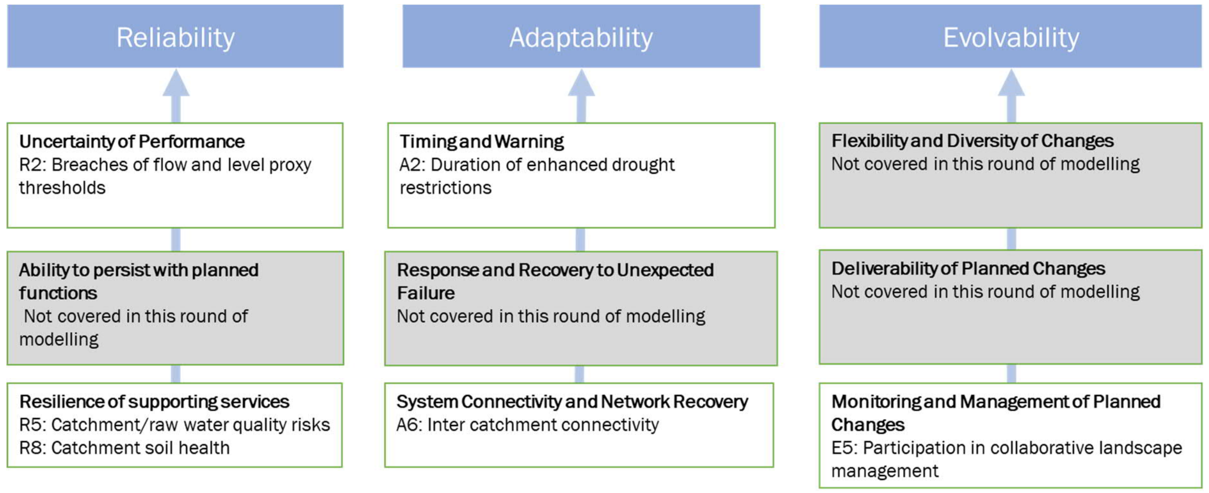


Metric	Scoring	Description	Scoring Approach
R2: Breaches of proxy flow and level thresholds	Scored at the Portfolio/System Level Only	Thresholds are identified and set for modelled water courses based on an assessment of representative Hands off Flow conditions for that water course. Measured as the percentage of time, on average, that flows fall below the proxy threshold. Assessed in system simulator for stage 2 only.	Change in ratio – as a percentage between the baseline condition and the portfolio. Each assessment point is scored -2 to +2 depending on the range of outputs, scaled according to the Q95 Ml/d flow at the assessment point.
R6. Capacity of Catchment Services	Subjective Scales	Capacity of catchment services are derived from the catchment workstream. Outturn scores will be graded 0 to +2, depending on the impact that the scheme has on the catchment. See Appendix B3 for further guidance.	The benefit provided scores on a 0 to +2 scale according to the number of points improvement in the benefitting catchment. These are scaled according to the length of water course benefitting, with the total length of rivers failing 'good' WFD status used as the denominator.
R8. Soil Health	Subjective Scales	Improved soil health across the South East will enhance resilience of the water system in the following ways: 1. It will reduce spikes in poor water quality by retaining nutrients and sediment on the land in heavy rainfall. This benefit will principally be achieved through the use of cover crops. 2. It will improve retention of soil moisture in the soil profile which will benefit resilience in the agricultural sector. 3. By increasing infiltration and storage in the soil profile there will be some benefit to the resilience of rivers and aquifers dependent on seepage for baseflow and recharge. 4. Soil health has benefits at the bottom of the food chain of the environmental system, thereby increasing overall resilience of the environmental system.	As above, the option score is based on the improvement seen in the catchment, based on a 0, 1, or 2 point improvement. An increase of 1 represents an improvement to soil health of the type that would be achieved through continuous cover – the cover retains sediment and nutrients in the soil during rainfall events. An increase of 2 represents a more significant improvement to soil health such as enhancing organic content and soil structure. For example, regenerative agriculture would score +2 Scaling is based on the area affected and area of soils in poor health across the region. See Appendix B3 for more details on scoring and scaling approach.

A2: Duration of enhanced drought restrictions	Modelled data Option and Portfolio level	Long term statistically expected duration (days/annum) with Drought Orders/Permits and NEUBs in place. This is only modelled at the system level when portfolios have been generated.	System simulator (Pywr) output. Scored -2 to +2 depending on the amount of change from the baseline, where each band must represent at least a 5% change). In this case the impact is only likely to be apparent once portfolios have been constructed – see Appendix A for scaling and calculation.
A6: Inter catchment connectivity	Scored at the Portfolio/System Level Only	Capacity of new transfers between catchments	Total transfer capacity between meteorologically distinct catchments, in Ml/d. It is important to demonstrate that there is evidence that the catchments have responded differently from each other during historic droughts (only some differences are required – e.g. the response to 1976 may be similar, but there is evidence that catchments responded differently during 1921). Score based on total capacity.
E5: Participation in collaborative landscape management	Subjective Scales	Additive benefit that reflects options that improve the understanding and management of water environments and/or engagement of public and stakeholders with catchment needs.	Most schemes score zero (no benefit) by default. Single domain medium scale catchment interventions score a +1, large scale multi-benefit schemes score a +2.

Table 4 Non-PWS metric descriptions

[A summary of the metrics that support the Non-PWS system is shown in advance of the table, followed by the metric description and assessment colour coding]



Metric	Scoring	Description	Scoring Approach
R2: Breaches of proxy flow and level thresholds	Scored at the Portfolio/System Level Only	Thresholds are identified and set for modelled water courses based on an assessment of representative Hands off Flow conditions for that water course. Measured as the percentage of time, on average, that flows fall below the proxy threshold. Assessed in system simulator for stage 2 only.	Change in ratio – as a percentage between the baseline condition and the portfolio. Each assessment point is scored -2 to +2 depending on the range of outputs, scaled according to the Q95 Ml/d flow at the assessment point.
R5: Catchment & raw water quality risks	Modelled data Option and Portfolio level	Risk represented by transient water quality events occurring in the catchment beyond those that are adequately covered by outage (e.g. high colour/turbidity/metaldehyde affecting multiple sources during runoff events, algal blooms causing widespread treatment problems). Represents the net impact that the option has on the risk to service – if this causes benefit or detriment to the existing risk for abstractors during shock events then this should be included in the scoring assessment. This can be mitigated by option components, but only where these represent 'failsafe' elements that mean outages>24 hours or contamination entering the network are highly unlikely (e.g. bankside storage with intake protection).	5 point scale based primarily on DWSP catchment risk assessment without control measures (1= notable increase in risk, 3 = 'typical', 5 = notable decrease in risk). Although this is a quantified metric based on catchment risk assessment scores, the standard DWSP approach allows flexibility between companies, so guidance is required - see Appendix B2. Where an option changes the raw water quality risk within a catchment (e.g. catchment management scheme) then these can score according to the difference that they make (up to +2, or as low as -2, although it is very unlikely in practice that options will be shortlisted that have a strong detrimental impact on water quality).
R8: Soil health	Subjective Scales	*If there are potential benefits against this metric, these should be scored according to the environment system guidance – see Table 3.*	See Table 3.
A2: Duration of enhanced drought restrictions	Modelled data Option and Portfolio level	*Long term statistically expected duration (days/annum) with Drought Orders/Permits and NEUBs in place. This is only modelled at the system level when portfolios have been generated.*	System simulator (Pywr) output. Scored -2 to +2 depending on the amount of change from the baseline, where each band must represent at least a 5% change). In this case the impact is only likely to be apparent once portfolios have been constructed – see Appendix A for scaling and calculation. In this case the impact is only likely to be apparent once portfolios have been constructed – see Appendix A for scaling and calculation.
A6: Inter catchment connectivity	Scored at the Portfolio/System Level Only	Capacity of new transfers between catchments	Total transfer capacity between meteorologically distinct catchments, in Ml/d. It is important to demonstrate that there is evidence that the catchments have responded differently from each other during historic droughts (only some differences are required – e.g. the response to 1976 may be similar, but there is evidence that catchments responded differently during 1921). Score based on total capacity.

E5: Participation in collaborative landscape management	Subjective Scales	Additive benefit that reflects options that improve the understanding and management of water environments and/or engagement of public and stakeholders with catchment needs.	Most schemes score zero (no benefit) by default. Single domain medium scale catchment interventions score a +1, large scale multi-benefit schemes score a +2.

Amalgamating the Metric Scores

Public Water Supply and Environment Systems

Resilience scores are generated in most cases against metrics for individual options, but for some metrics scores are derived only at the portfolio level either in the Investment model or subsequently through the Regional System Simulator. The metric level scoring provides the granularity of understanding that is required for the planning teams. However, to support Best Value Planning, investment modelling and consultation it is important that a single score can be generated for each of the three resilience attributes at portfolio level.

To do this, metric scores are scaled and summed to the attribute level based on the appropriate scaling factor. Appendix A provides details of the calculations used to generate the overall attribute scores. At this stage there is no weighting given to any of the individual metrics, they all scale and contribute the same amount to the attribute level score. A summary of the approach used to generate the overall portfolio scores is provided in Figure 6 below.

The scaling factors have been designed so that all metrics associated with options that generate a supply/demand balance benefit, are additive and in proportion with each other, without having to apply arbitrary ‘weightings’. Each option or portfolio impact for each metric is scaled according to the supply/demand benefit or population affected, so each metric is effectively given the same weighting in the additive calculation. As a simple conceptual rule, the resilience benefit of all options or system changes is equal to:

$$\frac{\text{Resilience score} \times \text{size of benefit provided (DO, demand reduction etc)}}{size\ of\ the\ regional\ deficit\ in\ relation\ to\ that\ aspect\ (total\ baseline\ SDB\ deficit\ etc)}$$

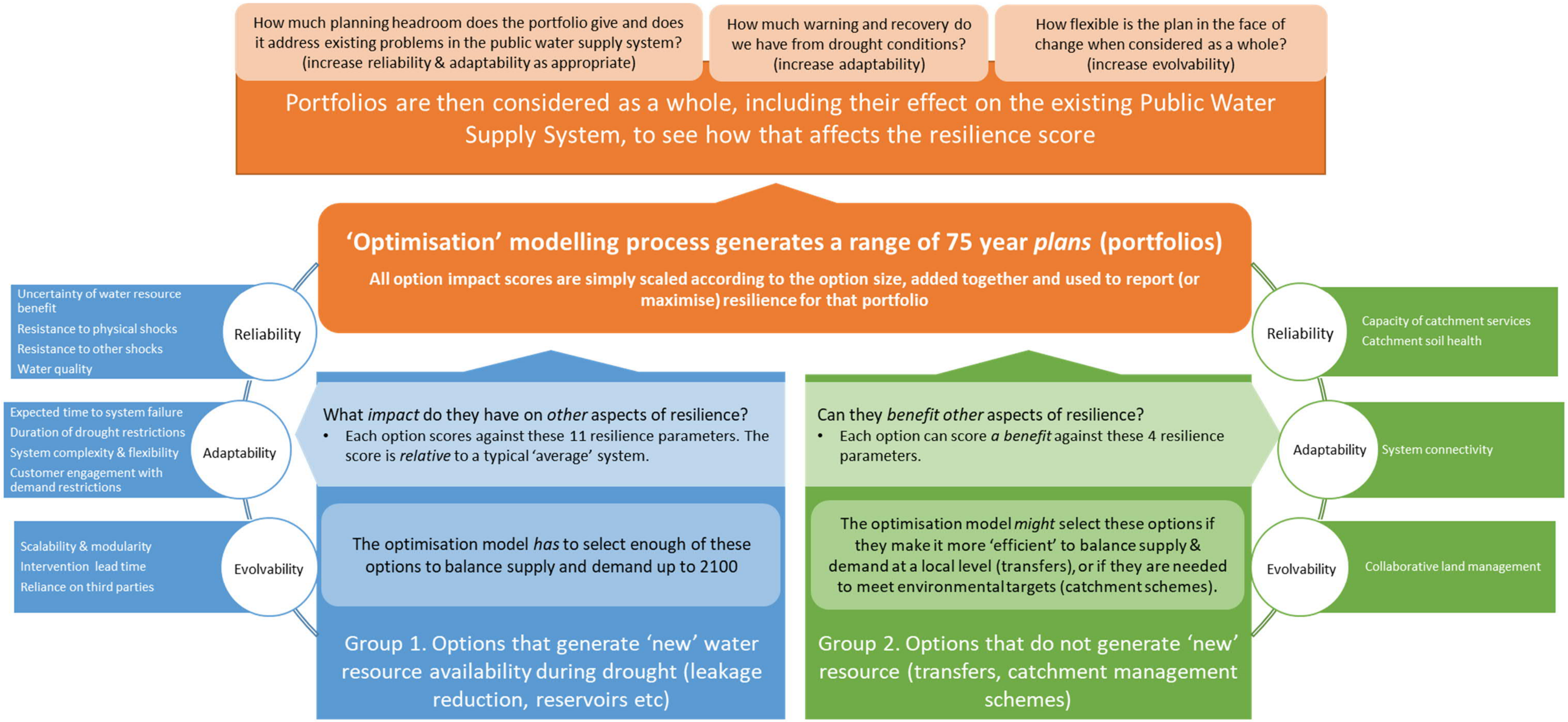
For SDB schemes, transfers and operational resilience schemes the ‘deficit’ (denominator in the above calculation) is equal to the mean SDB deficit over the planning horizon. For catchment schemes the denominator is the total length of water bodies in failing condition, or the total area of degraded catchment soils, as appropriate.

Because the approach is additive, each option will tend to have a small ‘impact value’, but on a relative basis (i.e. when the size of the option benefit is taken into account) this translates back to the 1-5 scoring. This means that, for each of the three attributes, a ‘perfectly’ resilient portfolio generated from the EBSD model for the South East would generate an overall score approaching ‘5’ for a given metric, whilst the worst performing portfolio would score a ‘1’. An average portfolio would score a 3 for each metric. Transfers, catchment management and resilience schemes can then increase overall scores by up to 2 points each for the relevant metrics. Once the portfolios have been generated then there is an additional metric that is generated for each attribute based on the portfolio – this could increase the score by up to 1 point. All of the portfolios that are generated will then be scored on a comparative basis from 1 – 100 based on the range between the lowest scoring portfolio and the highest scoring portfolio.

Non-Public Water Supply System

These metrics scores are generated after portfolios have been generated from the economic modelling based on the PWS system evaluation. As there are relatively few metrics and the attribute scores do not need to be included in the EBSD optimiser, each metric output is described on a stand-alone basis to help understand where the benefits and impacts are felt across these two systems.

Figure 6 Summary of the Impact Generation for Options and Scoring Process for Portfolios



Note – there are 11 metrics that are scored for the PWS system at the individual option level, as indicated.

Appendices – Scoring Guidance and Tables.

Appendix A: Details of the Aggregations of PWS Metrics to the Attribute Level in the EBSD Modelling

The mathematical approach to scoring, scaling and aggregating metrics for each of the three resilience attributes within the PWS system is provided in the table below. 'EBSD' refers to the economic optimisation model – initial scoring is either carried out at the input option level, or once a portfolio has been generated, or (in some cases) both, as the score is updated at the portfolio level once they have been generated. The 'Impact Value' of individual options, or whole portfolios, is the key to the scoring system. Essentially this is calculated based on the metric score × benefit scale (supply/demand benefit or population) ÷ need denominator (size of baseline deficit across the whole region or regional population).

Metric	Basic Option Evaluation Process	Method Used for Scoring the Metric	How Option Score is Scaled and Entered into the Investment Model ('Impact Value')	EBSD Calculated Benefit	post EBSD Calculation of Portfolio Benefit
Reliability Attribute – Sum of 'R' Metric Impact Values					
R1: Uncertainty of option supply/demand benefit	Estimate % difference between 10^{th} percentile and mean of option benefit (%)	Score 1-5 for each option based on the relative uncertainty for each of the option types	Value = (score*Ml/d benefit)/average baseline deficit Ml/d[3]	Sum of option impact values	
R3: Risk of failure of planned service due to other physical hazards	Score 1-5 (each option)		Value = (score*Ml/d affected)/average baseline deficit Ml/d		N/A: total score = output from EBSD model For metrics R3, R5 and R7 where water resource schemes can improve resilience 'hotspots' in the existing system, scores will be reviewed post EBSD modelling to identify any additional benefits that portfolios provide in addressing hotspots.
R5: Catchment/raw water quality risks (incl. climate change)	Score 1-5 for the option itself. Where options improve existing catchment quality then this is added or subtracted from the score (e.g. if the option improves the catchment score from a 3 to a 4 then +1 is added based on the total Ml/d supply fed by that catchment)		Value = ((baseline score + impact on catchment)*Ml/d of option) /average baseline deficit Ml/d). Needs to reflect area already included in score		
R7: Risk of failure of planned service due to exceptional shocks	Score 1-5 (each option)		Value = (score*M/d affected)/average baseline deficit Ml/d		
R6: Capacity of catchment services	Score 0, +1 or +2 based in level of improvement		Value = (score * water body length improved)/total water body length below WFD good status		N/A: options scored as EBSD inputs – benefits already represent improvements to baseline 'hotspot' issues.

[3] Average baseline deficit equals the deficit for that scenario as an average up to 2050 across *the whole of the WRSE region.* In this case demand = DI plus Target Headroom

Metric	Basic Option Evaluation Process	Method Used for Scoring the Metric	How Option Score is Scaled and Entered into the Investment Model ('Impact Value')	EBSD Calculated Benefit	post EBSD Calculation of Portfolio Benefit
R8: Improvements to soil health	Score 0, +1 or +2 based on level of improvement		Value = (score * catchment area improved)/total area of poor soils in region		
R4: Availability of additional headroom	Not relevant at the individual option level. Calculate based on available headroom beyond Target Headroom.				Amend portfolio level score = ((total WAFU capacity over 25 years/total demand over 25 years) -1) *10[4]

Metric	Basic Option Evaluation Process	Method Used for Scoring the Metric	How Option Score is Scaled and Entered into the Investment Model ('Impact Value')	EBSD Calculated Benefit	post EBSD Calculation of Portfolio Benefit
Adaptability Attribute – Sum of 'A' Metric Impact Values					
A1: Expected time to failure (PWS)	Change in mean time taken from 100% to failed resource state	Score 1-5 based on range of % impacts on WRZs affected	Value = (score * WRZ population)/total WRSE population	Sum of option Impact Values	Re-calculate in Pywr using the portfolio setup
A2: Duration of enhanced drought restrictions.	Change in mean duration	Score 1-5 based on range of % impacts on company areas affected	Value = (score * WRZ population)/total WRSE population		
A3. Operational complexity and Flexibility[5]	Score 1-5 (each option)		Value = (score*Ml/d affected)/average baseline deficit		N/A: total score = output from EBSD model. For metrics A3 and A5 where water resource schemes can improve resilience 'hotspots' in the existing system, scores will be reviewed post EBSD modelling to identify any additional benefits that portfolios provide in addressing hotspots.
A7: Customer engagement with demand restrictions	Score +0 to + 2 for activities that enhance customer relations and hence customer engagement with demand management strategy		Value = (score *Ml/d benefit from TUBs & NEUBs in that WRZ)/average baseline deficit		
A4: Inter WRZ connectivity	No scoring required.		Value = Ml/d of transfer/average baseline deficit. * 2[6]		
A5: PWS system connectivity	Score +1 if option is addressing a 'notable' hotspot (category 2 in the baseline evaluation), score +2 if option is addressing a 'very notable' hotspot (category 1 in the baseline evaluation).		Value = Score * DI benefitting/average baseline deficit		Add to overall score once the portfolio can be compared with resilience baseline 'hotspots'

[4] This has been calculated so that a surplus headroom of 10% generates a portfolio level score of +1, which is the same impact at the portfolio level that would occur if all the supply and demand options in a portfolio increased by 1 point in one of the reliability categories.

[5] For metrics R3, R5, R7, A3 and A5 there may be resilience only options that add to the overall score. These provide an added benefit of +1 or +2, depending on the severity of the 'hotspot' that they address, multiplied by the scale of the issue that is addressed (i.e. the Ml/d of existing supplies at risk from the 'hotspot'). These are added once initial portfolios have been generated.

[6] The connectivity benefits are doubled because this is reflective of the change from current (no additional connection) to ideal (connected) conditions – this is equivalent to a 2 point movement in the other metrics.

Metric	Basic Option Evaluation Process	Method Used for Scoring the Metric	How Option Score is Scaled and Entered into the Investment Model ('Impact Value')	EBSD Calculated Benefit	post EBSD Calculation of Portfolio Benefit
	In the rare cases where an option causes a SPOF then it is attributed either -1 or -2.				
Evolvability Attribute – Sum of Option 'E' Impact Values					
E1: Scalability and modularity of proposed changes	Score 1-5		Value = (score*M/d affected)/average baseline deficit	Sum of option Impact Values	N/A: total score = output from EBSD model
E2: Intervention lead times	Intervention lead time	Identify the ranges for all shortlisted options. Score 1-5 for each option based on an even allocation of options into each band	Value = (score*M/d affected)/average baseline deficit		
E3: Reliance on external bodies to deliver changes	Score 1-5		Value = (score*M/d affected)/average baseline deficit		
E5: Collaborative landscape management	Score 0, +1, +2		Score* area covered / RSE area		
E4: Flexibility of planning pathways	Not relevant at the individual option level				Adaptive Plan level uplift applied: Plan with lowest difference in NPV between highest and lowest scenarios and lowest number of decision points adds 20%, plan at other end loses 20%

Appendix B: Detailed Scoring Guidance Notes

Metric R3 – Risk of failure of planned service due to other physical hazards.

This metric is most similar in concept to *outage*, but it is evaluated for new sources or demand management measures. It is intended to reflect both the risk that the interventions' contribution to the supply/demand balance may not be available during key drought periods, and the risk that the intervention could fail to the extent that it results in a large scale[7] interruption to supply as a result of the combination of resource stress (drought/freeze thaw etc) and the option failure. This risk could materialise as a result of numerous physical hazards, as outlined previously. These are most likely to be:

- flooding,
- extreme weather - excessive cold, ice, snow, or heat,
- fire/explosion
- terrorism/vandalism
- geotechnical instability

There are two areas of potential overlap with other metrics, and scoring between them should be interpreted as follows:

1) All catchment water quality risks are considered separately under that metric (R5) and should not be included here. Where outage is referred to in the text below then that should exclude risks associated with catchment water quality. For effluent re-use schemes, the failure of the scheme to provide the required water into the relevant abstraction or recipient as a result of the failure of the process should be included under this metric.

2) This metric takes account of the reliability benefit provided by storage and other 'passive' operational measures that are designed to prevent service failure following outage events, but does not consider operational workarounds or the ability to change operations to maintain service. Similarly, although planned, standard measures for recovery following failures such as standby generators or on-site flood mitigation measures should be taken into account, issues such as accessibility or the ease of repairs are not included. Such factors are covered by the 'operational complexity and flexibility' metric A3 (which falls within the *adaptability* aspect of resilience, and refers to institutional arrangements, system makeup and other factors that affect the ability of supplies networks to be reconfigured during shock events). Typically, that means *outage* type risks fall within this -metric – see Appendix B guidance on the operational complexity and flexibility metric.

It should be noted that wider business and organisation risks are not considered within this evaluation at this stage – it is intended that it should concentrate on the infrastructure involved and the immediate operational

[7] Large scale in this case will mean whole towns or demand centres, typically more than 10,000 properties with interruptions lasting for more than 24 hours.

issues associated with keeping the asset running (e.g. access, consumable materials essential to operation, power etc). Organisational risks may be reviewed during latter stages of the Plan.

Options and interventions will typically be assessed according to the top 2-3 hazard types, only falling into a category of '1' if they are highly vulnerable to a single hazard, or notably vulnerable to 2 or more hazards. In some cases there may be specific concerns where an asset is vulnerable to multiple smaller likelihood hazards. In that case an asset could score a 1, but this would have to represent an abnormal situation. More typically such an asset would score a 2. Assets where there is some exposure to multiple less likely hazards is a typical situation for a water company, so such assets should score a 3.

Further guidance on scoring is provided below.

Metric R3 Scoring Guidance Notes

Score	Description	Notes and Application
1	Notably vulnerable. The location or nature of the scheme means that it is towards the upper end of risk. For PWS assets this means they are at a similar level of risk to those existing assets within the top 20% of outage scores, or they rely on systems that are notably vulnerable to a particular hazard type. Options that rely on multiple, exposed, in-sequence assets to function (e.g. multiple booster pumping stations) should be placed in this category.	Where risks have been deliberately and reliably designed out (e.g. fluvial floodplain protection) then options should not be placed in this category. This category should generally be used for sites where there is a clear, notable risk and should apply to around 10% to 20% of the options.
2	Vulnerable. This includes option types that are known to suffer from higher than 'typical' outage risks, options that have critical assets that do not have redundancy backup, or options and strategies where there is significant uncertainty around the level of risk that they face. Options that incorporate exposed critical assets where there are concerns over repair times could be placed in this category.	Overall, no more than 40% of options should fall into this category or notably vulnerable as above. Uncertainty in the option design is likely to be a key factor over the selection of this category. The precautionary principle should be applied where there are long transfer/supply routes or constraints on land availability that mean the option could have to be placed in a more vulnerable location.
3	Typical asset. Options that are typical of existing water company water resource schemes in terms of vulnerability and exposure will fall into this category.	Options and assets will be typical of existing water company arrangements in terms of duty/standby, number and exposure of sequential critical assets etc. Options where there are some uncertainties over location and nature can fall into this category, provided the uncertainties do not mean that critical assets could be vulnerable or exposed.
4	Less vulnerable. These options/strategies will tend to be relatively well defined and their nature or level of redundancy means that they are less vulnerable than a typical resource option.	Schemes need to be reasonably well defined, or relate to asset types that are inherently low vulnerability in low exposure locations, to be included in this category. *Demand management strategies will tend to fall into this category by default, although some may be vulnerable to weather related events.*

5	Notably less vulnerable. These options/strategies will be well defined and there are no notable vulnerabilities in the design, location or makeup to the scheme/strategy.	Schemes require a good degree of certainty about placement, lack of critical asset points etc to be in this category. Simpler schemes that supply raw water to existing, well established treatment and distribution systems that are known to be low risk could be a typical example. *Simpler, distributed demand management strategies that are unlikely to be significantly disrupted by shock events could be placed into this category*.

Metric R5 – Catchment & raw water quality risks.

This assessment relates to the risk of disruption to supplies as a result of water quality events during times where there is resource stress (drought, freeze/thaw etc). The approach to scoring is based on the use of catchment risk assessments under the DWI Regulation 27 reporting. When carrying out the evaluation on a supply side intervention or catchment resilience scheme the company should:

1) Identify the most similar equivalent[8] catchment covered by an appropriate Regulation 27 assessment (i.e. a catchment associated with an existing supply asset).

2) For an intervention that does not affect this catchment risk, select the *pre control* risk score for the catchment and assign that to the intervention (unless the scheme incorporates catchment improvements – see below). This can be modified if there are passive/failsafe controls in place that do not risk an outage of the service (e.g. bankside storage with intake protection).

3) Options are scored in the table based on their relative ranking (e.g. schemes in the lowest 20% by DWSP CRA score fall into the top score category of 5). Ideally this assessment would not be relative within each company and/or use an absolute scale, but there is no requirement for conformity of completion to this level within the DWSP guidance and companies will score catchments and hazards differently. Review and normalisation of scoring will be carried out by WRSE once scores have been submitted.

The use of scoring prior to control is deliberate, as schemes that require large amounts of mitigation will tend to be inherently more vulnerable to failure and shutdown, and hence tend to be less *reliable* than others, unless the protection can be considered to be passive and failsafe, where there is very little risk of long term service interruption.

For an intervention (e.g. catchment management) that affects the catchment risk for existing or other planned new sources, use available information (e.g. existing catchment management initiative reporting) to evaluate the impact of the scheme and determine by how much the risk score changes (based on the guidance under point 3). If it improves the scoring by one category, then the scheme scores a +1. If it improves by 2 categories then the scheme scores a +2 and so on. Where a scheme involves both catchment improvements *and* provides yield then

[8] In this case 'nearest' refers to the nature of the catchment, not physical proximity. For example, a smaller urbanised catchment could be

the risk score should be taken based on the catchment risk after the improvements are taken into account. Similarly, if schemes such as indirect effluent re-use generate a deterioration to other resources then the risk level should be taken based on the abstraction point *with* the effluent re-use in place.

Options that rely on effluent re-use will only perform badly on this metric if the failure of the process represents a risk to downstream abstractions – e.g. if the scheme does not incorporate a passive failure type mechanism that means transfers halt by default when there is a problem. Failure of the effluent as an available resource is covered by 'risk of service failure due to other hazards,' as defined under R3 & R7.

Assessors should be pragmatic when identifying suitable equivalent catchments – the exact risks around the individual options may not be well known, so it may, for example, be more appropriate to apply generic catchment level CRAs (if they are available) rather than individual source CRAs.

As noted below, demand management options score a '3' by default, as the benefit they provide is spread across the supply base so the relative risk will not change.

Score	Description	Notes and Application
1	Notably vulnerable. Equivalent to schemes scoring in the worst 20% of catchments.	Desalination schemes where there is a high variability in water quality other than the typical tidal cycle will fall into this category. Schemes where there are large unknowns and potential concerns over raw water quality should be placed into this category.
2	Vulnerable. Equivalent to schemes scoring in the 20% to 40% category.	Desalination schemes with a large, but predictable variability in turbidity etc fall into this category. Schemes where there are large unknowns/no reasonable DWSP equivalent but where there are no exceptional concerns should be placed in this category.
3	Typical asset. Equivalent to schemes scoring in the 40% to 60% category. *Demand management strategies score a 3 by default (they replace the need for water on a generalised basis)*.	Schemes where there are come uncertainties, but it is very unlikely that risks would be notably high should be placed in this category.
4	Less vulnerable. Equivalent to schemes scoring in the 60% to 80% category.	Need to be reasonably confident that the catchment with the DWSP score is a good representation of the catchment served by the scheme. Schemes that improve catchment risks by a single point score here.
5	Notably less vulnerable. Equivalent to schemes scoring in the 80% to 100% category.	Need to be very confident that the catchment with the DWSP score is a good representation of the catchment served by the scheme. Schemes that significantly improve catchment risk (i.e. by 2 or more points) score here.

For non-PWS options, scoring is as for PWS above, although for interventions that serve only non-PWS or environmental systems, then these will need to be based on an 'equivalent setting' type approach – i.e. identify how the setting of the option compares to catchments with existing water company risk assessments and use the appropriate score.

Metric R6 – Capacity of Catchment Services.

The purpose of this metric is to capture the change in the ability of a water body that is affected (positively or negatively) by an intervention to carry out its ecological services during 'shock' events (primarily drought). Each option is assessed based on the impacts (positive or negative) it has on the morphological, and biological conditions of the water body, in relation to its ability to cope with and recover from shock events (drought, large pollution incidents etc)

Component	Description	Factors to consider when assessing
Morphological state	Condition and function of the channel and riparian habitat, including introduction of structures/ barriers, which could affect the ability of the environment to recover from shock events	Does the option move the catchment towards or away from natural state? What is the scale of the options?
Biological state	Diatoms: Does the option impact the diversity and adaptability of diatom communities? Is the option likely to impact environmental factors known to affect diatom communities such as salinity, temperature, pH, water velocity, depth and available substrate? Macrophytes: Does the option impact on the habitat availability and ability of macrophytes to recover from shocks? Does the option lead to increase in nitrates or phosphates and affect dissolved oxygen levels? Does the option target multiple or single river fragments? Fish: Does the option directly impact on the ability of fish populations to recover from shocks?	Local vs. catchment wide impacts: Local and catchment wide impacts. Benthic diatoms adhere to substrata and are indicative of a local catchment, whereas planktonic diatoms are mobilised down a water course and are likely to be impacted by local and catchment wide impacts. Does the option reduce or increase network fragmentation? Resilience of ecosystems increases with the size of river fragments of adjacent stream reaches that are in a good ecological state, due to a larger probability of providing refugia to self-sustaining populations, which can act as sources for recolonization elsewhere in a catchment.

The table below outlines the scoring methodology and provides examples for information.

Score	Description	Example
0	No/negligible effect	Offline storage reservoir taking during winter only (high HoF).
+1	Positive impact	For options that have a beneficial, though marginal benefit to morphological and biological state of rivers, or only address one of these issues.
+2	Notably positive impact	For schemes that actively enhance the biological and morphological state of rivers.

Metric R7 – Risk of failure of planned service due to exceptional events.

This metric covers those shocks that tend to be either societal in nature, or affect the supply chain or supporting services. These typically include:

- cascading/long duration regional power outage events
- long duration communications loss - cyber attack/solar flare/ space weather/ telecoms failure
- Supply chain loss - materials shortages e.g. chlorine, fuel, strikes, commodity price change
- Human resource loss – Epidemic/ pandemic, civil unrest, skills crisis, national strike
- Rapid behavioural change – e.g. recent COVID conditions.

The level of risk and scoring therefore tends to concentrate on the availability of redundancy and storage in the system, and the risks presented by complex supply chains or specialist, limited human resources skills sets. Demand management measures may tend to score less well than they do under measure R3.

Metric R7 Scoring Guidance Notes.

Score	Description	Notes and Application
1	Notably vulnerable. The nature of the option means that it is towards the upper end of risk. Schemes/options in this category will tend to be notably vulnerable to more than one type of event – i.e. the nature of power supplies, availability of chemicals, dependence on remote control for remote assets etc have the potential to combine to cause significant problems. For networks it is likely that demand/weather shocks will be the largest risk and this category would apply to a scheme that is reliant on existing infrastructure that is known to be stretched during such events.	Very complex schemes that score poorly under metric A3 are more likely to fall into this category, and there may be synergy between the two metrics. *Demand management strategies are unlikely to fall into this category, except where they are known to be vulnerable to unexpected societal changes, such as those caused by the COVID-19 pandemic.*
2	Vulnerable. As above, but where there is only one notable risk, or where there are uncertainties over network capacity/redundancy.	Overall, no more than 40% of options should fall into this category or notably vulnerable as above. Uncertainty in the option design is likely to be a key factor over the selection of this category.

		Higher risk demand management strategies that contain some vulnerability to societal change, or vulnerabilities or significant unknowns in relation to data or network loss, or where they rely on supply chain or delivery arrangements that are vulnerable to medium term disruptions (pandemic/civil unrest/economic shock etc) could be placed in this category.
3	Typical asset. Options that are typical of existing water company water resource schemes in terms of vulnerability and exposure will fall into this category. Demand management strategies will only fall into this category if they rely on the more complex elements of existing customer interactions, or they are a 'mixed bag' with some medium term vulnerability in their ability to deliver during events such as pandemics/civil unrest/economic shock.	Options and assets will be typical of existing water company arrangements in terms of duty/standby, number and exposure of sequential critical assets etc. Options where there are some uncertainties over location and nature can fall into this category, provided the uncertainties do not mean that critical assets could be vulnerable or exposed. *High tech demand management strategies where there is relatively little experience of mass operation will tend to be placed in this category*
4	Less vulnerable. These options/strategies will tend to be relatively well defined and their nature or level of redundancy means that they are less vulnerable than a typical resource option. Demand management strategies that are not particularly vulnerable to data issues, cyber attack, or where events such as pandemics/civil unrest/economic shock will only have a short term, transient impact on delivery and implementation should be placed in this category.	Schemes need to be reasonably well defined, or relate to asset types that are inherently low vulnerability in low exposure locations, to be included in this category. *Demand management strategies that rely on well proven technologies, but where there is potential uncertainty about their effectiveness in the face of societal events will tend to be placed in this category.*
5	Notably less vulnerable. These options/strategies will be well defined and there are no notable vulnerabilities in the scheme/strategy.	Schemes require a good degree of certainty about placement, lack of critical asset points etc to be in this category. Simpler schemes that supply raw water to existing, well established treatment and distribution systems that are known to be low risk could be a typical example. Simpler demand management strategies that are unlikely to be significantly disrupted by societal shock events could be placed into this category.

Metric R8 – Catchment Soil Health.

Improved soil health across the South East will enhance resilience of the water system in the following ways:

1. It will reduce spikes in poor water quality by retaining nutrients and sediment on the land in heavy rainfall. This benefit will principally be achieved through the use of cover crops.
2. It will improve retention of soil moisture in the soil profile which will benefit resilience in the agricultural sector.

3. By increasing infiltration and storage in the soil profile there will be some benefit to the resilience of rivers and aquifers dependent on seepage for baseflow and recharge.
4. Soil health has benefits at the bottom of the food chain of the environmental system, thereby increasing overall resilience of the environmental system.

There are additional benefits to the WRSE system such as carbon sequestration and regulation of flows that mitigate flood risks.

Score	Description	Example
0	No change to soil	Demand management
+1	Improvement to soil cover	Reverse auction for cover cropping
+2	Improved organic content and structure in addition to measures in addition to cover cropping	Regenerative agriculture

The metric works by allocating a score of zero to options that have no positive or negative impact on soil health. One step improvement is allocated to options that cover the ground, protecting it against intense rainfall and heat. A second step improvement to a score of +2 is allocated to options that enhance soil structure, organic matter and infiltration in additional ways over and above the use of cover crops.

Step 5 will reflect the priorities of regenerative agriculture which is a set of activities designed to transition soil husbandry from a predominantly fertiliser based production model to a model that relies on the inherent organic activity of healthy soils. The regenerative agricultural show Groundswell[9] identify 5 principles of regenerative agriculture as follows:

1. Diversity of crops.
1. Armour soil surface – protect from heat and rains.
2. Minimise soil disturbance.
3. Maintain living roots.
5. Integrating livestock into the system.

For the design of a metric the key point is to identify an activity or collection of activities that are distinct and create a clear step change in soil health. Armouring of the soil is the first of these. There are two alternative strategies for the second step which would either be the increase in organic matter in the soil or the adoption of minimal soil disturbance (no-till). Given that the principal function of this metric relates to the resilience of the water system, then we propose the metric relates to the adoption of minimum disturbance – no till farming.

We note that the planting of cover crops is relevant to land that would otherwise not be covered over winter. For this reason the likelihood of exposed ground is included in assessing the baseline (based on the prevalence of crops that are associated with bare ground (spring planted; potatoes etc).

[9] See Groundswell Agriculture Show & Conference - Mission Statement Groundswell. Affinity Water are the headline sponsor of Groundswell.

Metric A3 – Operational Complexity and Flexibility

This metric is intended to focus on how the intervention affects the ability of the PWS to adapt, reconfigure and recover when shock events mean that normal modes of operation are disrupted. This essentially looks at how the option interacts with other factors such as network operation and network quality risks, and how much reliance there is on multiple organisations and/or specialist supply chains if the intervention has to be re-started or taken out of expected operational ranges.

Score	Description	Notes and Application
1	Notably complex. These interventions will tend to be both inflexible due to operational constraints on use (e.g. desalination water not suitable for transfer outside the intended area) *and* they either rely on multiple institutions to run, require specialist supply schemes/complex procedures to re-start after a failure event or are difficult to access to effect repairs.	This score is applied to supply side schemes where there is obvious inflexibility and complexities in the management/operation of the resource. *Not generally used for demand management*.
2	Complex. These interventions will tend to be both inflexible due to operational constraints on use (e.g. desalination water not suitable for transfer outside the intended area) *or* they either rely on multiple institutions to run or require specialist supply schemes/complex procedures to re-start after a failure event.	This score is used for schemes with single complex issues, or a number of lesser operational risks (e.g. difficulties in transfer combined with blending constraints). *Demand management can score within this category, but only in exceptional circumstances (e.g. it could result in significant amounts of 'locked in' supply capability as a result of demand reductions causing existing sources to become under-utilised, but where this is not certain enough to include as a change in Deployable Output).*
3	Typical asset. These interventions are 'typical' of a surface water type source in terms of complexity and management. Control curves, group licences, environmental procedures, transfers may be involved, but any co-operation needs across multiple institutions is unlikely to result in failure of the source to adapt or re-start. Typical transfers where there is some availability of workaround and storage fall into this category.	Use for schemes that represent typical PWS operation (clear, unambiguous asset management and operation agreements), some flexibility in the area and nature of supply etc), where any constraints (e.g. blending need) are straightforward and unlikely to significantly constrain scheme operation. *Demand management strategies will tend to score a 3 by default (they replace the need for water on a generalised basis), unless there is a clear risk that they will result in significant 'locked in' capacity for water company existing sources.*
4	Less complex. Interventions that involve typical, routine operational arrangements where group and annual licences are straightforward to manage, the site can be manually operated if required and there is reasonable connectivity/storage with the existing network	As for 3) above, but schemes need to be free from complex multi-institutional agreements, and have limited constraints on operation and use of the water in a flexible way.

5	Notably less complex. Intervention is simple to manage, with limited interdependencies and an ability to deploy across multiple areas	To fall into this category the scheme must have no obvious operational constraints, be free from complex multi-institutional arrangements, and the scheme should be notable in its ability to support various parts of the network without difficulty or operational constraint.

Metric A7 – Customer Engagement with Demand Restrictions

Score	Description	Example
0	No noticeable change for customers	Status quo – only applicable to demand management strategies that rely significantly on tariff management (which monetises the social contract) *and* passive approaches, primarily minimum standards associated with water labelling, which are likely to have minimal, or event slightly negative, impact on customers' awareness of water resource issues.
+1	Demand management strategies improve engagement with and understanding of the need to manage resources	Applies to demand management strategies where there is some reliance on tariffs or passive methods, or where methods are less likely to promote the 'social contract'.
+2	Demand management strategies significantly improve customer understanding of their role in drought management and they respond very positively to such measures.	Demand management that incorporate a strong element of behavioural change and awareness, and where they do not monetise or promote passive engagement in the 'social contract'.

The rationale for this metric is that customer action on demand management is essential to maintaining supply demand balance during drought. Where companies have the confidence of customers in drought management and leakage control then customers will be more responsive to calls for constraint or temporary usage bans – a representation of a 'social contract' between water companies and their customers in the management of drought. Conversely where companies have lost the confidence of customers, then they will be less inclined to respond to calls for restraint during drought.

Additional benefits of this metric are that it promotes demand management strategies that support Ofwat's social contract agenda. The metric operationalises the idea of the social contract by reflecting the fact that the supply demand balance is achieved by both parties playing their part during drought and this voluntary collaboration is enhanced by visibly reciprocal behaviours – the customers will be more or less inclined to play their part according to the commitment they see to this agenda in the actions of the company. The social contract is not just at an individual level: customers act, to some degree collectively. Therefore, if a company is seen to be active on leakage and seen to take action to enforce demand management then individuals will be less inclined to flout drought measures if their neighbours are compliant. If a customer's neighbours do not comply with drought management and the company does not manage leakage well, then response to demand restrictions during drought is likely to be lower.

This metric is designed to enhance adaptive behaviour in the system in response to drought stress and is therefore categorised as an adaptive system characteristic.

Metric E1 – Modularity and Scalability

This metric is relatively straightforward, and reflects the ability of a given option to be delivered in a staged way that limits investment risk and provides opportunity to either scale back or extend development if the intervention is proving to more/less viable following further investigation and initial development. Scalability and modularity may also help address uncertainty in the need (supply/demand balance) as a modular plant can be implemented in phases depending upon the needs that arise in future, reducing the risk of stranded assets.

Score	Description	Notes and Application
1	Notably inflexible. Option is fixed and binary without any real opportunity to scale back or extend development once the scheme has started.	Some reservoirs, where there is no real choice or flexibility around the source water availability, fall into this category. *Similarly, demand management strategies that present an either/or approach where the benefits are not well known until key policies are in place and large-scale implementation has started (e.g. Water Efficient Labelling) could fall into this category.*
2	Fairly inflexible. Option is fairly fixed and can only be changed in relatively minor ways once development has started.	As above, but there is some flexibility -e.g. reservoirs where there is flexibility around water sources, 'binary' demand management initiatives that can be effectively trialled before full scale implementation etc.
3	Typical scheme. The scheme will become well defined prior to full implementation, but can be scaled and adjusted as the detailed design is being developed.	'Typical' resource schemes where assets can be re-sized or adjusted once constraints are fully understood, and there is some opportunity for modular development of certain components (e.g. treatment streams). Demand management initiatives where changes can be made as the rollout progresses, but the scale and scope of the initiative is reasonably fixed, fall into this category.
4	Fairly flexible. Some modular development is possible and/or the intervention is scalable in response to external factors.	Schemes where there are relatively few 'hard constraints' so development can be pursued in a relatively modular way, and there may be some scope to extend or scale back the size of the scheme as required. Many demand management initiatives will tend to fall into this category as they may have expectations on their maximum size, but ultimately can be scaled back as required if they are not providing to be effective.
5	Notably flexible. Scheme is fundamentally modular and there is significant opportunity for scaling as required.	Probably limited to options such as desalination where development can be fully modular, or demand management initiatives where there is full flexibility in scale and the ability to adapt the initiative as better information becomes available

Metric E3 – Reliance on External Organisations to deliver changes.

This metric is intended to reflect the risk that a scheme cannot practically be delivered because of dependencies on multiple institutions to implement, or uncertain approvals and delivery mechanisms that rely on third parties. Bilateral agreements and simple water trading are not intended to be highlighted by the metric.

Score	Description	Notes and Potential Data Sources
1	High risk. The scheme has known, significant challenges and relies on third party organisations to approve or deliver the scheme using processes that are not yet well established.	Complex schemes that required support and consent of multiple actors and institutions where there are significant uncertainties over delivery mechanisms and future working arrangements. *Demand management schemes that require major policy or regulatory changes that have not yet been committed to.*
2	Increased risk. The scheme has known challenges and is relying on some third party organisations to approve or deliver the scheme. The processes involved are reasonably well defined, but non-statutory or have little precedent.	Complex schemes that require the support or consent of institutions other than the planning authorities, with associated risks to scope. *Demand management schemes that require minor external policy support or legislation, which has not yet been committed to, or where there is a need to develop technologies externally that are not yet available.*
3	Typical scheme. Although the intervention or scheme faces challenges to approval or implementation, this is through well known processes with mature institutional arrangements.	Schemes that could involve bilateral trade, but do not rely on multiple institutions and will follow standard planning application routes (DCO or conventional) where there is likely to be some opposition. *Typical demand management schemes that only require existing policy support and follow known and well-practiced regulatory processes.*
4	Lower risk. The scheme is not only reliant on well known processes with mature institutional arrangements, but the likelihood of challenge and major delay is low due to a lack of opposition or widespread support.	Typical supply schemes where expected objection risks are low. *Typical demand management schemes where there is broad support and customers and customer representatives are likely to be supportive*.
5	Negligible risk. The scheme is highly unlikely to experience substantive challenge or delay.	Smaller supply schemes that are carried out within permitted development rights, or where there is clear planning support and no known opposition. '*Flagship' demand management schemes with strong policy and/or customer support where delivery mechanisms are similar to existing, well tested approaches.*

Metric E5 – Participation in Collaborative Landscape Management.

Score	Description	Example
0	No noticeable change for catchment stakeholders	Pipeline
+1	Single domain medium scale catchment interventions.	Catchment partnership
+2	Large scale multi-benefit landscape restoration with multiple revenue schemes.	LENs style, blended finance

The rationale for this metric is that collaborative approaches to environmental management are essential to create transformative systemic change in the resilience of environmental systems. The environmental system supports the public and non-public water supply systems that are the focus WRSE. The metric will come under the category of evolvability because of the long term need to change the way that the four systems respond to the on-going changes affecting the environment.

The metric will work apply a score of 0 for options that do not involve collaborative land management. A one step increase to a score of 1 would be achieved by a collaborative intervention that is of medium scale and with impacts that are predominantly environmental; and predominantly third sector driven with engagement from some private sector actors in the agricultural sector. A two-step enhancement would be achieved by a major intervention that has multiple objectives and has a range of sectors engaged from the private sector collaboration as well as third sector. A score of 2 is achieved where the private sector is able to increase scale by capitalising risk.

The emphasis of this metric is not simply a matter of increasing environmental benefit – that effect is covered up in the environmental metrics. The purpose of this metric is to reflect the enhanced resilience of collaborations that a plural in purpose and multi-sectors in membership.

Examples of major, multi-benefit initiatives, that would score 2 in this metric include:

- Cumbria LENs http://www.3keel.com/wp-content/uploads/2018/01/healthy-ecosystems-cumbria-lens.pdf
- The Greater Manchester Natural Capital Investment Fund. https://naturegreatermanchester.co.uk/project/greater-manchester-natural-capital-investment-plan/
- Hampshire Avon LENs Creating a landscape network in Hampshire – 3Keel

The Hampshire Avon collaboration is driven by the local Catchment Based Approach (CaBA) group and addresses numerous multi-sector private sector actors. Provided that funding is derived from these actors at scale, then this partnership would score 5.

Appendix C. Mapping to other Resilience Frameworks

Although it is not required to generate the metric scores and evaluations, the reason why each metric has been included is provided in the table below. This helps provide background understanding of the metrics. This also shows how the 4 'R's described in the Cabinet Office description of resilience are covered by the framework. In summary:

- Reliability in the 4Rs is covered by the metrics contained within reliability in this framework. Key metrics describe different facets of the Cabinet Office definition.

- Resistance in the 4Rs is also covered by the metrics con within reliability in this framework. Key metrics describe different facets of the Cabinet Office definition.

- Redundancy in the 4Rs is split between reliability and adaptability in this framework. 'Passive' forms of redundancy (e.g. storage, spare production capacity) are covered by reliability, whilst 'active' forms of redundancy (e.g. network and treatment capacity that can be re-purposed during shock events) are covered in adaptability.

- Response/recovery in the 4Rs is covered by the metrics contained within adaptability. The only exception is where planned/passive operational processes (e.g. standby generation) are routinely used to maintain the running of a system when it is exposed to expected and planned for shocks.

As noted within the 'Naturally Resilient' report[10], it is important that resilience is viewed in relation to longer term stressors, as well as transient stresses and system shocks caused by acute hazards. The framework presented here is focused on modelled investment requirements, so it ensures that both transient shocks and stresses, and longer term/chronic stresses are addressed by splitting the metrics according to:

- Reliability and adaptability, which reflect portfolio resilience to transient shocks and stresses
- Evolvability, which reflects the portfolios ability to respond to unplanned, longer term or chronic stresses.

[10] Wildlife and Countryside Link Report, draft at the time of writing

Table C.1: Mapping of Reliability and Adaptability Metrics to the 4Rs and Hazard Type Coverage

The key measure of 'resistance' to drought hazard, as described under the 4Rs, relates to the 1 in 500 year failure metric that underpins the supply/demand balance. The linkages that the resilience metrics have to the 4'Rs of resilience attributes (as detailed by the Cabinet Office – Resistance, Redundancy, reliability and Response/Recovery) and the main hazards that link the attributes described by the metric

Public Water Supply System

Metric	Mapping to '4Rs'	Main hazard types linked to the attribute
R1: Uncertainty of option supply/demand benefit	Maps to 'reliability' under the 4R classifications.	Drought, possibly societal where there are significant licencing uncertainties.
R3: Risk of failure of planned service due to other hazards	Maps to 'resistance' and 'reliability' under 4R classification, but covers physical hazards other than meteorological shock or exceptional demand events	Physical and adversarial hazards. Only considers hazards that can cause long term failure due to loss of asset function. Events such as forest or heath fires that could prevent access for repairs are particularly significant.
R4: Availability of additional headroom.	Maps to 'redundancy' under 4R.	General system headroom to help allow operations to continue due to shocks caused by all hazards described under other metrics.
R5: Catchment/raw water quality risks (incl. climate change)	Maps to 'reliability' of service under 4R.	Raw water quality hazards that lead to sustained loss of supply, particularly during drought or demand shock events[11].
R7: Risk of failure of planned service due to exceptional shocks	Maps to 'resistance' and 'reliability' under 4R classification, but covers societal/supply chain hazards other than meteorological shock or exceptional demand events	Societal and supply chain hazards. Only considers shock events that could cause disruption resulting in outages and failures > 24 hours.
A1: Expected time to failure (PWS)	Maps to 'response' under 4R – the greater the warning time the more likely it is that drought response measures can be made to be effective.	Drought

[11] Demand shocks relate to peak demands outside of dry weather expectations, and can occur as a result of a number of circumstances – recent examples include freeze/thaw in 2017, high demand as a result of COVID-19 lockdown in some areas and localised issues during the 2018 prolonged heatwave.

A2: Duration of enhanced drought restrictions.	Maps to 'redundancy' and 'recovery' under the 4Rs. Recovery is included because the impacts and hence recovery measures will tend to increase the longer that the exceptional period lasts for.	Mainly relates to human factors and the risk that these materialise during the drought event (e.g. demand shocks, supply chain failure due to civil or economic issues).
A3. Operational complexity and flexibility.	Generally maps to 'response/recovery' areas of the 4Rs. Core element to enable non-routine operational responses and workarounds during shock events.	All hazards other than drought, as described under other metrics.
A5: PWS system connectivity	Covers both 'redundancy' and 'response/recovery' potential. Removing risks to critical points and SPOFs is key to enabling work arounds during shock events.	All hazards other than drought, as described under other metrics.
A7: Good customer relations support engagement with demand management	Maps to both 'redundancy' and 'response/recovery' under the 4Rs. Customer 'buy in' to calls for restraint and usage bans affects both the likelihood of more severe emergency measures, and reduces the risk of demand spikes that could interact with other hazards during drought events.	Drought/human factors