MOTT MACDONALD

WRSE Resilience Phase 2

Multi-sector resilience and systems approaches

August 2021

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Executive summary

Systems for an integrated multi-sector approach to water and the environment

The call to take a systems perspective on water, environment, and infrastructure projects in new and emerging policy in England is consistent. The National Infrastructure Commission frames its appeal for resilience in terms of infrastructure systems, Defra sets out the 25 Year Environment Plan (25 YEP) with an appeal that the environment is "managed more as a system", and Ofwat's strategy, 'Time to act, together' embraces 'systems thinking' building on earlier work in 'Resilience in the Round' which located the water sector within multiple interdependent systems all built around customer needs.

By taking a systems-based approach across infrastructure, water, environment, and a number of different water-using sectors, this report investigates the interdependencies across these domains reflecting their interconnected nature. This is particularly appropriate to analyse resilience. The shocks and trends that we examine impact different parts of these interconnected systems and resilience refers to the way in which the system can maintain its functions, in current or modified form, in face of these shocks and trends.

Water is a vital connector running through the major systems that society needs to thrive such as our natural environment, agriculture, business, government, and society as a whole. They are all interconnected by pipes, rivers, drains, floods, droughts, reservoirs, soil moisture and aquifers. Water runs through the types of system-wide approach society needs for resilience to major threats like climate change, biodiversity loss and pandemics.

This work focusses on resilience of the public and non-public water supplies, and yet locates this analysis in broader system perspectives. The environmental system is the foundation that supports all the other systems we consider in this report. Understanding the resilience of the multi-sector systems, such as farming, is essential to understanding the interaction between agriculture and the water system. Understanding society's objectives – for environmental stewardship, reliable water supplies and low utility bills are key drivers on the systems we are considering.

While the call for a systems approach is clear, there has been limited guidance on the substance of what that means in practice. Defra addressed that gap in the report 'Systems analysis for water resources' by applying a systems perspective to two catchments in England – the Medway in Kent and Sussex and the Eden in Cumbria. This report addresses feedback on the draft resilience framework for WRSE by taking the learning from the Defra work on catchments and applying it more broadly with a multi-sector regional perspective, thereby addressing the broader systemic perspective that Ofwat, Defra and the National Infrastructure Commission propose.

Purpose and scope of this report

This report is written in response to feedback from the consultation on the draft framework. The report has two objectives: firstly, to review the approaches to resilience across different sectors including agriculture, power, paper, canals, golf and quarries and, secondly, to develop a systems based framework covering all of these sectors, the environment, the public water supply and the social and economic system. The two elements of the work are combined so that the multi-sector work reflects WRSE's systems based approach.

The multi-sector analysis in this report has been developed through interviews and meetings with multi-sector actors on the WRSE working group. The work on the public water supply (PWS) and environmental systems has been developed in partnership with the water companies through the coordination mechanisms, development, and application of the metrics.

Main findings on multi-sector resilience

Across the sectors that engaged with this study there is strong, or at least emerging, awareness of the need for more integrated approaches to water resources management to tackle the resilience challenges that the WRSE region faces. Simultaneously, the provision of new policies across numerous sectors is enabling that transition to a more integrated approach. The 25 YEP and associated policy has created a suitable framework. Across the country, new approaches to collaborative multi-sector working are being developed. The regional approach articulated in the EA's National Framework sets a suitable scale for multi-sector regional planning. While these initiatives are developing in the environment and water sectors, they are mirrored by developments in finance such as the Task Force on Climate-related Financial Disclosures (TCFD) which provides a driver, and a framework, for business to engage with the environmental agenda with an entry point on climate. Together these concurrent initiatives have created a window of opportunity for genuine systemic change in the management and governance of environment and water resources.

Agriculture is the largest non-public water supply consumer with 41Ml/d of abstracted water. There are several ways that farms are increasing resilience in face of a perceived increase in the threat of drought and the need to improve business resilience in the context of policy and market uncertainty. Farmers are investing in water storage to enhance irrigation. Concurrently there is significant interest and uptake in regenerative farming practices that focus on improving soil health and cutting input and machinery costs. Both approaches are potentially synergistic with PWS resilience. Increasing farm storage means that farmers may look to abstract less water during critical summer months when demand for the PWS may be high. Improving soil health has numerous potential benefits for the PWS in improving regulation of water resources and control of sediment. Water companies are actively exploring these approaches.

The tolerance of risk for farmers is influenced by the market arrangements for their produce. Where an open trading arrangement exists such as wheat then there may be a high tolerance of a variable output. However, for other agricultural sectors such as vegetables or fruit farmers may lose ongoing contracts, or migrant work force, in subsequent years if their harvest fails. In these cases, connection to the PWS may be an important resilience strategy for the farm. Similarly, livestock farms may connect to the PWS as a resilience strategy for welfare of their livestock in drought. Increased collaboration is a feature of new approaches to farm resilience. Farmer groups can work collectively to avoid over-abstraction and maintain a dialogue with the regulator for a collaborative approach to risk management. Likewise, there is growing potential for constructive collaboration with water companies based on understanding the respective needs of different water users at different times of the year.

The paper sector is the largest industrial user of water taking 64% of the regions 52 Ml/d industrial abstractions. Paper making requires a consistent reliable supply of water. There is potential to enhance water reuse. Trading arrangements are not attractive to the paper sector given the high impact of being priced out of water at a critical time and thereby losing production capacity. Current constraints on the sale of surplus licence also undermine interest in water trading.

The power sector is facing a period of major transformation, aiming to transition to net zero carbon emissions by 2050 with some companies seeking a faster transition. The significance of hydrogen for energy is growing. Given the high level of investment in new power installations the power sector has minimal tolerance of residual risk on its water supplies, thereby requiring control of water resources through a robust licence rather than relying on traded supplies. There is, however, interest from power companies in engaging in water markets as vendors – for potable and raw water. Power companies are interested in exploring the potential of dynamic controls on abstraction for resilience such as establishing protocols for short term relaxations of HoF constraints for major shock events.

Canals are diversifying their revenue streams and face a degree of uncertainty over the security of the trust status of their governing body. They put a major emphasis on the well-being benefits of the canal system thereby creating the case for trust status. In their efforts to diversify funding streams they are interested in water vending opportunities, such as providing non-consumptive supplies for cooling. The Canal and River Trust have articulated an aspirational level of service of 1 in 20 years providing a clear planning basis for residual risk.

The golf sector lags behind others in creating awareness of the potential risks of drought, but yet has potential for multi-benefit schemes including water storage and biodiversity benefits. The importance of cultural change is a factor in the slow development of drought management in golf. This challenge is being addressed by the leisure sector and water companies with initiatives such as creation of the new Leisure Operator Water Charter in July 2021.

Quarries do not see drought as a significant risk given their interest in dewatering their sites rather than using water resources. They are, however, interested in the emerging uptake of multi-benefit environmental programming as there are potential opportunities for decommissioned quarries to host multi-benefit water resource schemes.

A systems perspective

This report demonstrates WRSE's response to the feedback on the draft resilience framework, notably with respect to the following priorities:

- A broadening of the scope away from the public water supply system (PWS) with more attention on the multi-sector elements of the programme.
- More focus on the environmental system given its role in underpinning water resources in the South East.
- Greater clarity around the systemic rationale for the resilience metrics.

Figure S.1 shows the four systems of interest to WRSE: the environmental system, the public water supply, the multi-sector system (and associated non-public water supply), and the social and economic system interact. The environmental system is shown as underpinning the other systems, a position similarly reflected in the detailed system mapping in this report. This report present systems maps as indicated on Table S.1. Agriculture is shown straddling both the multi-sector and environment systems.

This report has undertaken two types of systems mapping. A high-level flow diagram that shows value flows and outputs categorised with the six capital framework has been created. The role of resilience and system health are indicated with this technique. In addition, participatory system mapping (PSM) has been used to explore the influence of different factors on system function and how different systems and sub-systems interact. The PSM is undertaken with more detail on the different systems of interest.

This report has reviewed, modified, and validated the metrics presented in the draft resilience framework by annotating systems maps with the resilience metrics. This exercise showed where metrics were concentrated and where metric coverage was inadequate and needed correction.

Figure S.1 WRSE systems

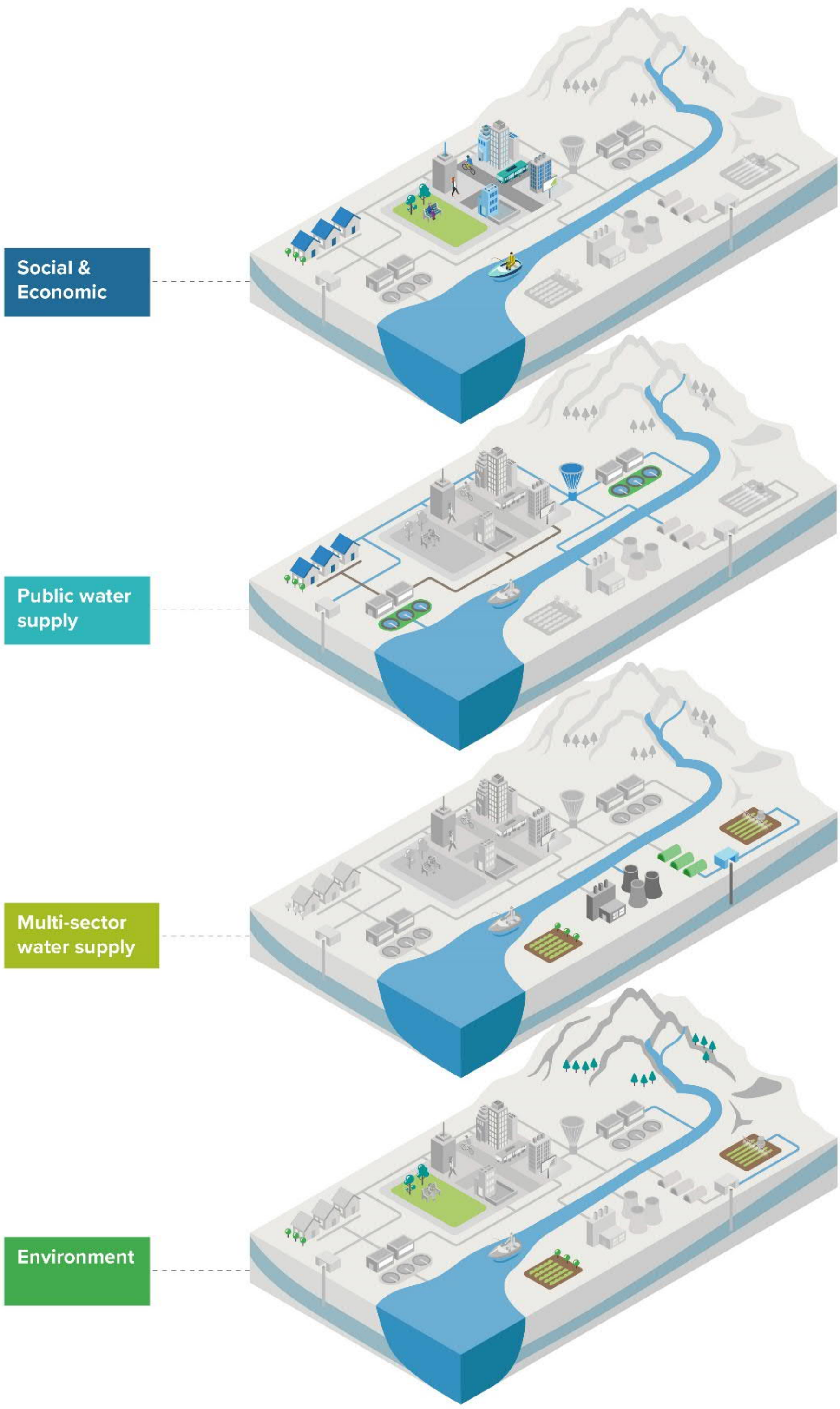


Table S.1 Systems and sub-systems mapped

System	Sub-systems mapped				
Social and economic	Addressed only with reference to the systems below.				
Public water supply	Public water supply	Wastewater			
Multi-sector/ non-public water supply	Power	Paper	Canals	Golf	Quarries
Agriculture: Multi-sector and Environmental systems	Farm decision making and field management	Irrigation and water storage			
Environmental system	Land use	River Health	Flooding		

As a result of this exercise there was some reorganisation of the existing metrics and the addition of three new resilience metrics for soil health, customer relations and collaborative land management.

- Soil health has emerged as a highly influential factor in the overall system resilience, benefitting resilience against agricultural drought, and with improved water quality and resources for the public and non-PWS systems.
- Customer relations are important in enabling short-term system adaptation to drought conditions and long-term evolution of the supply-demand balance in more resource-constrained circumstances.
- Collaborative landscape management such as ELM schemes are set to enable a more integrated approach to resource. This will enhance the degree to which land management will address evolving environmental pressures and constraints on land use.

The system resilience attributes tabled in the draft report were clarified in this report as follows:

- Reliability is an attribute that means the system can maintain its original function in face of shocks.
- Adaptability is an attribute that means the system can undertake a short-term modification of its function to withstand a shock.
- Evolvability is an attribute that enables the system to modify its operation in the face of long-term stresses or trends.

The system attribute of recovery is addressed in the categories of adaptability to reflect the means by which a system will return to normal operation after a shock event to which it has responded, or in reliability in the extent to which it resumes operation to a shock to which it provided passive resistance.

The report found that the different approaches to addressing resilience across the sectors fell into distinct categories. Risk may be *controlled* through the provision of infrastructure or regulation, *capitalised* through engagement with markets, *pooled* through collaboration or coordination or *accepted* as residual risk. Different sectors operate these strategies at different scales. For example, the power sector has a clear focus on control of their water resource risks through secure licencing but are happy to engage in water markets as vendors on the assumption others will capitalise risk. Smaller organisations operating at more local levels have less capacity to control and capitalise risk, but may have an ability to generate collective action and pool risk, drawing on a sense of the common good. The diversity of risk management strategies is an important consideration in establishing coordination mechanisms at regional and catchment level.

The way forward

This project has set a precedent in turning the ambition for a systems-based approach laid out in Defra's 25 YEP, Ofwat's Resilience in the Round and the EA's National Framework into a workable approach. It demonstrates approaches that are important to Ofwat's new strategy 'Time to act, together', emphasising the need for collaboration, focus on long term challenges, public value and environmental benefits. The precedent set here provides a platform for ongoing development of systemic resilience planning at the regional and organisational level and with respect to practical approaches to systems mapping.

As we have seen above, the systems of interest to the regional water sector are layered. The report also finds that the governance arrangements for those systems are layered and interleaved among the systems. A stacked set of systems and governance arrangements emerges as follows:

- Social and economic system – culture, economy and society driving the layers below
- National policy – governance
- Regional water resource planning – coordination mechanism
- Multi-sector organisations – systems with their own governance and coordination arrangements
- Regional transmission and storage network – collaboration between water companies
- Water companies with their own governance and coordination arrangements
- Local government – resilience forums to coordinate emergency services, NHS, the EA, transport, and other categories of resilience related service at the local level
- Catchments – systems with their corresponding governance/collaboration mechanisms.
- The natural environmental system – as a foundation to everything above.

Water provides a key interconnecting perspective on resilience, being vital to numerous systems and relevant to many important shocks and trends.

Recommendations

1. The resilience framework should be promoted for wider uptake and further development. The collective work across the six WRSE water companies, their consultants, the multi-sector, and environment working groups has enhanced the framework, which can now be used as a platform for further development in similar planning processes. The key features of the framework to build on are:
   - The clear categorisation of resilience attributes in terms reliability, adaptability and evolvability relating to passive and active responses to shocks and trends.
   - A set of metrics scalable by deployable output in a way that reduces subjectivity of weighting between metrics
   - The validation of the metrics with participatory system mapping, providing an audit trail for the selection of metrics.
   - The clear framing of public and private water systems that are reliant on the environmental system, interface with multi-sector systems and serve the social and economic systems.
2. The metrics developed in this report should be evaluated, managed, and developed to ensure that they bring the right balance of incentivisation across the systems of interest to WRSE. By maintaining the link between the system mapping and the metrics, then the system mapping may be updated, and the metrics revised over time as required. Suitable

governance arrangements are required for the metrics to ensure ongoing implementation and relevance beyond the PWS system alone.

3. The metrics need rigorous baselining as part of the planning cycle to inform option development and prioritisation. This need now informs the next round of planning. Identifying where the system has weaknesses would allow targeting of effort in option development, in addition to providing a platform for investment modelling.
4. The system maps need to be reviewed, integrated, shared, developed, and democratised. The insights that come from them must be made available for planning processes, stakeholder engagement and option development at the catchment level.
   - Approaches to collaborative option development should be explored, developed and adopted. These would use maps to investigate problems, identify interventions and identify co-benefits of those interventions with a view to generating more integrated interventions with more partners to influence system change. This type of exercise would provide the basis for developing multi-benefit schemes with blended finance and collective implementation and monitoring.
   - Work on the catchments should be downscaled to be made catchment specific so that they inform planning at that level.
   - Insights from the maps should be used for other objectives. Implications for a regional carbon net zero strategy should be explored using the systems mapping presented in this report.
5. The role of water as a super-connector of systems and a central focus in resilience planning gives regional water resource organisations a significant role in regional multi-sector resilience planning in the management and coordination of resilience and systems management. The benefits of this perspective should be taken forward through liaison with other resilience planning mechanisms and objectives.
6. The insights on risk culture should inform the development of coordination and governance structures, with each organisation playing to its natural strength or strengths in a framework that reflects the respective benefits that each risk culture brings.
7. The systems perspective should be developed as a management tool over time. The addition of real-time monitoring would be added as the system maps are used over time. In combination with a GIS, this then creates the basis of a digital twin for the regional water resource system. A digital twin of this type would allow integrated systemic planning of the regional water resources, with plans then transformed into monitoring and management tools as they are implemented. This live tool would also be used as a scenario analysis tool, enabling further development of strategic interventions.

Acronyms

25YEP	25 Year Environment Plan
BAT	Best Available Technology
BNG	Biodiversity net gain
CaBA	Catchment Based Approach
CCS	Carbon capture and storage
CECAN	Centre for the Evaluation of Complexity Across the Nexus
CHP	Combined Heat and Power
Defra	Department for Environment, Food & Rural Affairs
DWP	Department of Works and Pensions
DWMP	Drainage and wastewater management plans
EA	Environment Agency
ELM	Environmental Land Management
ESG	Environmental, Social and Corporate Governance
ET	Evapotranspiration
ETS	EU Emissions Trading Scheme
FCA	Financial Conduct Authority
GIS	Geographical Information System
GVA	Gross Value Added
HOF/HOL	Hands-Off Flow restrictions /
IDB	Internal Drainage Board
IIRC	International Integrated Reporting Council
KTP	Knowledge Transfer Partnerships
LEN	Local Enterprise Network
NC	Natural capital
NFU	National Farmers Union
NGO	Non-Governmental Organisation
NIS	National Infrastructure Strategy report
PSM	Participatory Systems Mapping
PSMD	Potential soil moisture deficit
PV	Public value
PWS	Public Water Supply
SDB	Supply Demand Balance
SDGs	Sustainable Development Goals

SEA	Strategic Environmental Assessment
SRO	Strategic resource options
STW	Sewage Treatment Works
TCFD	Task Force for Climate-related Financial Disclosure
UKIA	UK Irrigation Association
WEF	World Economic Forum
WRMP	Water resources management plan
WRSE	Water Resources South East
WRZ	Water Resource Zone

1 Introduction

This section introduces the scope and purpose of the project.

The new and emerging environmental, infrastructure and water policies in England all lay down the challenge for us to think in terms of systems. Systems thinking is intended to enable us to understand complex interlinkages between interventions and see how multiple impacts create transformative change in the world around us. This systemic approach is needed to harness synergies as we make our water supplies resilient to drought, our communities resilient to flooding, to reverse the loss of biodiversity and target other similar pressing objectives at scale.

This report takes a systems approach to apply the concept of resilience to the work of WRSE. Resilience is the measure to which a system can keep operating notwithstanding shocks and trends that impact it. The report updates the earlier resilience framework and metrics in response to feedback during consultation on the first version.

1.1 Project scope and purpose

The WRSE method statement for resilience was published for consultation in July 2020.[1] The statement presented a systems-based resilience framework including a set of resilience metrics. Feedback on the metrics demanded,[2] *inter alia*:

- A broadening of the scope away from the public water supply system (PWS) with more attention on the multi-sector elements of the programme.
- More focus on the environmental system given its role in underpinning water resources in the South East.
- Greater clarity around the systemic rationale for the resilience metrics.

To address these issues WRSE commissioned the current piece of work with the following two objectives:

A. **Multi sector resilience analysis** – working with key multi sector partners to support their resilience planning/thinking and the data, information and options thinking which will be incorporated within the WRSE resilience framework.
B. **System aspects** – support development and finalise the systems aspects of the framework.

This report is written to address both of these objectives. The multi-sector work is therefore written within a systems framework. The technical detail on Objective B was circulated to water companies in December 2020 and was used in the development of the technical guidance note on resilience metric scoring, shown in Appendix A. The scope of this report is therefore on Objective A – multi-sector resilience and development of the systems aspects across all four systems. Detail on resilience metrics has not been reproduced in this report, because it has been taken forward with subsequent modification to the Technical Appendix to WRSE's Resilience Method Statement.

[1] See: https://www.wrse.org.uk/media/x1nm0m35/wrse_file_1325_wrse-ms-resilience.pdf

[2] See: https://www.wrse.org.uk/media/qybbxsqw/resilience-framework-response-to-feedback-03-august-2020_final.pdf

1.2 WRSE programme context

The work of WRSE comprises an investment plan with a portfolio of options for implementation with a design horizon of 2100. The options come in four categories:

- Water resource options – reflecting the supply side work of the PWS
- Demand management options – reflecting the demand side work of the PWS. This reflects a PWS engagement with the social and economic system.
- Blue/green or catchment options – promoted by the PWS and other actors, reflecting engagement with the environmental system
- Multi-sector options are water resource and demand management options driven by actors other than the PWS.

Over 1000 water company sponsored options have been identified. The options are modelled in different combinations or "portfolios" to ascertain how they meet the water needs of the south east. The portfolios are assessed against "best value" criteria meaning that they are selected against three factors.

- Least cost.
- Environmental benefits - indicated by a set of environmental metrics.
- Resilience of the water system - indicated by a set of resilience metrics.

This report updates the set of resilience metrics and shows how they relate to the environmental, water, economic and social systems WRSE is addressing.

The revised schedule of resilience metrics produced in this report is given in Table 2.2. The report was held till scoring had been completed to include the final schedule of metrics which was modified further following this report to address complexities identified during the scoring process. The final schedule of metrics is shown on Table 2.3 and described in detail in the Technical Appendix to WRSE's Resilience Method Statement.

1.3 Project method and report structure

Following this introduction, a review of the systems mapping approaches adopted in this report is provided in Section 2. The system mapping is undertaken in two ways, firstly a high-level perspective is taken to map the flows of value between one system and the next. The six capital framework developed by the International Integrated Reporting Council (IIRC) is used to categorise value and capital.[3] Secondly the component sub-systems are mapped using participatory systems mapping (PSM) to explore causality, influence and control of the systems.[4]

Shocks and trends are reviewed from a business perspective in Section 3. This perspective complements work done to date on the PWS system. Shocks and trends are further developed in the reviews of the multi-sector systems. The environmental system is reviewed in Section 4 as the foundational system for of all the system mapping that follows. The environmental system maps were reviewed by the WRSE environmental group. The PWS system is mapped in Section 5 and was reviewed and added to by the project steering group over a number of meetings as the framework was developed. This includes and updated system map following further developments made as the resilience metric scoring process was rolled out.

[3] International <IR> Framework | Integrated Reporting

[4] Defra (2020) Systems Analysis for Water Resources
http://sciencesearch.defra.gov.uk/Document.aspx?Document=14947_WT15121.FinalReport.pdf

At this point, the report moves to more detailed work on the multi-sector systems. The work on the sectors has made a detailed system map with an influence and control perspective and a discussion of the flow of value. These maps are relatively high level and are available for down-scaling, modification and use in the ongoing analysis underpinning option and programme development in the region. Alongside the systems mapping semi-structured interviews of representatives from the power, paper, quarrying, golf, and canal sectors have been undertaken. The semi-structured interviews have been based on the following set of questions, sent to the interviewees in advance of the interviews.

- What are the main risks and trends that affect your industry (in general terms)?
- How is your industry changing?
- What are the impacts on water use?
- What combination of PWS and private sources do you use?
- What are your assumptions around drought planning?
- Please describe the impacts, and your responses, to increasingly severe drought – from normal operation to the point you are unable to operate.
- What types of options have you identified that would address these water resilience problems?

The multi-sector systems are discussed in Section 6. In Section 7 we provide a review of the social and economic system. Section 8 provides the main analytical discussion of the system maps and of the interview results. In Section 9, we summarise the findings of the report and discuss their implications for regional water resources management and the adoption of a systems approach to resilience. We provide recommendations at an organisational level and for the development of systems management for resilience.

1.4 How to read this report

The report addresses both parts of the project together – the multi-sector resilience analysis and the work to strengthen the systems analysis, to ensure the resilience analysis is grounded in the systems framework. For readers with focussed interest in the report, ways into the report are proposed in Table 1.1. For detail on the metric scoring, weighting and aggregation, see the Technical Appendix to WRSE's Resilience Method Statement.

Table 1.1: Ways in to the report

Area of interest	Way into the report
Specific sector resilience	Read the relevant discussion in Section 6; use Section 2 for reference if additional background on systems is of interest. See Section 3 for a business perspective on shocks and trends
Environment	See Section 4 on the environmental system and Section 6.1 on agriculture. Draw on Section 2 for information on systems as required.
PWS	See Section 5 A discussion of how this is taken forward with metrics shown in Appendix A. Since the original work in this report this discussion has been taken forward in the Technical Appendix to WRSE's Resilience Method Statement.
Metrics	See Appendix A on the modification of the resilience framework. This discussion has been taken forward in the Technical Appendix to WRSE's Resilience Method Statement.
Systems analysis	See Section 2 for the framework and Section 8 for the analysis. See chapters 4 to 6 on the use of system mapping. See the conclusions for ideas on taking the work forward.
Policy considerations	See the discussion of policy implications and coordination in the conclusions.

2 Systems, resilience, value, and control

This section introduces key ideas around systems and how they are mapped. It sets up the analytical framework for this report and demonstrates how ideas of systems, resilience and value are linked.

2.1 Systems thinking in water and environmental policy

The benefit of a systems approach to environmental problems is that it reflects more of the complex interactions inherent in real world situations. The need for a holistic approach to problems underpins the 25 Year Environment Plan (25 YEP) which sets out a vision for the environment to be *"mapped and managed more as a system"*[5] Defra's report 'Enabling a Natural Capital Approach' similarly aims to "*support systems-based thinking, identify new lines of inquiry linking previously disconnected spheres of operation or data, and support identification of priority areas of investment."*[6]

Ofwat, likewise, adopt a systems perspective as the basis of their flagship report "Resilience in the round":

> *"Resilience in the round is built upon the concept of interdependencies between related systems with customers at the heart of it all. To deliver against expectations, companies will need to demonstrate a sophisticated understanding of these interactions. This will enable them to deal with the causes of future threats, rather than just the symptoms, through adopting a stronger systems-based approach."*

Ofwat's scope is broad and acknowledges that water operates within a broader systemic context:

> *"Water and wastewater services are made up of a complex set of operational, corporate, and financial systems. They are also linked with a wide range of other systems. These include the broader natural environment, social systems, the economy, and agriculture. These macro systems also operate in association with infrastructure systems such as communications and energy networks and highways drainage."*[7]

The appeal for systems thinking is clear, but what has been less apparent is concrete demonstration of the application of systems thinking to practical problems. To address this question, Defra recently commissioned a study to apply systems thinking to water resource problems at the catchment level, using the Medway in Kent and Sussex and the Eden in Cumbria as case studies.[8] This demonstration of a systems-based approach to environmental problems forms the methodological basis of this report for WRSE.

[5] Defra (2018) A Green Future: Our 25 Year Plan to Improve the Environment https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

[6] Defra 2018https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869801/natural-capital-enca-guidance_2_March.pdf

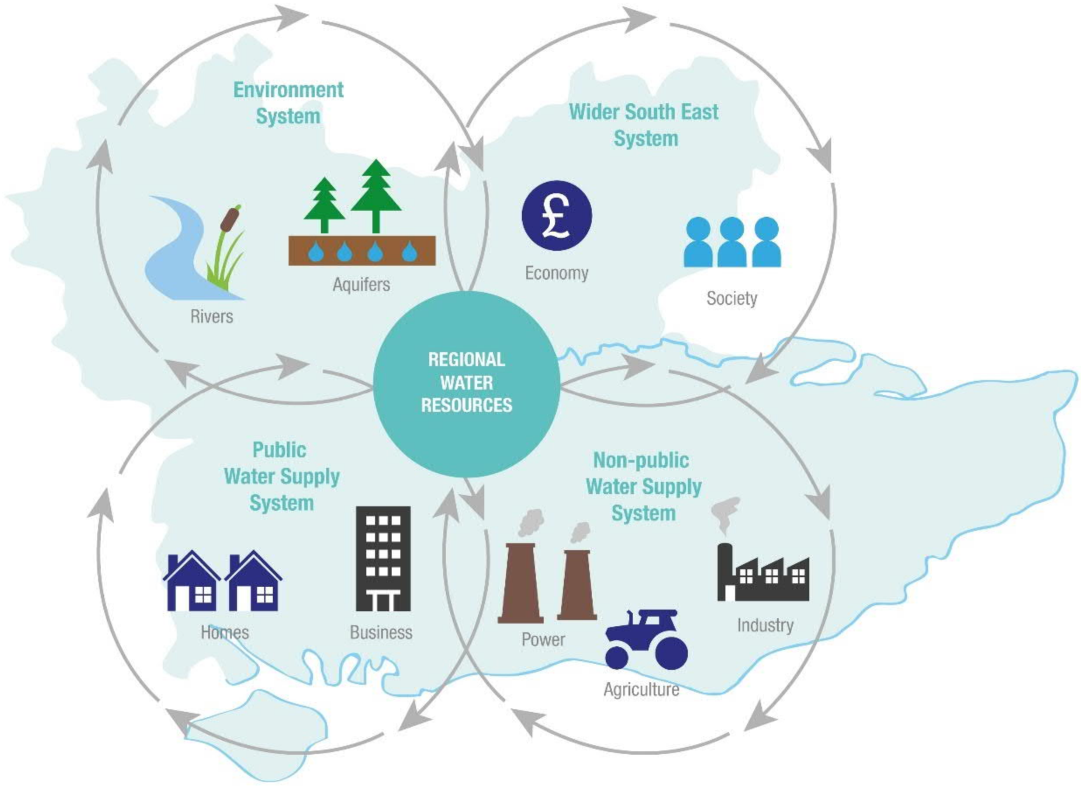
[7] Ofwat (2018) Resilience in the Round. https://www.ofwat.gov.uk/publication/resilience-in-the-round/

[8] Defra (2020) Systems Analysis for Water Resources http://sciencesearch.defra.gov.uk/Document.aspx?Document=14947_WT15121.FinalReport.pdf

2.2 WRSE systems

Essential to any analysis of a systemic problem is the definition of the system boundaries. WRSE's systems framework in the draft resilience method statement is shown comprising four systems (environment, PWS, non-PWS and wider South East systems) as shown on Figure 2.1.

Figure 2.1: The four systems of interest to WRSE in the draft resilience method statement.



Source: WRSE Method Statement: Resilience – Consultation version – July 2020

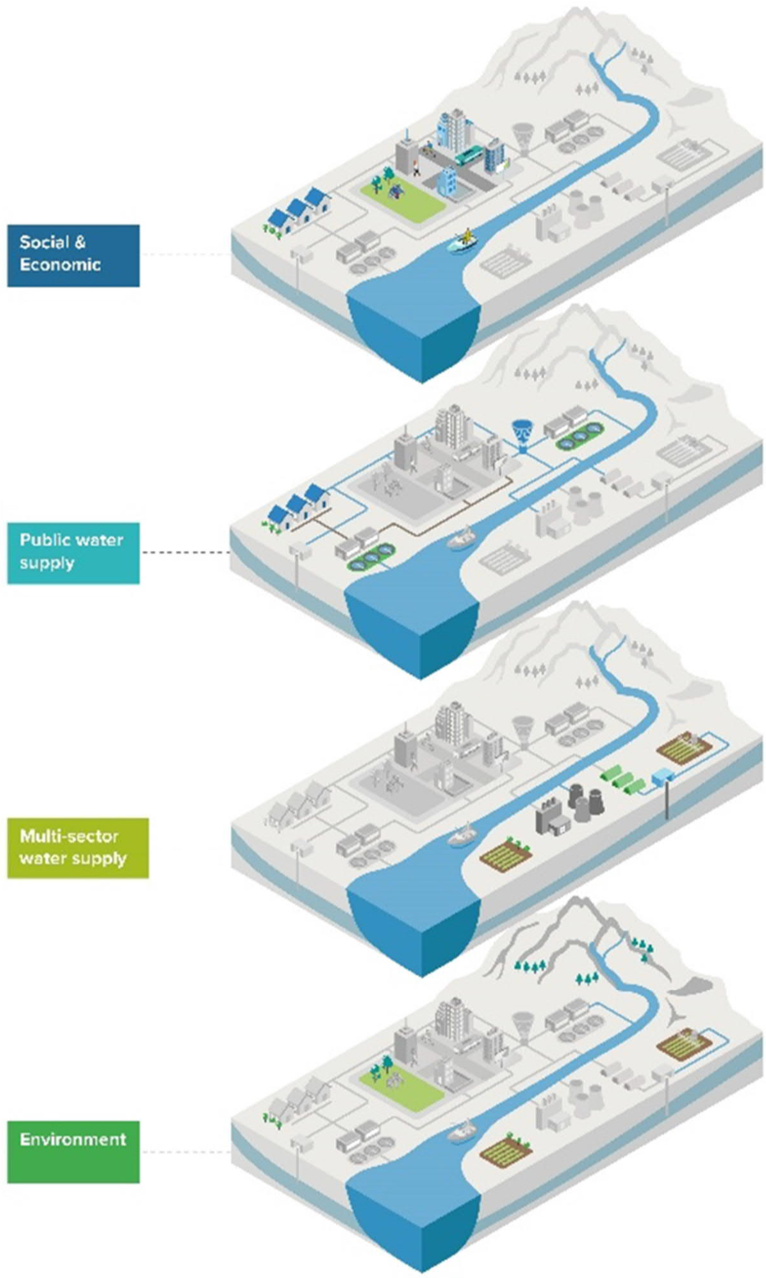
While retaining the overall framing of four systems, the feedback indicated that there is a need to show some hierarchy of the systems as they are not all to be given the same weight in WRSE's work. In addition, experience of working with the systems has also highlighted some points that need clarification. The draft framework referred to the PWS system, the non-PWS system and the environmental systems as the core systems indicating that the wider social and economic system is of interest as a derivative of these systems. We propose the following:

- The environment system should be clearly portrayed as foundational to the other systems.
- The term multi-sector system is preferable to non-PWS system because the sectors are defined on their own terms, rather than in opposition to the PWS. However, where we refer to water supply operated by the multi-sector system then non-PWS is retained as the contrast to PWS is useful.
- The wider south east system will be referred to as the social and economic system. For our interest, it is built on the other systems and has feedbacks to them. One of the key feedbacks from the social and economic system is the cultural and political adoption of an environmental agenda which drives environmental change within the three core systems.

- Agriculture straddles both the environmental system and the multi-sector system.
- There is a need to consider the wastewater system in addition to the supply system as it is part of the link from the PWS system back to the environment system.
- The components of the multi-sector system identified for focus in this project are agriculture, power, paper, quarries, canals, and golf, selected based on priorities in the region, advised by WRSE.

To reflect these changes the WSRE systems are now represented as shown in Figure 2.2.

Figure 2.2 Revised representation of the WRSE systems



The resulting list of systems and component sub-systems considered is as shown in Table 2.1.

Table 2.1 Systems and sub-systems considered

System	Sub-systems mapped				
Social and economic	Addressed only with reference to the systems below.				
Public water supply	Public water supply	Wastewater			
Multi-sector/ non-public water supply	Power	Paper	Quarries	Canals	Golf
Agriculture: Multi-sector and Environmental systems	Farm decision making and field management	Irrigation and water storage			
Environmental system	Land use	River Health	Flooding		

To determine the scope of the systems we consider, we need to define our interest in looking at the resilience ***of*** *what* ***to*** *what*? In theoretical terms, we're looking at the resilience of a system to undertake its key function in face of a given list of shocks and trends. In our case, the key function or WRSE as a whole is to provide a stable water supply demand balance (SDB) for water users.

Two considerations arise. Firstly, while the provision of water resource is central to the focus of the resilience plan, it does not mean that each component system has water resources as its own key function. The key function of the multi-sector system is value creation. The key function of the environmental system is the provision of its numerous ecosystem services. So, while our focus remains on water, it is important that these systems are not represented as having water services as their key function.

Secondly, that this framing principally requires the provision of a resilient water resource to the customer; but not to see customers as passive recipients. As Ofwat observes: "*Companies need to move from seeing customers as recipients of services, to seeing them as active participants in the delivery of those services".*[9] Demand management measures are an important element of achieving a resilient SDB both at times of acute water stress and with respect to chronic strain on sustainable resources.

We propose the following understanding of the core systems:

- The principal function of the PWS is the provision of a resilient, cost effective and low carbon supply demand balance for customers.
- The environmental system functions to produce numerous ecosystem services. Our primary interest is in the provision of water resources. Thereafter, WRSE has secondary objectives of enhancing the environmental system and avoiding detriment. We note that the environment is also a water user (consumptive and non-consumptive) and can transport water resources – these additional functions provide important opportunities for mutual interaction with different systems.
- The multi-sector system has the purpose of economic value creation. The multi-sector system is really a collection of systems, the diversity of which is the focus of this report.
- Defining the overall purpose of the wider social and economic system relating to human well-being and other societal objectives is beyond the scope of this project. Our interest is in how

[9] See https://www.ofwat.gov.uk/wp-content/uploads/2017/03/1941_OFWAT_Cust_Participation_Report_final.pdf

the three systems above provide value inputs to social and economic system and what feedbacks are achieved.

2.3 Resilience

The draft resilience framework adapted the 'Resilience by Design' framework to identify three key system characteristics that make up resilience.[10] We maintain the same approach in this report with the following clarification. Shocks refer to short term forces that act to disturb the system. Trends and stresses refer to long term changes on the influence of the system or the behaviour of actors within the system. Trends are changes over time – where these inhibit system operation then stresses occur. A trend could include a pattern of increasing severity or frequency of shocks:

- **Reliability** is an attribute that means the system can maintain its original function in face of shocks.
- **Adaptability** is an attribute that means the system can undertake a short-term modification of its function to withstand a shock.
- **Evolvability** is an attribute that enables the system to modify its operation in face of one or more stresses or trends.

Adaptability and evolvability allow the system managers to respond to the shock or trend. Reliability is a passive form of resilience rather in contrast to the active responses involved in adaptability and evolvability.

2.3.1 Metrics

The metrics presented in the draft framework are shown on Figure 2.3. The analysis of systems described in this report led to a number of modifications to the metric schedule which are shown on Table 2.2. The PWS system map that indicates the changes proposed at this time (in gold and pale pink) is given on Figure 5.2. These changes were communicated to the water companies in the technical note reproduced in Appendix A.

Subsequently, additional changes have been made to the metrics in response to issues raised during the scoring process. The metric table as of June 2021 is provided on Table 2.3. The corresponding developments on the PWS system map are shown on Figure 5.3.

For details on the final version of the metrics and the scoring methodology see the Technical Appendix to WRSE's Resilience Method Statement.

Correspondence with the strategic environmental assessment has been indicated with on the system maps. This correspondence is indicative. Reference should be made to the SEA for details of the assessment. Correspondence with the SEA has not been made on the PWS maps in order to avoid complication given the space dedicated to the resilience metrics on these maps.

[10] 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

Brown, C., F. Boltz, J. Tront, D. Rodriguez, and S. Freeman. 2020. Resilience by design: a deep uncertainty approach for water systems in a changing world. Water Security 9: 100051 https://doi.org/10.1016/j.wasec.2019.100051

Figure 2.3: Resilience metrics in the technical guidance following the consultation (Refer to WRSE Resilience Assessment Technical Guidance V2)

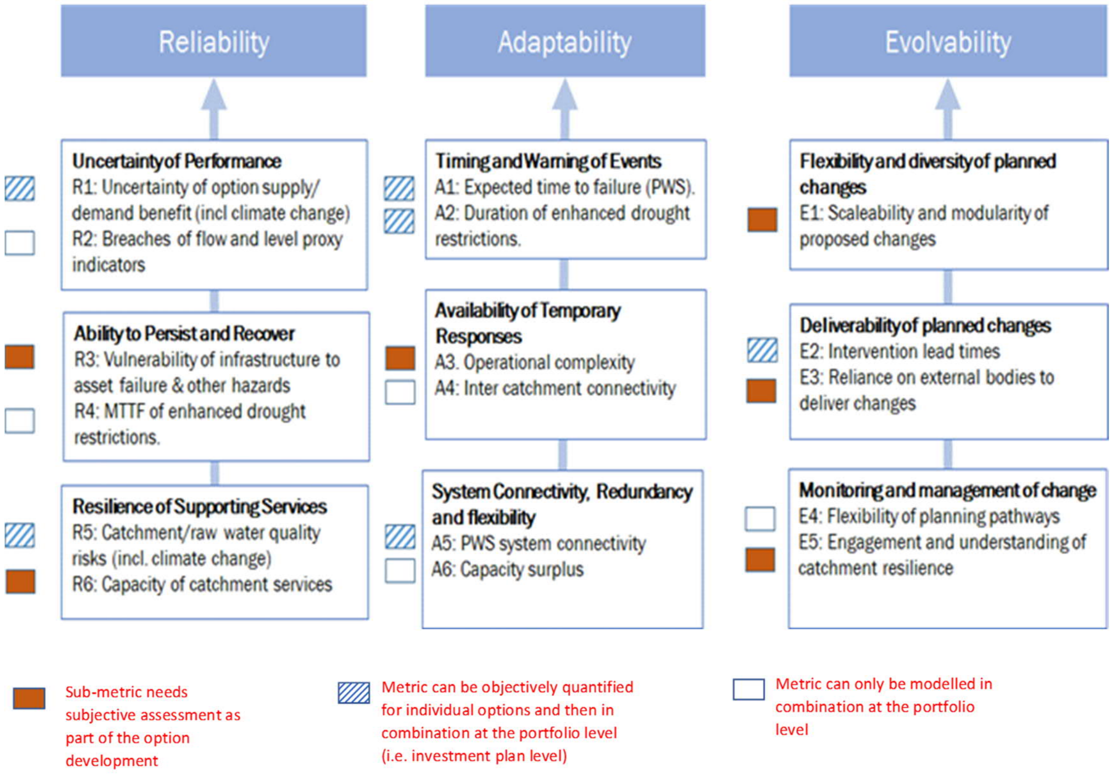


Table 2.2 Revised schedule of resilience metrics (December 2020)

System attribute	RELIABILITY		ADAPTABILITY		EVOLVABILITY	
System characteristic		**UNCERTAINTY OF PERFORMANCE**		**TIMING AND WARNING OF EVENTS**		**FLEXIBILITY AND DIVERSITY OF OPTIONS**
Metric	R1 PWS	Uncertainty of option / supply demand benefit	A1 PWS	Expected time to failure (PWS)	E1 PWS (Non-PWS)	Scalability and modularity of proposed changes
Metric	R2 Non-PWS	Breaches of flow and level proxy indicators	A2 PWS / (Non-PWS)	Duration of enhanced drought restrictions		
System characteristic		**ABILITY TO PERSIST AND RECOVER**		**AVAILABILITY OF TEMPORARY RESPONSES**		**DELIVERABILITY OF PLANNED CHANGES**
Metric	R3 PWS	Risk of failure of planned service due to other physical hazards	A3 PWS	Operational complexity	E2 PWS / Non-PWS)	Intervention lead times
Metric	R4 PWS	MTTF of enhanced drought restrictions	A4 All	Inter-catchment connectivity	E3 (PWS)	Reliance on external bodies to deliver change
			A7 PWS	Customer relations enhance engagement with drought demand management measures		
System characteristic		**RESILIENCE OF SUPPORTING SERVICES**		**SYSTEM CONNECTIVITY, REDUNDANCY AND FLEXIBILITY**		**MONITORING AND MANAGEMENT OF CHANGE**
Metric	R5 Env	Catchment / raw water quality risks	A5 PWS	PWS system connectivity	E4 PWS	Flexibility of planning pathways
Metric	R6 Env / All	Capacity of catchment services	A6 PWS / Non-PWS	Capacity surplus	E5 Env/All	Engagement and understanding of catchment resilience
Metric	R7 PWS	Risk of failure of supporting service due to exceptional events			E6 All	Collaborative landscape management
Metric	R8 Env/ All	Soil health				

Table 2.3: Final schedule of resilience metrics (June 2021)

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 relations support engagement with demand management	**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	**A4** PWS	WRZ connectivity	**E4** PWS	Flexibility of planning pathways
Metric	**R6** ENV	Capacity of catchment services	**A5** PWS	PWS system connectivity	**E5** N-PWS ENV PWS	Collaborative landscape management
Metric	**R7** PWS	Risk of failure of supporting service due to exceptional events	**A6** ENV N-PWS	Inter-catchment connectivity		
Metric	**R8** ENV	Soil Health	**Metric applied to:** PWS Public water supply N-PWS Multi-sector water supply ENV Environment			

2.4 Four perspectives on systems

The Defra study on catchment systems mapping in the Medway and Eden, that this project draws on, explored the implications of the fact that there are different ways of perceiving systems across different organisations and sectors. For example, at the level of catchments a contrast can be seen between the EA's asset performance team who implement infrastructure projects and take formal engineering management approaches to controlling systems, and catchment management partnerships who have greater flexibility, creativity and reach by taking a more informal approach to systems that is well suited to generating collective responses. The asset performance approach to systems is more one of command and control with the system more tightly focussed on well-defined and measurable engineering functions. Catchment partnerships, by contrast, take a broader perspective on systems considering the interaction of social and environmental dynamics that may be hard to define and quantify. The salient point is that different organisations have different cultures relating to systems that can be seen in the way that systems are articulated and reflect the potential interventions available to the organisation. See the Defra's report "Systems Analysis for Water Resources" for a discussion of this categorisation in English catchment management. [11]

The theoretical basis for this diverse understanding of systems is referred to as Cultural Theory or Plural Rationality.[12] The theory identifies four main preferences in the way risk is managed each of which has a corresponding influence in the way that systems are perceived:

- **Control of risk**: A "bureaucratic" approach to systems will focus on the harder elements of the system and looks for means to control and influence the operation of the system. Bureaucrats are risk regulators. This approach is prevalent in government who tend to address risk through regulation. Similarly, engineers prefer well-defined systems approaches and address risk through design codes and operational protocols. These approaches fit well with hierarchical organisation structures with an ethos of clear authority and control. We refer to this as a risk control strategy. We refer to the maps that reflect this perspective as 'control and influence' maps.
- **Collaboration / coordination / risk pooling**: An "egalitarian" approach to systems eschews the formality of the bureaucrats and seeks collective responses to systemic problems. Tolerance of a less well-defined approach is adopted because it enables greater collaboration and it more realistically reflects the complexity of real-world problems. Egalitarians are risk poolers. This approach is prevalent in third sector organisations such as environmental NGOs. In more grass-root organisations the approach may be one of collective action. In more formal contexts the same perspective is evident in coordination mechanisms. We refer to this risk management strategy as collaboration indicating both collective action and coordination according to the context.
- **Capitalisation of risk**: An "individualist" or "entrepreneurial" approach to systems sees risk as an opportunity. Analysis of systems focusses on the analysis of value or commodities. Precise definitions of systems are useful only if they serve the purpose of addressing problems and creating opportunities. This perspective is prevalent in the private sector. We refer to this strategy as capitalisation of risk referring both to those who outsource risk and those who purchase risk as an opportunity for value creation / profit.
- **Risk accepters**: The fourth category of actor is not part of one of these groups with a clear strategy to risk but is more inclined to accept risk. They are less likely to be interested in

[11] Defra (2020) Systems Analysis for Water Resources
http://sciencesearch.defra.gov.uk/Document.aspx?Document=14947_WT15121.FinalReport.pdf

[12] Thompson, M., Ellis, R., & Wildavsky, A. (2018). Cultural theory. Routledge.

systems analysis being less inclined to engage in the control or exploitation of systems. This perspective is found in society where people chose to be less engaged in government, collective or entrepreneurial activity. The academic literature refers to this group as fatalist – a term we avoid because of its pejorative tone. Defining a clear acceptable level of service is a useful contribution to a risk strategy. We refer to this group as risk accepters.

For our purposes it is important to note that different sectors of society ask different questions when they undertake investigation of a system:

- Government and engineers tend to ask how a system can be controlled or influenced. They are risk regulators or controllers.
- The private sector looks at as systems and asks about value creation, markets, and flow of capital. They can capitalise risk and benefit from the opportunities of doing so.
- The third sector looks at systems and asks who they should be collaborating with for collective benefits. They are risk poolers. Coordination mechanisms work with a similar rationale of working together to reduce individual exposure to risk.
- Risk accepters are less engaged with analysis of systems. They live with the impacts of variable system outcomes.

By way of illustration, these categorisations may be seen in the different attitudes of customers to utility bills. An entrepreneur would shop around for the best deal. A bureaucrat would check that their supplier is compliant with the relevant policies and targets. An egalitarian customer would check that their company is doing their bit for the environment – serving society as a whole. A risk accepting customer may neglect to open their bill and just pay it on direct debit without assessing the implications or options.

This categorisation sets up our review of the WRSE framework because it acknowledged that there are numerous perspectives on systems. Different elements of the water systems described above require different risk strategies and are therefore addressed with different perspectives and strategies. All of these perspectives will be seen in our analysis and will be useful in the discussion of how the systems can be integrated and coordinated.

At this stage, however, we focus on two perspectives. Firstly, we take a high-level perspective on the flow of value and how and why the systems are interconnected; what resilience means in this context and how it can be measured. This is the entrepreneurial perspective, looking at the system from the perspective of value creation. We categorise different types of value with the six capital (Integrated Reporting) framework.[13] Secondly, we will consider an influence and control perspective which represents the system control view. We will seek to understand what influences what within a system and what the consequences of operation or failure within a system are. These two perspectives are complementary and are described below.

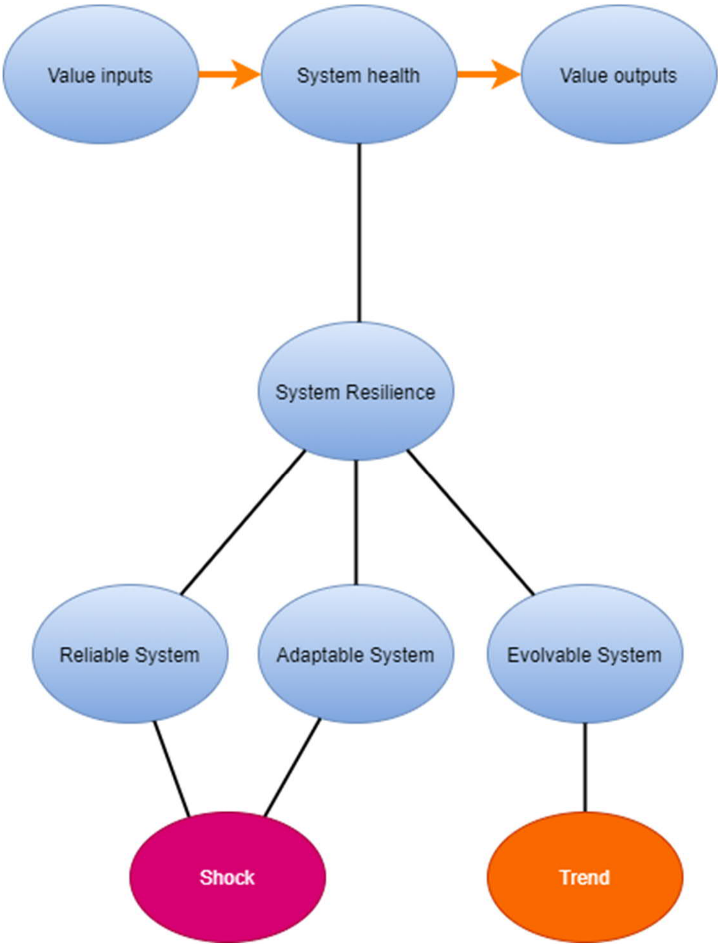
2.4.1 A value creation perspective

A healthy system takes value inputs, processes them in some way and then produces value outputs. In this case a system perspective considers flows of value, useful to those working with the system. System resilience reflects the extent to which system health is maintained and its function continues notwithstanding the shocks and trends to which the system is subjected. The draft framework identified three aspects of resilience as reliability, adaptability and evolvability. The basic system diagram from the value creation perspective is shown in Figure 2.4. Value, in the form of multi-capitals, flows from the input node through the system health node to the value

[13] International <IR> Framework | Integrated Reporting

output node (the orange line). System resilience has a supporting role to system health and provides the interface with shocks and trends.

Figure 2.4: System diagram – value creation perspective



Multi-capital accounting

To provide a basis of discussing flows of value we use the multi-capital Integrated Reporting Framework developed by the International Integrated Reporting Council (IIRC). The IR framework, referred to in the water sector as the six capitals framework, was developed as an approach to corporate reporting noting that a company's value consisted in more than its financial assets. It allowed company Boards to hold directors accountable for previously intangible aspects of a company's value such as its stakeholder relations or its intellectual capital. The approach has been taken up by some 2000 companies globally and has been the subject of significant interest in the UK's water sector.[14] We have adopted this framework given its emerging role in the water sector and the fact that it has traction in the multi-sector business world. The six categories of capital are:

- financial
- manufactured
- human
- social and relationship
- intellectual
- natural

[14] See 13-12-08-THE-INTERNATIONAL-IR-FRAMEWORK-2-1.pdf (integratedreporting.org)

System overview

A map indicating value creation across the WRSE system is shown on Figure 2.5 with examples indicated on Figure 2.6. Metrics and potential measures of value are shown on Figure 2.7. The three core systems are aligned next to each other with the environmental system shown on the left in green, the PWS system shown centrally in blue and the multi-sector system shown on the right in pale pink. Above this links are shown to the wider social and economic system which is not described in detail.

Each system has nodes that represent value inputs, system health and value outputs. For the core systems, these nodes are aligned across the middle of the map. They are connected with orange or blue lines. The orange lines represent flows of value or capital in terms of the multi-capitals. The blue lines likewise represent flows of value or capital in terms of the six capitals, but the predominant flow is natural capital in the form of water. The following notes are provided on the interpretation of the system maps.

- The environmental metrics indicated, on Figure 2.7, include natural capital (NC), biodiversity net gain (BNG), the habitats assessment and the strategic environmental Assessment (SEA).
- Public value (PV) and gross value added (GVA) are not currently assessed for WRSE so Figure 2.7 indicates where these could be measured rather than where they are measured.
- The metrics are indicated in two ways the larger markers indicate the main cluster of metrics of a given type (such as the large Resilience (R) metric on the PWS system) and smaller markers for where there are fewer metrics (such as the small R metric on the environmental system).

The main line of interest runs from left to right across the diagram in which a healthy environmental system produces value outputs for the wider social and economic system (orange line representing multiple capitals going up the page) and water for the PWS system and multi-sector system. The health of the environmental system is measured with metrics for NC, BNG, SEA and habitats. There are some resilience metrics that apply to the environmental system relating to water quality in catchments, and catchment ecology and soil health. We recall that the resilience metrics relate to the resilient provision of water and consequently health of the environmental system – a healthy environmental system underpins resilient water supply systems.

The PWS receives water from the environmental system and diverse inputs from the social and economic system (such as “labour and know-how” or human and intellectual capital). Inputs from the multi-sector system include power and chemicals – manufactured capital. The PWS has a number of important feedbacks to the environmental system – intellectual capital for management of resources, financial and human capital in catchment management programmes and so on.

The multi-sector system receives water from the environmental system and from the PWS system. The health of the system determines the extent to which it can achieve its intended outcomes of value creation. This report considers power, paper, quarries, canals, and golf in the multi-sector system. Agriculture straddles both the multi-sector system and the environmental system – a major feedback from the value creation in the multis-sector system to the environment system.

Figure 2.5: WRSE value creation systems

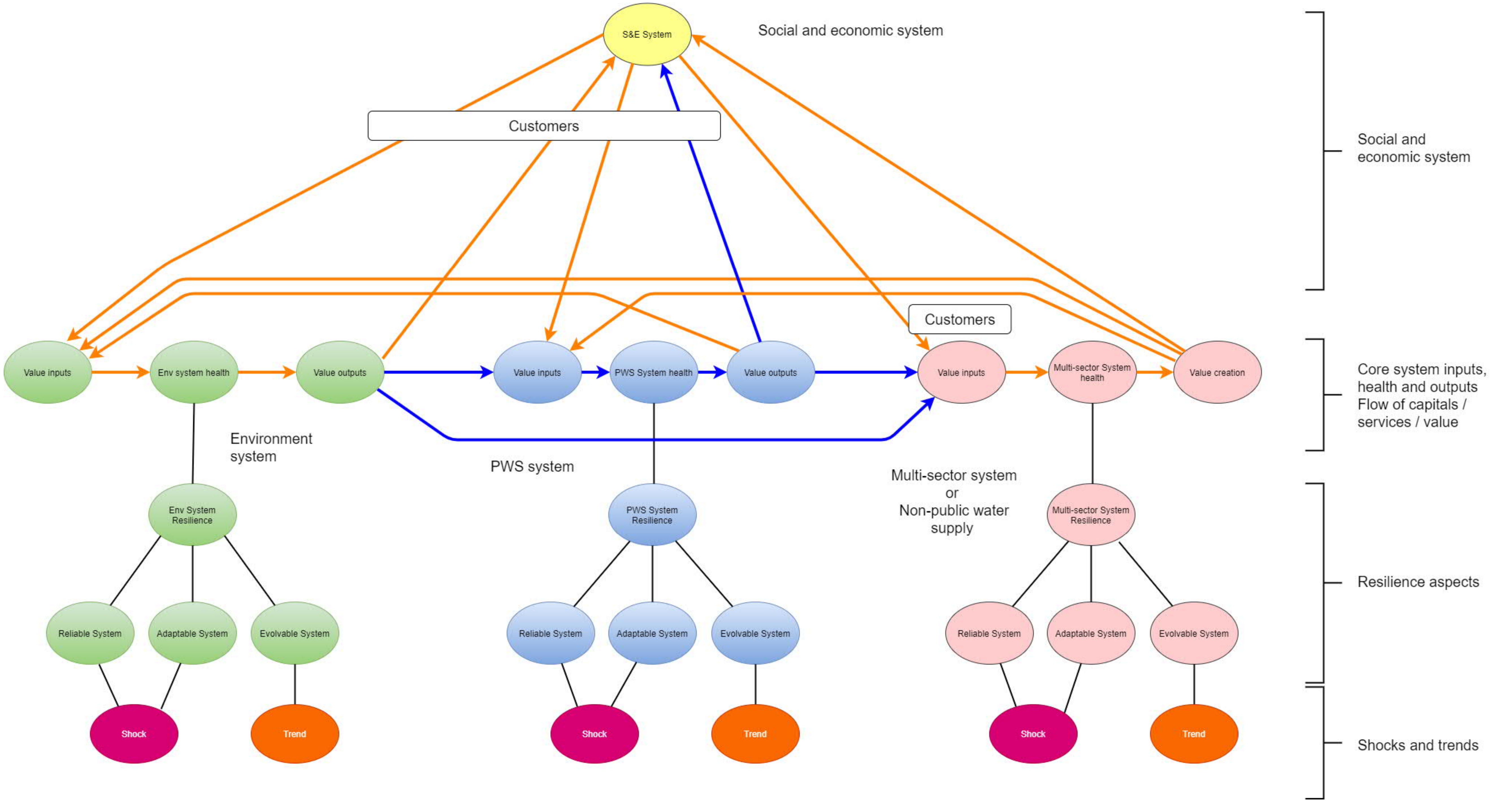


Figure 2.6: Multi-capital flow map with examples

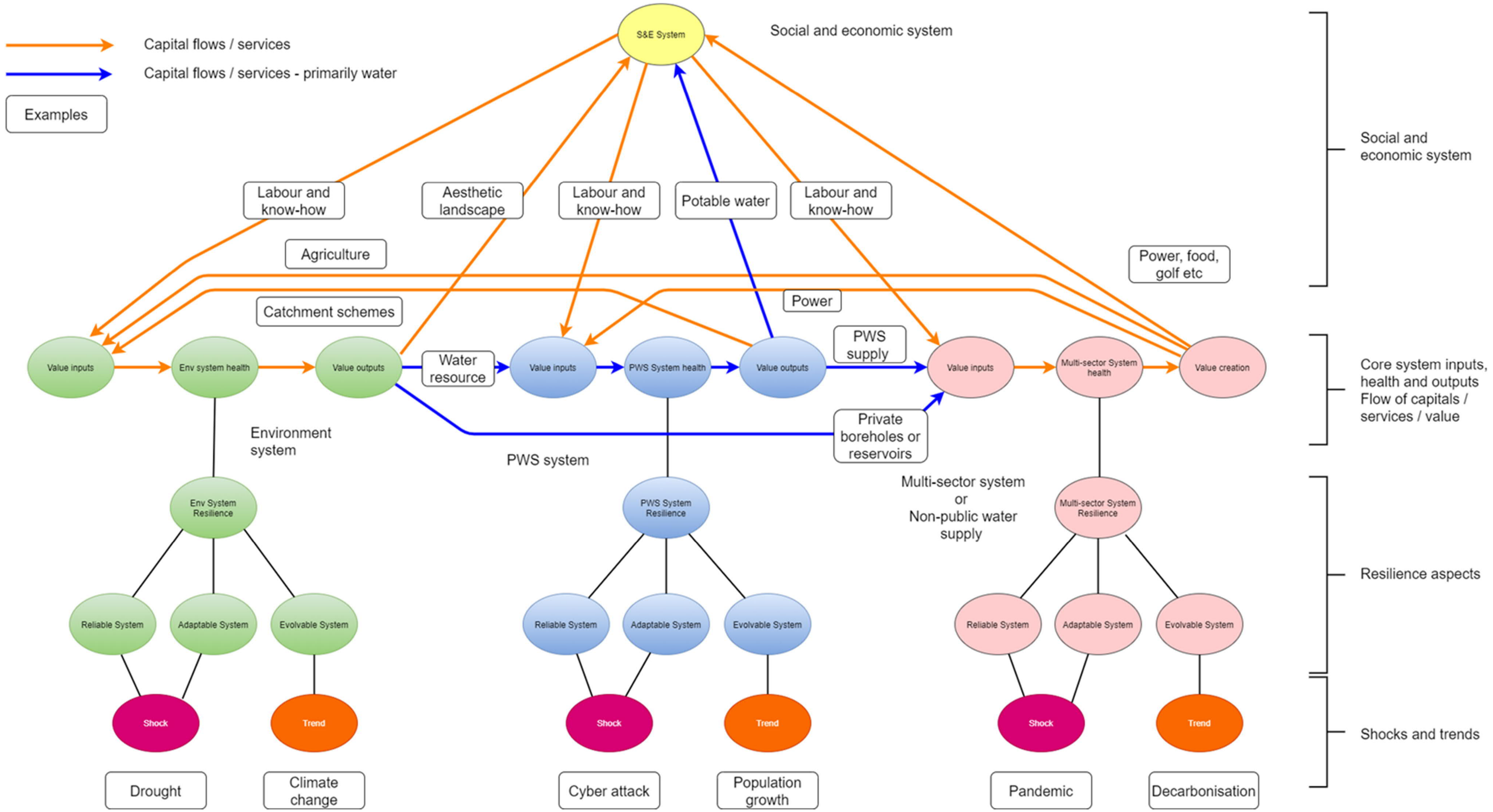
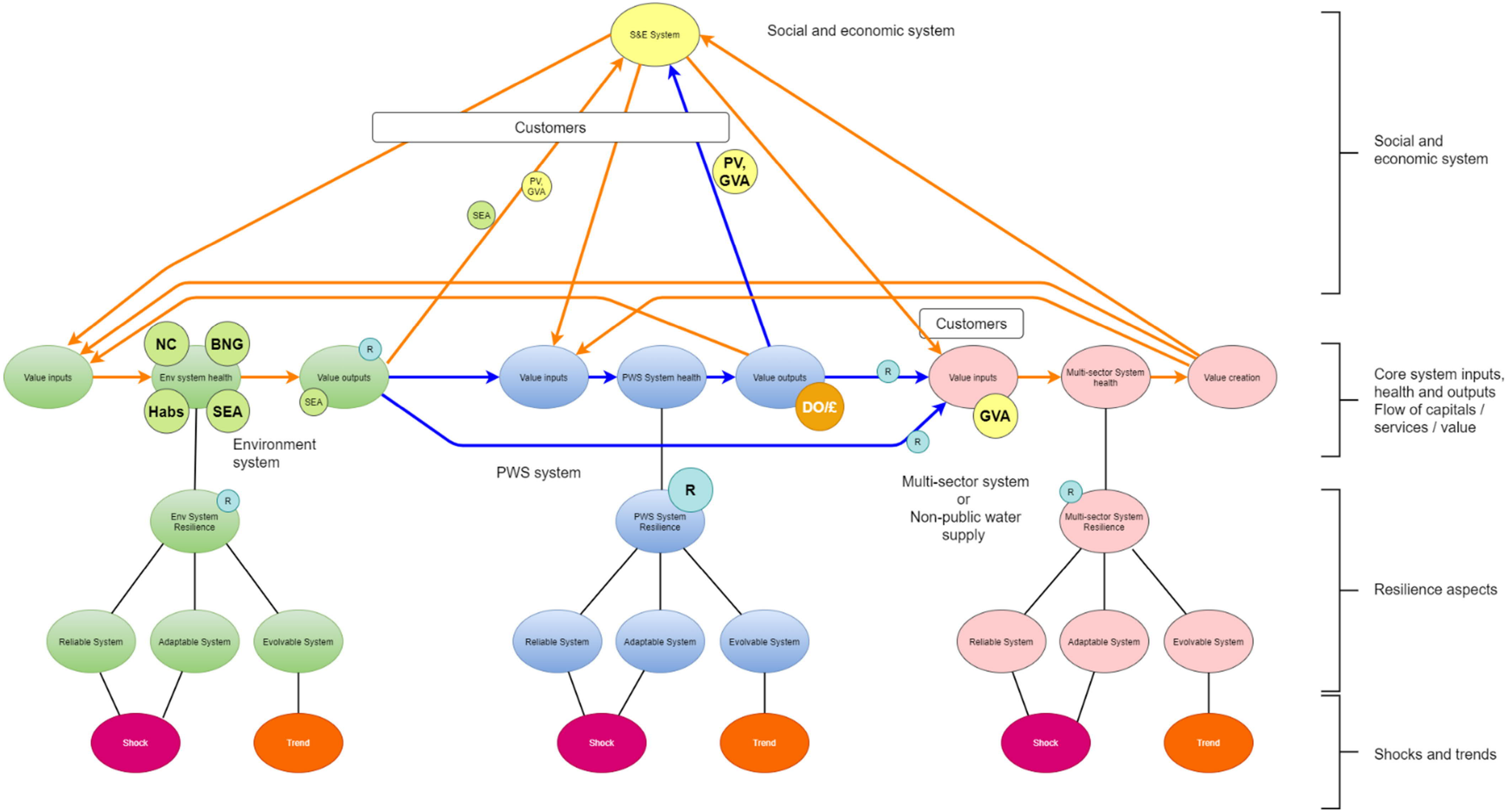


Figure 2.7: Multi-capital flow map showing metrics



2.4.2 An influence and control perspective

The second perspective on systems we consider is an influence and control perspective. In this analysis we consider system functions and factors and the influence they have on each other. This is the type of mapping we use from here onwards in this report (Sections 4 to 6 and 8). We use a version of the Participatory Systems Mapping approach developed by CECAN – the Centre for the Evaluation of Complexity Across the Nexus (Barbrook-Johnson and Penn 2021). In this approach nodes are system factors or functions that can go up or down – there can be more or less of each node. The links between the nodes are arrows of one of three colours that have the following meanings:

- Green indicates a positive influence: If A increases then B increases. If A decreases, then B decreases.
- Red indicates a negative influence: If A increases then B decreases. If A decreases, then B increases.
- Blue indicates a more complex connection that does not fit easily into either category above.

The maps are produced at the level of the sub-systems described in Table 2.1. The following colour coding is used to provide information on the nodes.

- One or more key functions are shown in gold – such as supply demand balance in the PWS water supply map.
- Blue indicates a link to the PWS system.
- Green indicates a link to the environmental system.
- Pale pink indicates a link to the multi-sector system.
- Yellow indicates links to the wider social and economic system.
- Red indicates key link nodes to numerous systems.
- Orange indicates shocks.
- Red indicates trends.
- Nodes that are rectangular are composite nodes that comprise a group of nodes that act in the same way but are not all shown for the sake of clarity on the map.

In the descriptions of the maps, we use italics to indicate when a node is being referred to specifically.

The system maps are live documents that have been updated over the course of this project. The main changes to the framework made as a result of this work are described in Appendix A.

The final version of the PWS map is given in Appendix B.

3 Shocks and trends – a multi-sector perspective

This section considers a multi-sector perspective on shocks and trends. The approach taken here is to start with a business perspective on shocks and trends to ensure that the multi-sector dimension of WRSE is addressed. Having looked at how systemic shocks and trends influence business then the section introduces the Task Force on Climate-related Financial Disclosure (TCFD) which is the framework in which business operates its resilience planning and reporting.

3.1 Identifying shocks and trends

The World Economic Forum (WEF) Global Risks Report 2020[15] provides an overview of shocks and trends from a business perspective. This global perspective is important given the global economic significance of the South East region. London is important not just as a major global economic centre, but also as a leader in climate finance. A financial perspective on resilience will therefore prove to be an important contribution to WRSE's stated objective of creating a multi-sector resilience plan.

We categorise trends as long-term processes and shocks as rapid onset change that may be reversed. As such a pattern of increasing frequency of shocks may constitute a trend as in the case of drought and climate change.

3.1.1 Environmental shocks and trends

The WEF report highlights the impacts of climate change as the number one long-term risk by impact and number two by likelihood. But it is not just that urgent realities of climate change are striking hard, it is also that they are striking more rapidly than many expected. Across the world, we are seeing many environmental trends that are driven in the main by climate change:

- The last five years are expected to be the warmest on record[16].
- Emergencies such as droughts, wildfires and hurricanes are more intense and more frequent[17].
- Polar ice is melting more quickly than anticipated, with drastic implications for rising sea levels and impacts on coastal populations[18].

These headline impacts are well-known. What is less apparent is that the complexity of the climate system means that some of the potential impacts have yet to be identified. Cross-system shocks that have been identified include:

- Loss of life – natural disasters are much more frequent because of climate change. Different groups have different levels of vulnerability. Globally, women and children are 14 times more

[15] WEF_Global_Risk_Report_2020.pdf (weforum.org)

[16] Schwartz, J. and N. Popovich. 2019. "It's Official: 2018 Was the Fourth-Warmest Year on Record". The New York Times. 06 February 2019. https://www.nytimes.com/interactive/2019/02/06/climate/fourth-hottestyear.html ; Kaufman, M. 2019. "All the Ways Climate Change Has Impacted Earth in 2019 (So Far)". Mashable. 16 March 2019. https:// mashable.com/article/climate-change-2019- list/

[17] Harvey, F. 2019. "One Climate Crisis Disaster Happening Every Week, UN Warns". The Guardian. 07 July 2019. https://www. theguardian.com/environment/2019/jul/07/ one-climate-crisis-disaster-happening-everyweek-un-warns

[18] The Economist. 2019. "The Greenland Ice Sheet Is Melting Unusually Fast". The Economist. 17 July 2019. https://www.economist. com/graphic-detail/2019/06/17/the-greenland-ice-sheet-is-melting-unusually-fast

likely to die during a natural disaster than men,[19] and there are health spill overs for the elderly, infirm, and the poor. Similarly, Covid-19 appears to have disproportionately affected poorer regions and ethnic minorities in the UK[20]. Flooding affects the poor disproportionately due to their location on more marginal land.

- Ecosystem stress – we are witnessing significant biodiversity loss with a quarter of all living species facing extinction.[21] Additionally, tipping changes can occur, such as disruption to the Gulf Stream and thawing of the permafrost, both with follow-on ecosystem impacts.
- Food and water crises – a long term downward trend in food prices is causing economic stress to farmers who are being tasked with an increasingly complex challenge of environmental stewardships[22].
- Sharpening geopolitical tensions – climate change is exacerbating tensions between countries as they deal with changing security and access to historic common property resources. Witness the battle around fishing waters in the UK's exit from Europe, tensions over new shipping routes through the Arctic as polar ice retreats, and conflicts around upstream and downstream water use in over 40 countries[23]. In the South East, farmers will be impacted by increased transaction costs following the UK's exit from the European Union. International trade works as a pooling mechanism for climate risks creating increased variability in agricultural output.
- Refugees and migration – already extreme weather has forced over 20 million people to leave their homes, between 2008 and 2016[24]. This rate of climate driven displacement is expected to rise[25].
- Economic losses and opportunities - the economic stress and damage caused by natural disasters are well known. However, wrapped up in the challenges of climate change are significant economic opportunities as well. In a 2019 study from the Carbon Disclosure Project, more than 200 of the world's largest companies are forecast to have costs from climate change in the region of $1 trillion, with much of the pain due in the next five years. However, they also saw potential opportunities that could be twice that if the right strategies were put in place to decarbonise[26].

The environmental shocks that are identified above are global and affect a globally integrated political economy such as the South East as a result. A more down-scaled perspective on these risks is developed in the sector by sector systems analysis.

3.1.2 Socio-economic shocks and trends

The biggest socio-economic shock in 2020 came from a source that was regarded as having a high potential impact but a low likelihood: a global pandemic. Yet, the impacts from the coronavirus pandemic are stretching across all sectors of the globe, in terms of demand

[19] UNDP (United Nations Development Programme). 2013. New York: "Gender and Disaster Risk Reduction". Gender and Climate Change: Asia and the Pacific Policy Brief 3. UNDP. https://www.undp.org/content/dam/undp/library/gender/Gender%20and%20Environment/PB3-AP-Gender-and-disaster-riskreduction.pdf

[20] Submission of evidence on the disproportionate impact of COVID-19, and the UK government response, on ethnic minorities in the UK

[21] See IUCN Red list: IUCN Red List of Threatened Species

[22] Allan, T., Bromwich, B., Keulertz, M., & Colman, A. (Eds.). (2019). 'The Oxford Handbook of Food, Water and Society.' Oxford University Press. https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190669799.001.0001/oxfordhb-9780190669799

[23] Brosig, M., P. Frawley, A. Hill, M. Jahn, M. Marsicek, A. Paris, M. Rose, A. Shambaljamts and N. Thomas. 2019. Implications of Climate Change for the U.S. Army. United States Army War College. https://climateandsecurity.files.wordpress.com/2019/07/implications-of-climate-change-for-us-army_army-war-college_2019.pdf

[24] UNHCR (The UN Refugee Agency). 2016. "Frequently Asked Questions on Climate Change and Disaster Displacement". 6 November 2016. https://www.unhcr.org/en-us/ news/latest/2016/11/581f52dc4/frequently-asked-questions-climate-change-disaster-displacement.html

[25] Tim Lenton speech, Thinking Ahead Institute Sustainability Summit, Willis Towers Watson, London Dec 2109

[26] Green, M. 2019. "World's Biggest Firms Foresee $1 Trillion Climate Cost Hit". Reuters. 04 June 2019. https://www.reuters.com/article/us-climate-change-companies-disclosure/ worlds-biggest-firms-foresee-1-trillion-climate-cost-hit-idUSKCN1T50CF

collapse, unemployment, supply chain disruptions and systemic risks to global economies. These are the sort of shocks that are predicted in the long-term for climate change, but the world had to face an early reckoning on these matters in 2020. How governments and economies cope with the pandemic will be pointers to what to expect in the longer-term given the potential for an increasing pattern of global shocks.

A coronavirus epidemic is not the only infectious disease risk that governments and populations face. Bacteria, parasites, fungi, and other viruses can also cause the uncontrolled spread of infectious diseases. The strains on health systems are leading to trends in the slowing of gains in lifespan and health span in both developing and developed countries[27]. Resilient health in a population faces an increasing inequality between rich and poor in the United Kingdom and elsewhere[28].

In many countries, the failure of urban planning acts as a significant source of societal risk: poorly planned cities and urban sprawl create social, environmental and health challenges. This is underlined by the assessment in 2015 from UN Habitat that more than 60% of the area projected to be urban in 2030 was yet to be built[29]. An emphasis in the UK is now being made on integrated, systemic urban and infrastructure planning as a means of enhancing resilience[30].

The digital economy is significant in addressing resilience challenges, but also brings new vulnerabilities and inequalities. Cyberattacks have become one of the most impactful risks facing individuals, businesses, and governments across the world. Digital attacks on infrastructure are now assumed to be part of the "new normal" in sectors such as energy, healthcare, and transportation[31]. Cyber dependency increases the vulnerability to outage of critical information infrastructure (particularly where the internet or satellite infrastructure is used).

Overall, the context in which organisations now operate has been transformed by climate change, biodiversity loss, social unrest around inclusion, working conditions, and the impacts of the pandemic. To continue to thrive, organisations need to build their resilience to these multi-dimensional challenges while enhancing their licence to operate. They can do this through a stronger commitment to sustainable value creation across a longer time horizon, and by embracing the wider demands of people, planet, and prosperity.

We now look at how integrated responses to these interconnected systemic risks at regional, strategic, and organisational levels.

3.2 Downscaling global risks to regions and organisations

Focusing on the intended value creation of system enables a systemic approach to design a resilience strategy. This applies at the level of each of the systems and sub-systems addressed in WRSE: the PWS system is designed to generate a resilient supply demand balance of water

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[27] Cardona, C. and D. Bishai. 2018. "The Slowing Pace of Life Expectancy Gains since 1950". BMC Public Health (2018) 18:151. DOI 10.1186/s12889-018-5058-9. https:// bmcpublichealth.biomedcentral.com/track/ pdf/10.1186/s12889-018-5058-9

[28] Public Health England, Gov.UK. 2018. "Health Profile for England 2018. Chapter 5: Inequalities in Health". https://www.gov.uk/government/publications/health-profilefor-england-2018/chapter-5-inequalities-inhealth; Bleich, S. N., M. P. Jarlenski, C. N. Bell and T. A. LaVeist. 2012. "Health Inequalities: Trends, Progress, and Policy". Annual Review of Public Health. 33 (1): 7–40. https:// www.annualreviews.org/doi/full/10.1146/annurev-publhealth-031811-124658

[29] https://www.preventionweb.net/disaster-risk/risk-drivers/urban/

[30] Flourishing Systems - Re-envisioning infrastructure as a platform for human flourishing | Centre for Digital Built Britain (cam.ac.uk)

[31] http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

for customers. It also applies at the wider social and economic system for the South East to which WRSE contributes.

For WRSE it is important to understand this in terms of its own regional context and what are the key areas of regional purpose and value creation it is aiming to drive. We have identified the Oxford-Cambridge Arc Economic Prospectus[32] as a good example how regional purpose can be presented. It clearly highlights the regional strengths and value inputs that the Arc has and what its ambitions are in terms of value creation and overall purpose.

The vision of the prospectus places the Arc as a world-leading place for high-value growth, innovation, and productivity, incorporating exemplary models of 21st century development. It expects to have impacts across local borders as well as in shaping the UK's national priorities. To enable this, the collective ambition across the Arc is to unlock investment, drive economic growth, promote research and innovation, and transform the ability to deliver sustainable development. Clearly, the scope of the work to deliver on the Arc envisages the inter-locking and meshing of multiple systems across the region.

The multi-system mapping undertaken as part of this project could be used to develop an overall set of regional value creation objectives that would help boost the economic, social, and environmental systems across the WRSE region in an aligned manner. This could bring together the purpose drivers for the PWS, agricultural, power, paper, canals systems etc. and all the interlinkages and co-dependencies these systems have and how they can work together to deliver maximum value and resilience at the regional level.

The Building Forward report from the Bennett Institute for Public Policy reflects the same focus on working across multiple systems[33]. It finds that investing public resources in people's health and skills and in social, natural and physical capital is the best way, in light of the pandemic, to bring about a more resilient and prosperous future, and to deliver the "levelling up" agenda. In particular, the report shows how human capital (health, skills, and education) interacts with social capital (personal networks and family or community support) to ignite virtuous cycles of productivity and growth. However, the same interactions could also bring about problematic feedbacks, without co-ordinated investments in skills development, knowledge sharing and infrastructure investment.

To support a commitment to aligning corporate objectives with society's long-term goals, the International Business Council's members invited the WEF to identify a set of universal, material metrics that could be used by them in their disclosures and reporting. The result of this work is 21 core metrics relating to activities within an organisation's own boundaries, and 34 expanded metrics with a wider value chain scope. The metrics are organised under four pillars: principles of governance, planet, people, and prosperity. Some of the metrics are drawn from established framework and standard-setters, while others incorporate specialised work that has emerged under the leadership of the TCFD and the work on purpose led by the British Academy and the Embankment Project for Inclusive Capitalism.[34]

The Crown Estate offers an example of an organisational strategy for operation in the context of system change. In its 2019-20 Integrated Report[35], it identifies key areas of change that have

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[32] Oxford-Cambridge Arc economic prospectus | Oxford City Council

[33] Building forward: investing in a resilient post-Covid-19 recovery (cam.ac.uk), Bennet Institute for Public Policy, university of Cambridge, Nov 2020

[34] See Embankment Project for Inclusive Capitalism | Coalition for Inclusive Capitalism

[35] The Crown Estate, Integrated Annual Report and Accounts 2019/20, the-crown-estate_ar_2020.pdf

the most important influence on its own ability to remain relevant and successful and designs its strategy around these priorities.

3.3 Climate resilience from a financial perspective: TCFD

This report considers resilience for the water system in the South East of England. The corresponding initiative for the financial system is the Task Force on Climate-related Financial Disclosures (TCFD). To understand multi-sector resilience planning as framed in this report it is important to seek an integrated understanding of the two frameworks: WRSE as the water resource perspective on multi-sector resilience and TCFD as the financial framework for multi-sector resilience.

TCFD was created by the Financial Stability Board to improve and increase reporting of climate-related financial information. This was because "financial markets are judged to need clear, comprehensive and high-quality information on the impacts of climate change"[36].

TCFD provides a framework to help public companies and other organisations more effectively disclose climate-related risks and opportunities through their existing reporting processes. It has four core areas that firms need to use to disclose their approach to managing the implications of climate change:

- Governance – the mechanism the organisation uses to govern its climate risks and opportunities.
- Strategy – the actual and potential impacts of climate-related risks and opportunities on strategy and financial planning.
- Risk management – how an organisation identifies, assesses, and manages climate-related risks.
- Metrics and targets – the metrics used to assess and manage climate-related risks and opportunities.

Across the world, over a hundred regulators and government entities support the TCFD, including those in Europe, North America, Asia, and Australasia. The European Union, the United Kingdom and New Zealand have been at the forefront wanting its inclusion for corporates and financial institutions. In the UK, Chancellor Rishi Sunak announced in November 2020 the intention that TCFD aligned disclosures would be fully mandatory across the economy by 2025. The UK's roadmap[37] includes:

1. The Financial Conduct Authority (FCA) commitment to introduce climate disclosure, on a 'comply or explain' basis, beginning 2021, for UK premium listed firms.
2. Consultation by the Department of Works and Pensions (DWP) on mandatory climate disclosure requirements for larger occupational pension schemes, with smaller schemes to follow.
3. Stronger requirements from the Bank of England for Prudential Regulation Authority - regulated banks and insurers to disclose their climate risks.

In effect, the TCFD framework translates climate risks and opportunities into actual or potential impacts on financial capital. This provides an illustration of the analogue challenge facing the water industry of translating climate risks and opportunities into the impacts on the multiple capitals that it deals with. While the water industry needs to prepare its own climate resilience framework relevant to its industry, it also needs to respond to the TCFD disclosure challenge,

[36] https://www.fsb-tcfd.org/

[37] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/933782/FINAL_TCFD_REPORT.pdf

since Chancellor Sunak is expecting the requirements of that framework to be economy-wide by 2025.

UK firms are not well-prepared for TCFD reporting at this point. A November 2020 benchmarking exercise by Willis Towers Watson[38] found that 70% have yet to publish a TCFD disclosure or to begin the process of preparing their response, and 63% are still in the exploratory phase of considering how climate-related risks and opportunities will impact business strategy and financial planning. 70% are concerned about defining the metrics used for TCFD reporting, and only 10% are likely to include climate-related metrics and targets into remuneration policy in the next 12 months.

While TCFD represents an important climate resilience issue for the finance sector, it is not the only such issue that companies will have to step up to address. The EU Sustainable Taxonomy is a tool to help investors understand whether an economic activity is environmentally sustainable, and to navigate the transition to a low-carbon economy[39]. Although the EU taxonomy may not apply to the UK water industry directly, it is widely expected that all European (including UK) financial institutions will seek to report to the taxonomy's requirements and will, therefore, need this reporting from the organisations they finance. The environmental objectives addressed in the EU taxonomy include climate change mitigation and adaptation, protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems.

[38] TCFD: coming, ready or not, Willis Towers Watson Insights blog, Nov 2020: https://www.willistowerswatson.com/en-GB/Insights/2020/11/TCFD-coming-ready-or-not

[39] EU Taxonomy for Sustainable Activities, https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en#

4 The environmental system

This section introduces the environmental system and the system maps. The environmental system is prioritised because it is foundational to all the other systems discussed in this report – as the feedback on the draft framework highlighted. Refer to section 2.4.2 for a description of how to read the maps.

The environmental system has analysed with three sub-system maps.

- flooding
- river health
- and use and natural capital

The PWS map in Section 5 and farming maps in Section 6.1 also show parts of the environmental system.

The scope of the environmental system has been derived from the work on the Eden and Medway catchments in Defra's Systems Analysis for Water Resources project.[40] In both catchments there were important mapping elements around flooding that informed the maps here. In the Eden map there was a significant list of land uses that influenced key environmental factors: that framework informs the land use and natural capital map here. While the Eden is, of course, a different context to the South East, the Eden map was useful in having a lot of detail on the environment and therefore provides useful insights that inform the layout of the environmental system maps elsewhere. The river health map has been added to reflect the significance of river health, particularly chalk streams, to the South East of England.

4.1 Flooding

The flooding system, shown on Figure 4.1 is made up of three clusters.

- On the left of the map, a cluster shows influences such as *soil health*, *infiltration* and *rainfall intensity* on *flashy rivers*. Links are made to other systems via r*ural pollution*, *wastewater,* and *urban runoff*.
- The central cluster shows impacts on the size of fluvial and estuary floods leading to the key node on *flood impact*.
- On the right there is a cluster that shows flood impacts mediated by impacts on housing, commercial property, and lost days at work.

There is a feedback loop from the impacts of flooding via public and political engagement to investment in flood defences and engagement in Natural Flood Management Schemes which reduce the flashiness of rivers and the impact of flooding.

4.1.1 Observations

- There are extensive and interconnected social impacts of flooding.
- There is an important link with the *PWS* from fluvial flooding to sediment in intakes. When flooding occurs then sediment, in water treatment work intakes may be high, overwhelming

[40] Defra (2020) Systems Analysis for Water Resources
http://sciencesearch.defra.gov.uk/Document.aspx?Document=14947_WT15121.FinalReport.pdf

the clarifiers. Control of sediment and pesticides in water courses is therefore a resilience issue for the PWS.

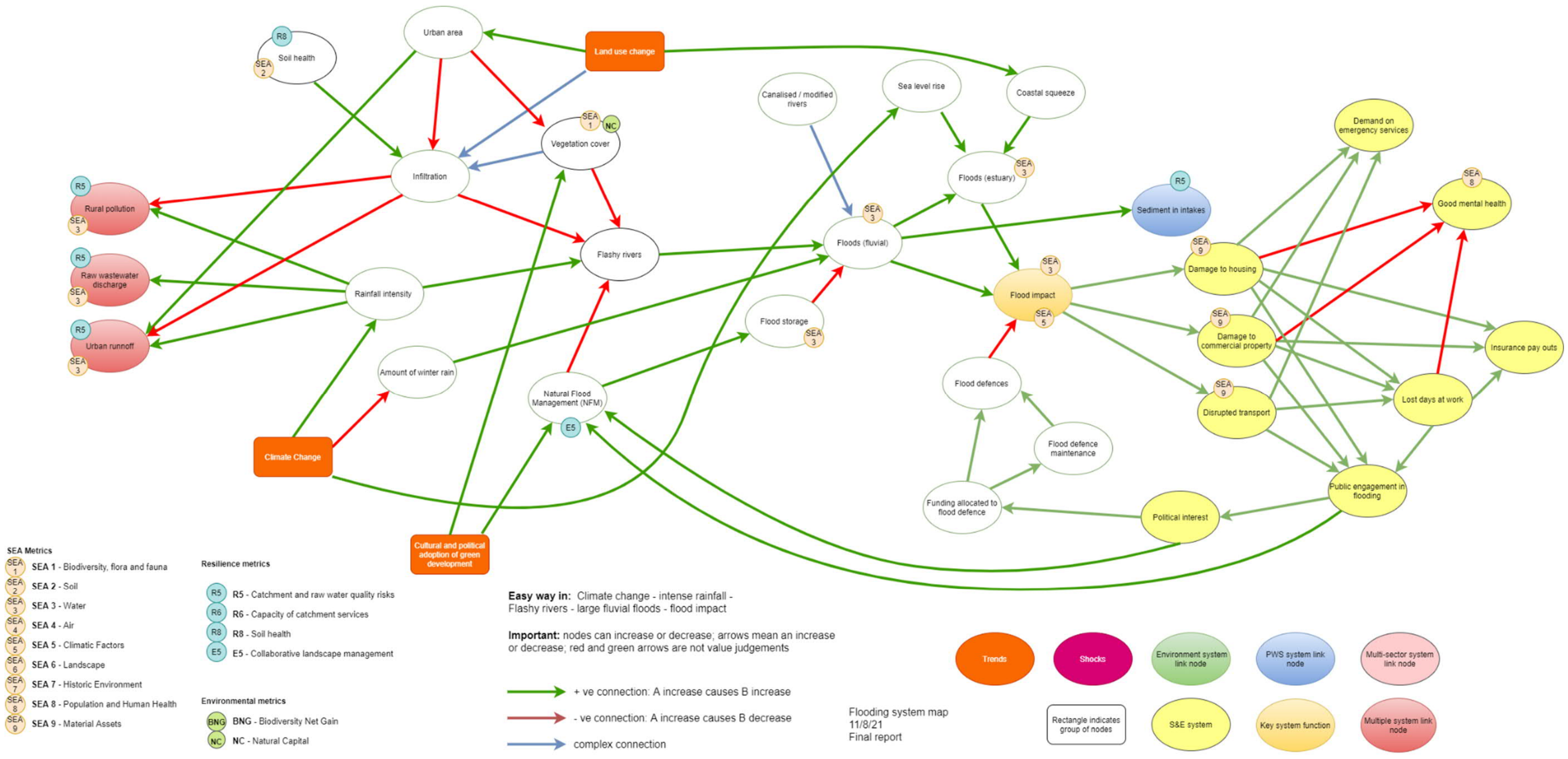
4.1.2 Control points

- Flood impact is controlled in each of the four clusters of nodes. The first cluster includes catchment interventions such as improving soil health, natural flood management and vegetation cover. The second addresses the control of the flood in the river including flood storage and river channel modifications. Thirdly, through direct interventions on the flood impact such as flood defences, and fourthly through controlling the vulnerability of assets to the impacts of flooding.

4.1.3 Value creation

- A key element of the potential value creation in the flowing system is the regulation of flood risks and impacts by mitigation of pollution events to the PWS and other sectors.

Figure 4.1: Flooding



4.2 River health

The river health sub-system, shown on Figure 4.2, is made up of two clusters and a feedback loop.

- The main cluster links river restoration activity and buffer strips with the environmental benefits via factors such as *natural channel morphology and flow regime* and *bank side conditions* to their main environmental benefits such as *water quality* and *connected habitat* and *biodiversity*. These elements are reflected in the node for *healthy rivers* and in that way influence a range of social and amenity benefits.
- A chalk stream cluster on the top right connects specific issues that relate to rivers with high base flows. *Groundwater abstraction* has an important influence on *groundwater levels* and *chalk stream base flow*. The arrows in this part of the map were subject to a high level of discussion, during the stakeholder review of the maps, noting that in general terms a declining groundwater level leads to a reduction in chalk stream base flow, although there are cases where the two bodies of water may not be connected and the interrelationship, such as it is, is more complex. Much of this cluster are relevant to rivers more broadly than chalk streams and the map could be developed further to reflect that. The cluster was developed with stakeholders to reflect the issues relating to chalk streams so is included on that basis.
- There is a feedback loop from the social value that people derive from the system with engagement in river restoration activities. *Public access to rivers* enables the social benefits to be realised and the feedback of social engagement to the system.

4.2.1 Observations

- The influence of the *cultural and political adoption of green development* is significant in this map, notably through the work of environmental NGOs driving an agenda to protect the ecological status of chalk streams and through driving river restoration activities.
- There is a need to contextualise and democratise these maps at the catchment level. This base-map allows for that activity.

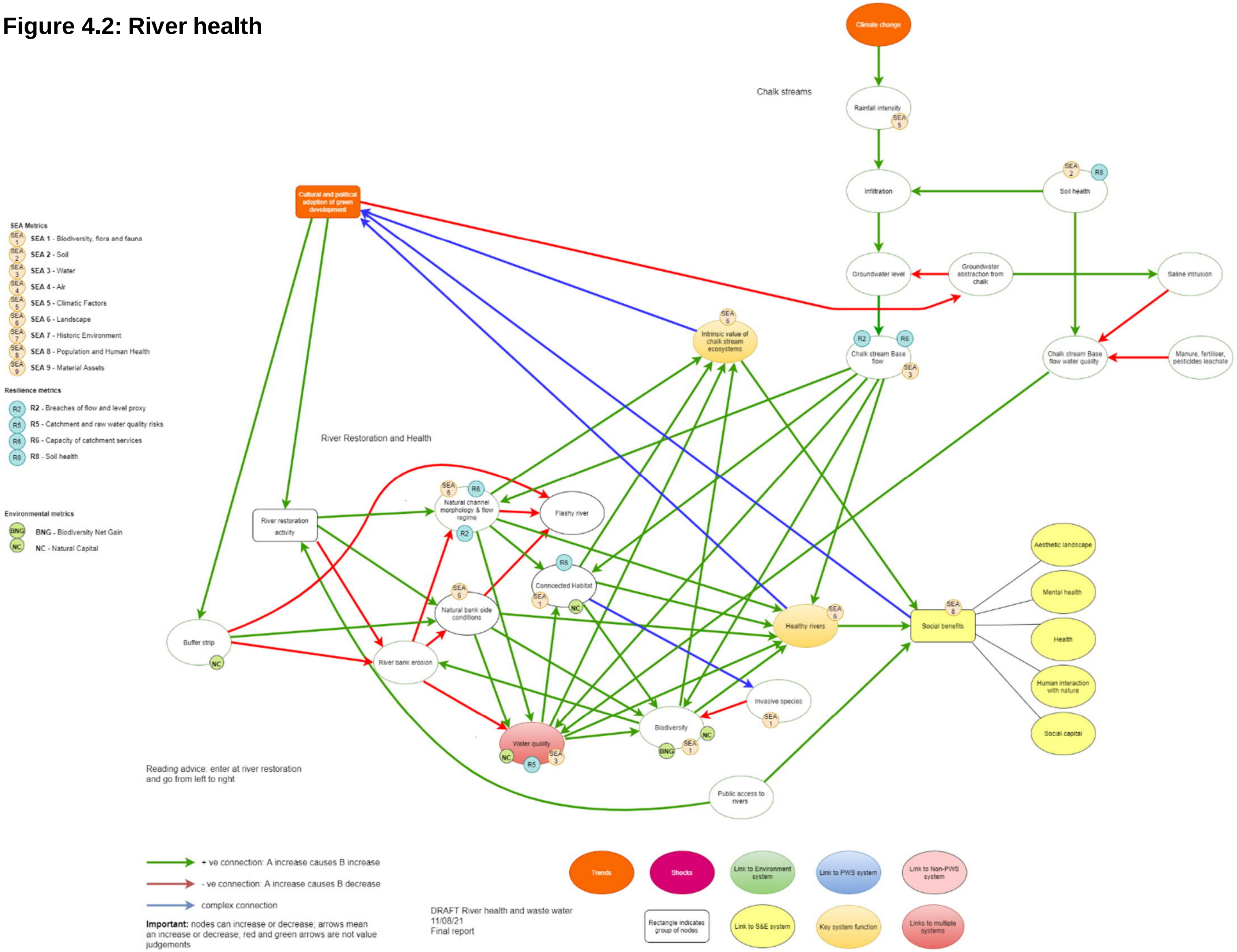
4.2.2 Control points

- *River restoration activity* and *buffer strips* and the policy and public engagement around these are the key drivers of change in this system.
- For chalk streams the key control points are *groundwater abstraction*, *soil health* and rural pollution in the form of *manure, fertiliser, and pesticides*. These factors are important alongside the impacts of climate change and rainfall. Other maps show additional connections with important nodes in this map, such as land use and infiltration on the flooding map.

4.2.3 Value creation

- The value creation of this system will be considered in the environmental destination workstream. The social, amenity and natural capital and ecosystem services are considerable.
- Public access to rivers has an important potential multiplying effect on the social and amenity value of healthy rivers and an important influence on the ability of public to engage with river restoration activities.

Figure 4.2: River health



4.3 Land use

The land use system, shown on Figure 4.3 is based around different land use factors across the centre of the map. The map is set up to show land use change on a number of important nodes relevant to the environment and wider water systems including natural capital, water quality, biodiversity (via habitat), soil health and carbon sequestration.

4.3.1 Observations

The *natural capital* node is generic although there is more detail that relates to natural capital in the land use types. The arrangement and classification of this map requires further consultation to ensure it is presented in the most useful way.

Only limited consideration of drivers of land use change have been provided here. This boundary of our analysis of the map is reasonable given our focus on WRSE activities but would require extension for the maps to provide a fuller analysis of land use change.

4.3.2 Control points

This map is presented on the basis that land use is a critical control point on the environmental system.

4.3.3 Value creation

A full analysis of potential value creation associated with land use is beyond the scope of this system mapping exercise. The key forms of value for the WRSE system such as natural capital are indicated. Further consideration of this issue will be made in the environmental destination work stream.

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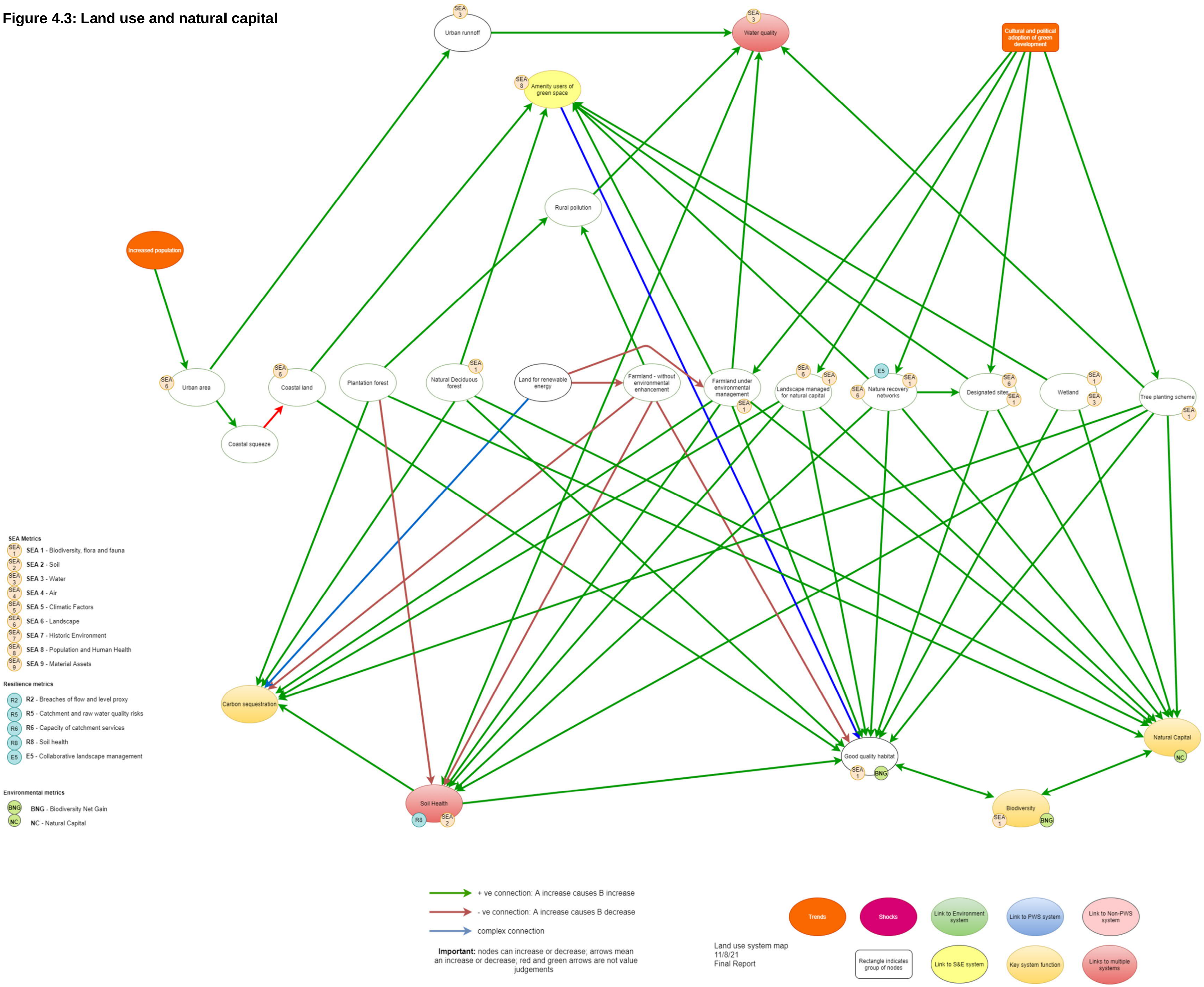
Figure 4.3: Land use and natural capital



5 The public water supply and wastewater systems

This section reviews the PWS and wastewater systems. The PWS is considered in detail and has a simplified and full system map to enable easier reading of the system. A light touch has been taken to the wastewater system. This provides a basis for further analysis and yet fills an important gap at this stage.

5.1 Water supply

More than all the system maps presented in this report, the PWS map is the one that has been developed through detailed active debate over how the system operates. That is to say that this map was been used extensively in discussion and analysis of the resilience metrics and has been developed, scrutinised and modified as a result. Consequently, we have two versions of the map. The simplified PWS map, shown on Figure 5.1, represents the starting point of the detailed work on the system. The more detailed map on Figure 5.2. shows the collective development of the map that occurred during the time frame of this project[41] with additional clarifications made throughout the metric scoring and analysis of options submitted to WRSE.

5.1.1 Observations

An accessible way in to reading the map is to follow the key feedback loop that begins with the node for a *competent company* on the left of the map and has a positive influence on the three nodes to the right: *resilient engineering operation*, *resilient engineering infrastructure* and *resilient water source*; all of which enable a *resilient water supply service to customers*. This service, along with the contribution from customers allows the *supply demand balance* to be achieved. The SDB has a feedback to *company has confidence of the regulator* at the top of the page, a feedback that is enhanced by *good customer relations*. This situation means that the *regulator trusts the company and allows innovation*, permitting development of a *creative/innovative strategy* on the lower left side of the page, which in turn influence the three nodes representing resilient engineering operation, infrastructure, and water source. Additional features of the simplified map include:

- Interdependency among *financial resilience* and *corporate resilience*, *competent company,* and *confidence of the regulator*, reflecting the "Resilience in the Round" perspective and the Business Plan review process.
- *Effective collaboration* has feedback loops (double headed green arrows) including *collaboration at the regional scale* shown on the bottom left of the page map.
- There are important feedback loops in the cluster around *good customer relations* on the right-hand side of the map. These include *customer engagement in drought management* and *customer engagement in environmental activities*.
- There are important social and economic benefits from both the provision of water and from the economic activity in associated with the sector.

The detailed system mapping shown in Figure 5.2 adds:

[41] The gold coloured metrics indicate where metric R3 was reorganised to become R3 and R7. The pale pink metrics. R8, E6 and A7 were introduced at this point.

- Elements of the environmental system at the bottom of the page.
- Shocks and trends influencing the system.
- Additional aspects of the core PWS system including carbon footprint, supply chain and cyber security, IT, and information management.

5.1.2 Control points

- Control by the water company is undertaken by through the outgoing links from C*ompetent company node*: *Resilient engineering operation; Good planning* and *Resilient engineering infrastructure; Creative / innovative strategy; Resilient water source, Good environmental practice; Good customer relations; Good regional & national collaboration including water sharing; Produce good submissions* (planning).*; Cyber, IT and information management; Supply chain.*
- The regulator has a control point relating to the supervision it has over the adoption of creative and innovative strategies produced by the water companies.
- Customers have the opportunities to influence the system through *Customers active in demand management* and *Customer engagement in environmental activities.*
- Regional planning groups have the opportunity to influence the system notably through enhancing the activities of water companies including water sharing as indicated by the link to *Resilient water source*.

5.1.3 Value creation

- Value creation occurs principally through the activities of the *Competent company* that leads to a resilient water *Supply demand balance*.
- The *Competent company* creates *Employment in the supply chain*
- The *Supply demand balance* ensure that *Businesses have water to operate and Population has health and wellbeing.*
- The regional coordination group creates value by enhancing the impact of the water companies.

Figure 5.1: Simplified public water supply system map

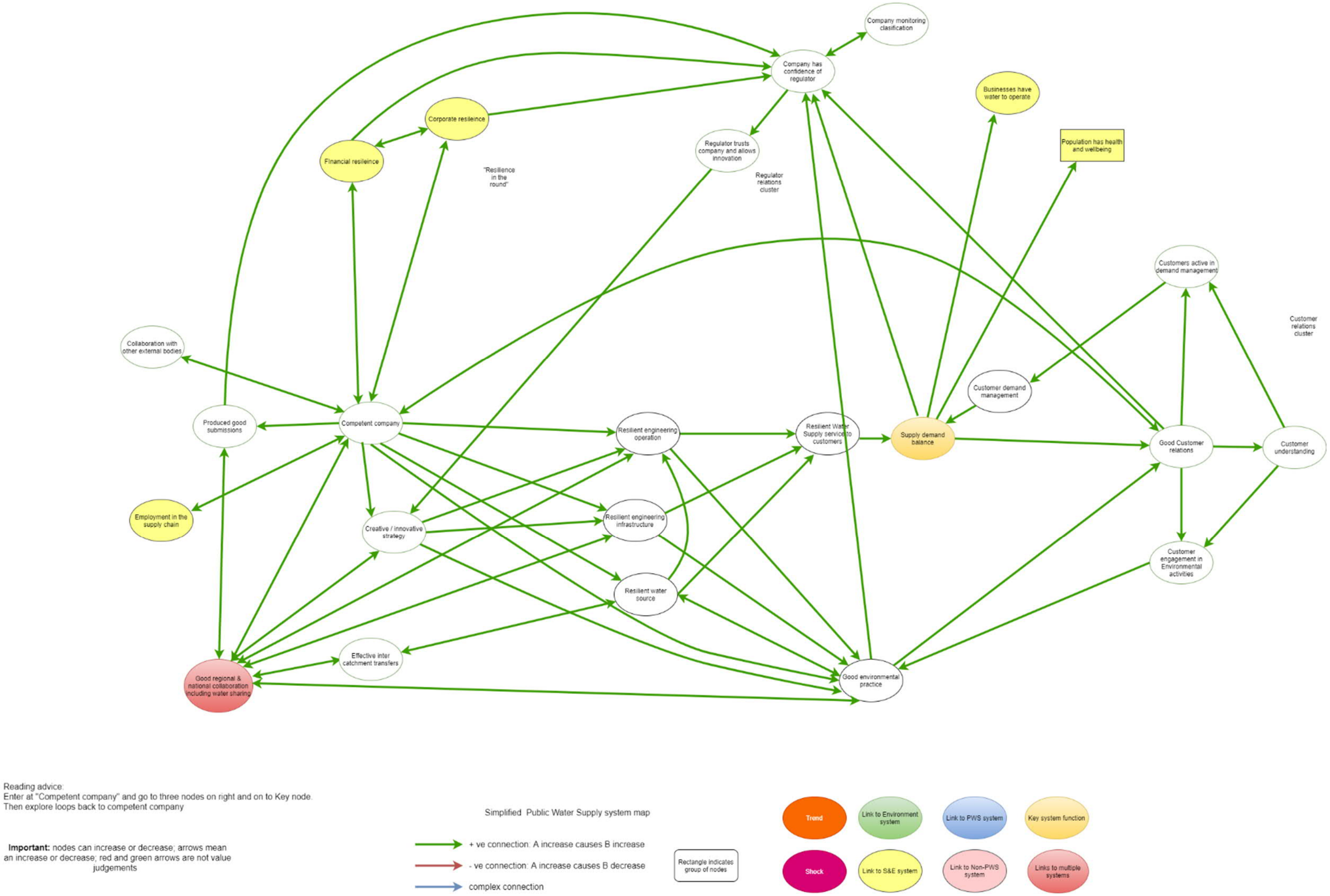


Figure 5.2: Public water supply system (December 2020)

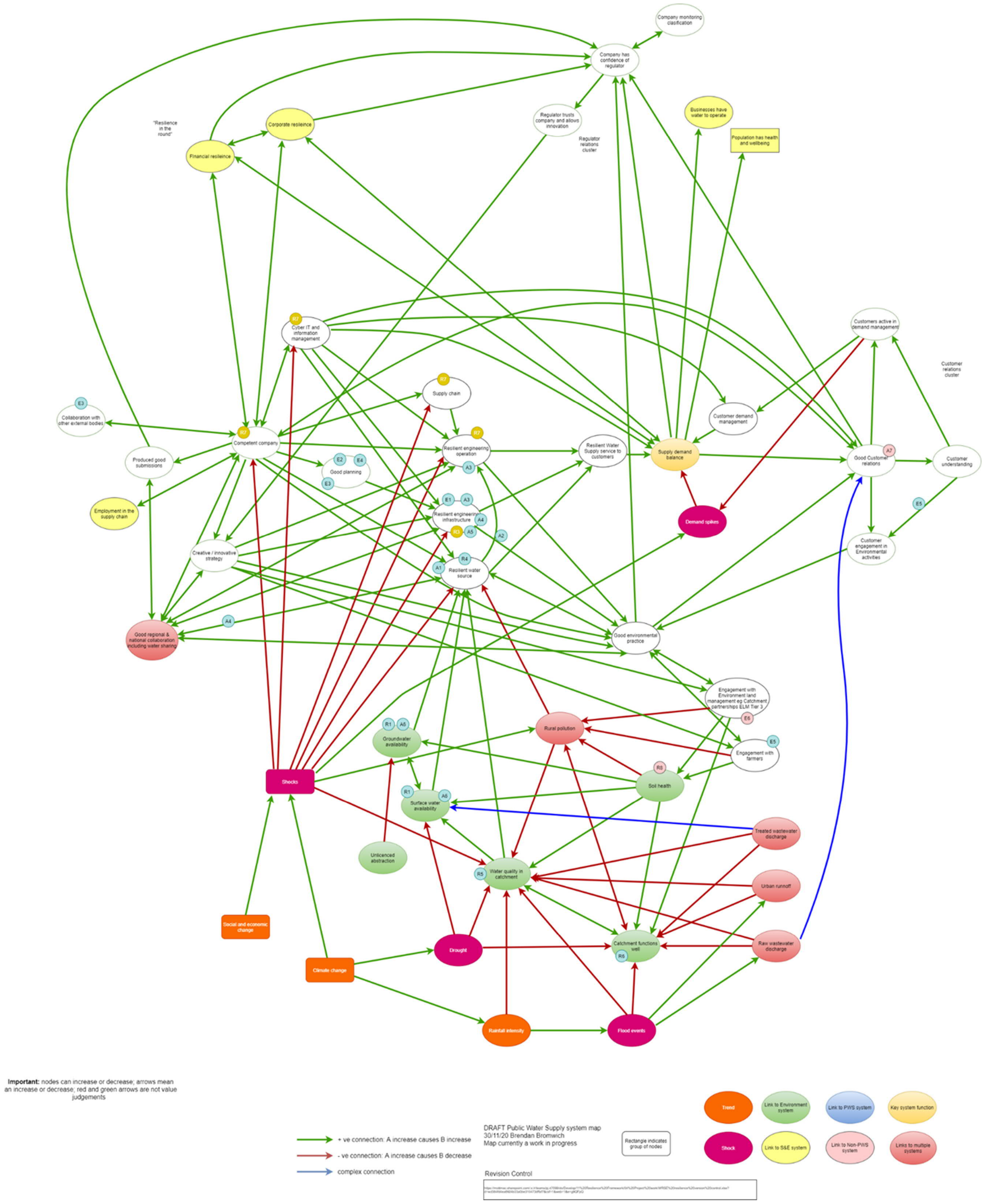
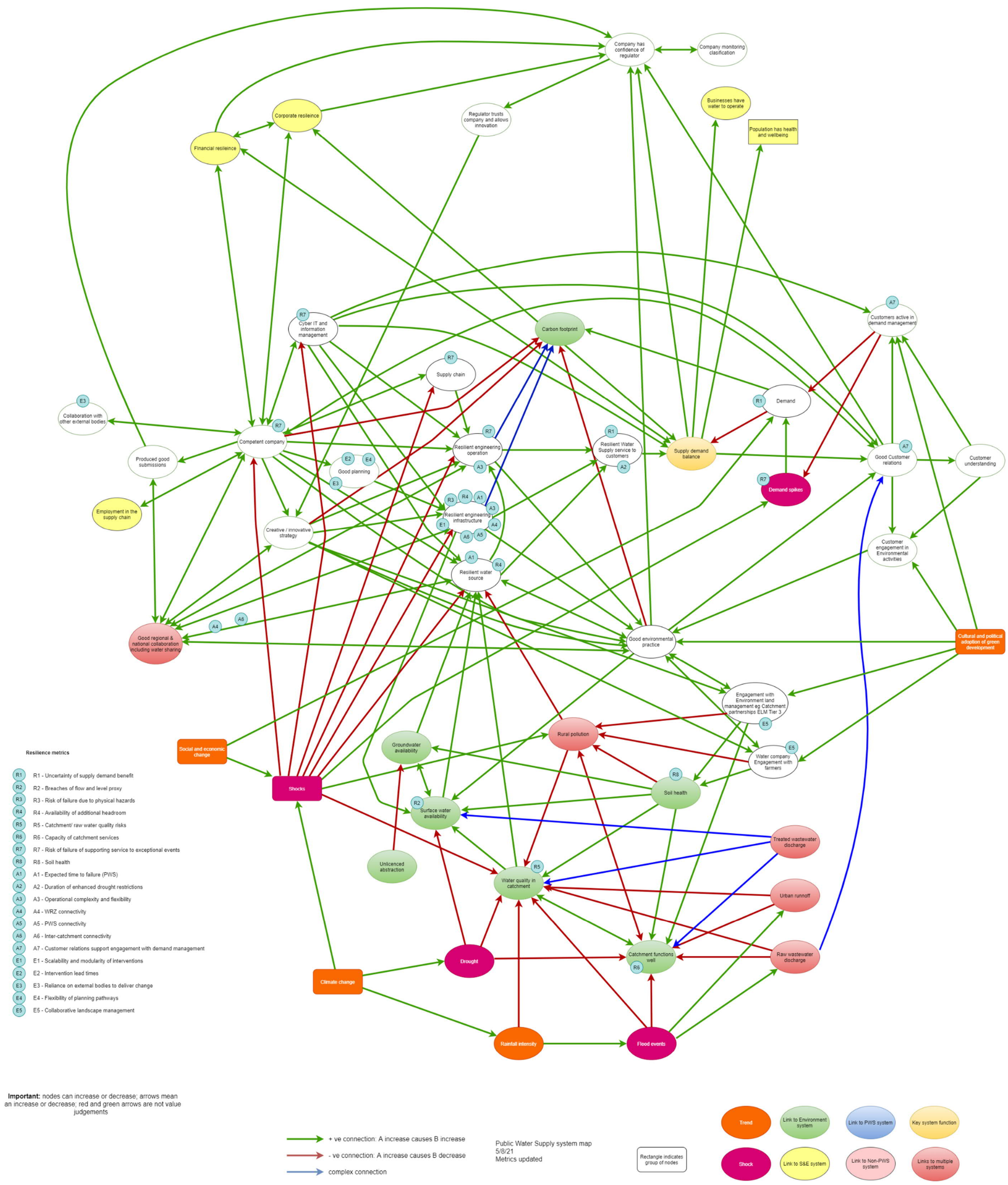


Figure 5.3 Public water supply system (May 2021)



5.2 Wastewater

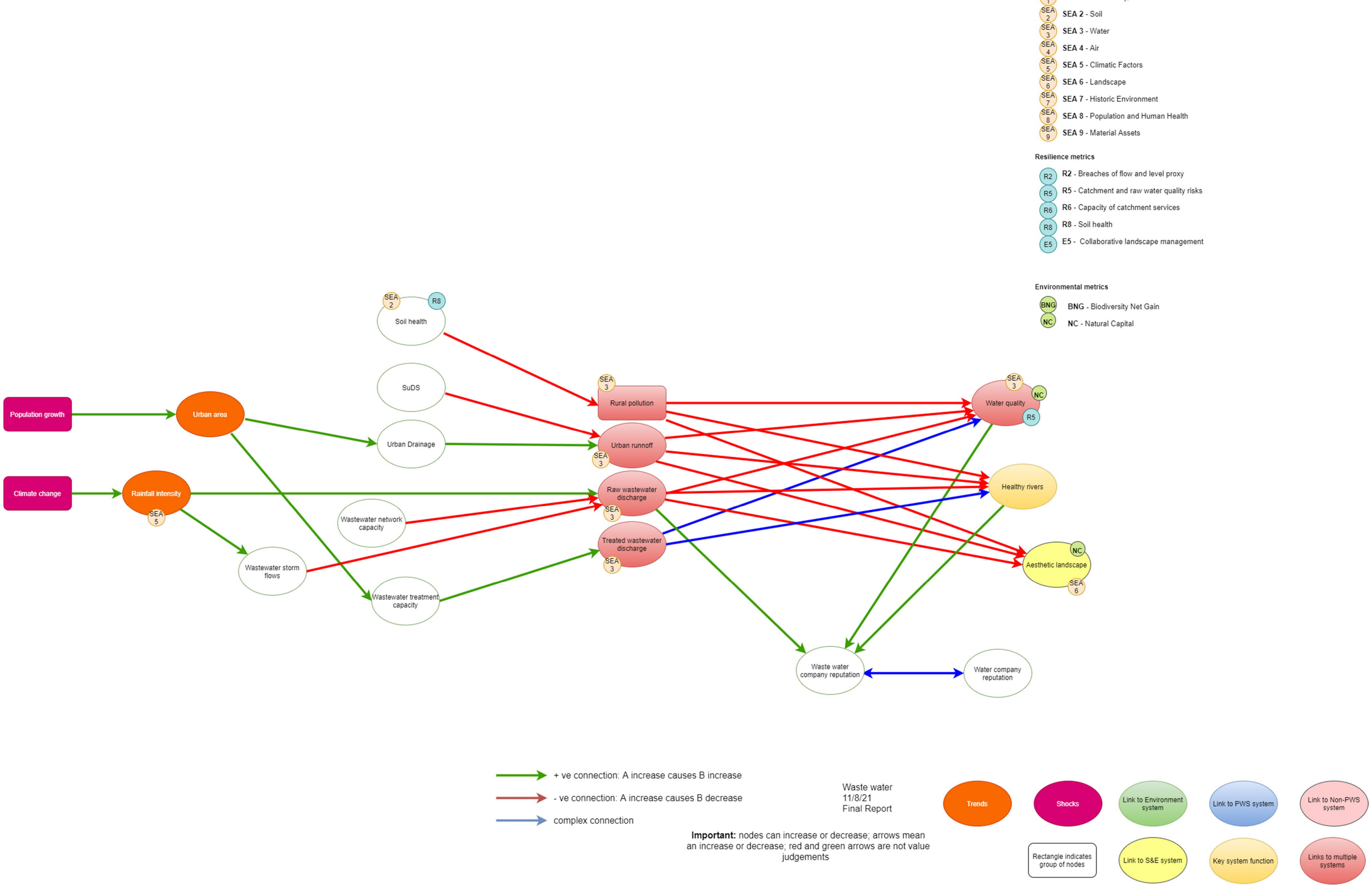
The wastewater system map is shown on Figure 5.4. This system has not been developed to the same level of detail as the PWS system, although many parts of the system would be the same – such as corporate and financial resilience.

The map may be read from left to right considering trends, then shocks, then different system functions including different forms of pollution and the impacts of pollution. At the bottom of the page there are links to *wastewater company reputation.* A complex two-way link to *water supply reputation* is shown. This type of link via public perception or association of ideas rather than direct causality is known as contagion. It is an important element of mapping the 'soft' elements of systems.

This map needs more development such as links with the PWS. The four nodes indicating different types of pollution appear in numerous other system maps.

This map has potential to be developed as part of the drainage and wastewater management planning process.

Figure 5.4: Wastewater



6 The multi-sector system

This section introduces the multi-sector system. It addresses agriculture, paper, power, canals, golf, and quarries. Each sector is analysed with a production of system map showing influence and control and a discussion of value creation. A semi-structured interview was held with representatives of each sector and the findings of those interviews covering sector trends, attitudes to resilience, drought management and potential options are recorded.

The multi-sector system refers to business systems that use water. Industrial water demand is 52 Ml/d with the breakdown as shown on Figure 6.1. Agricultural consumptive water demand from abstractions is 41 Ml/d with the breakdown as shown on Figure 6.2. There are four factors which increase the significance of these demands from a resilience perspective. Firstly, because the licences held are frequently greater than the current and historical patterns of use, there is potential for abstraction to increase under current licensing. Secondly, they have a high significance to peak demands because these sectors are more likely to draw on PWS supplies as back-up to their private supplies. Therefore, enhancing multi-sector resilience has potential knock on benefits to the PWS. Thirdly, the multi-sector system has potential to create multi-benefit schemes thereby enhancing the environment and social benefits that are considered in the 'best value' aspects of the regional plan. Finally, agricultural abstractions are largely (but not entirely) for consumptive use meaning that the water is lost to evapotranspiration and therefore not returned to the catchment – in contrast to most water use in inland PWS systems.

Multi-benefit schemes lie at the heart of the systemic vision of the 25YEP. Where the multiple benefits of a scheme are articulated and funded then the costs of the scheme to any one investor seeking a particular benefit are diminished – thereby making the scheme more cost effective.

Figure 6.1: Industrial water demand in the south east. Source: Environment Agency National Framework

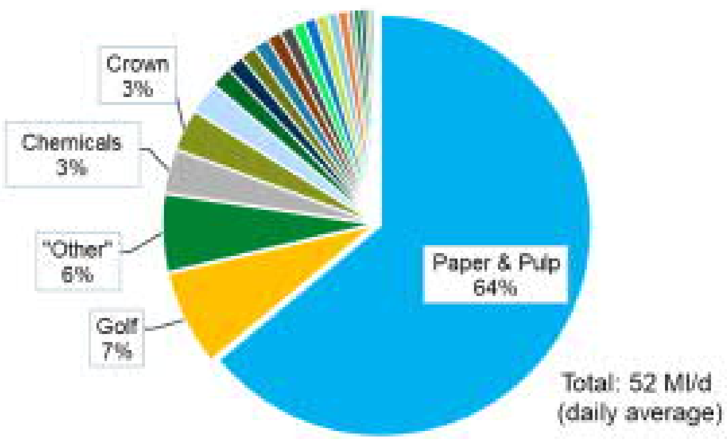
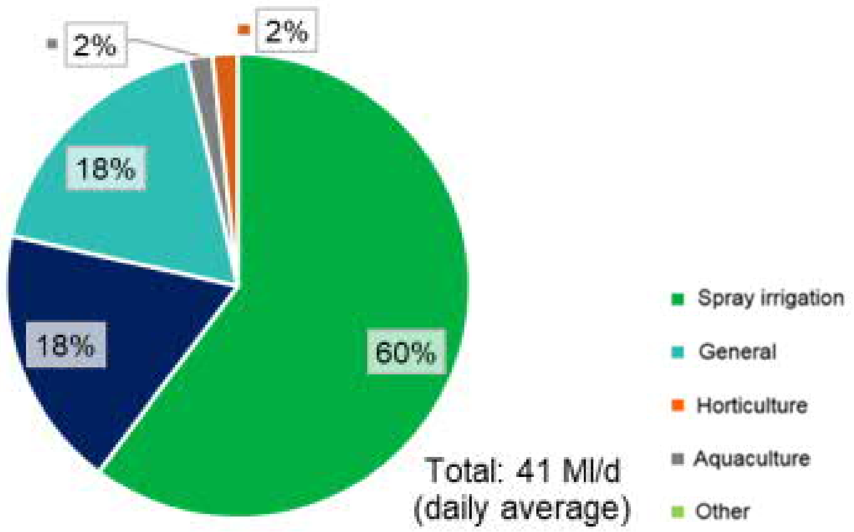


Figure 6.2 Consumptive agricultural water abstraction in the south east: Source: Environment Agency National Framework



Our approach has been to hold semi-structured interviews with representatives from each of these sectors from the multi-sector group of WRSE. In the interviews we reviewed draft system maps for the sectors and then discussed the following questions. The questions and draft maps had been sent to the interviewees beforehand:

- What are the main risks and trends affect your industry (in general terms)?
- How is your industry changing?
- What are the impacts on water use?
- What combination of PWS and private sources do you use?
- What are your assumptions around drought planning?
- Please describe the impacts, and your responses, to increasingly severe drought – from normal operation to the point you are unable to operate.
- What types of options have you identified that would address these water resilience problems?
  - Treated effluent.
  - Water efficiency.
  - Shared development of storage.
  - Boreholes, rivers etc.
  - Water sharing and trading.

6.1 Agriculture

Agriculture operates within the environmental system and the multi-sector system, and yet has highly significant overlap with the PWS and social and economic systems. Agriculture functions by stewarding natural capital to create a number of ecosystem services, principally food. Agriculture also uses other capitals such as human capital (labour); intellectual capital (know-how); manufactured capital (machinery and inputs); and financial capital.

Agriculture is both upstream and downstream of the PWS as represented by water flows and by the way each system influences the resilience of the other. In the UK, estimates suggest that about 60% of nitrates and 25% of phosphorous in water bodies, and 75% of sediments polluting water bodies come as a result of farming practices.[42] Water companies are increasingly recognising the need to work with farmers as a means of increasing the resilience of the water resources on which they depend. Farmers are often best placed to protect or improve water quality that may deteriorate and adversely affect water treatment works during periods of intense rainfall or drought. Downstream of the PWS, farmers may benefit by being connected to water supplies for PWS for irrigation or livestock. Due to the costs involved, the use of the PWS for farming is a fall-back option, often a response to drought rather than a routine use of water.

Some farming practices increase run-off and reduce infiltration making catchments more vulnerable to both floods and droughts. Land management cannot prevent floods or protect from all droughts, but sensitive management can make catchments and society less vulnerable. For example, contour ploughing can help reduce run-off and sediment transport. Bank-side roughness, hedges, and trees can slow flood flows and reduce peaks. During extreme flooding, fields can be used as flood plains to protect urban areas but may impact agricultural output. The choice of crops also influences water availability. A farmer changing a food crop say, to an energy crop such as Miscanthus, would almost double evapotranspiration and directly reduce water available for groundwater recharge and river flows.[43]

Agriculture should also be seen as a vital element of the wider social and economic system of the South East. Agriculture's fundamental relevance to society is the provision of food. Good quality food is highly significant for cultural identity and our social interaction in addition to its economic and nutritional value. The landscape, shaped as it is by farming, is similarly essential to our social identity and wellbeing. The 25 YEP opens with the observation that: "The environment is one of our most valuable assets and helps define us as a nation." The iconic chalk landscapes of the South East are of high social and cultural significance and ones in which farmers and water companies have important roles in co-stewardship.

In this section we consider agriculture from both system perspectives – value flow and creation and influence and control; we then review agriculture in the South East of England; and finally identify potential interventions to enhance resilience.

6.1.1 A systemic view of agriculture

6.1.1.1 Flow and creation of value

Agriculture contributes less than 0.5% to the United Kingdom's economy but it provides half the food we eat, employs half a million people, and is a key part of the food and drink sector which contributes £112bn to the national economy.[44] Agriculture in the southeast region directly employs over 50,000 people with total sales over £2 billion. Horticulture (mostly irrigated) and arable (rainfed) are the largest sectors and then livestock production (private and public water supplies).[45] Employment numbers increase to over 180,000 when jobs in input supply (e.g. seeds, machinery), food and drink manufacturing, wholesale, and professional and technical services are added. The consumer end of the food chain employs a further 920,000 people

[42] Global Food Security Programme (2018a) Agriculture's impact on water quality: Farming and water 1 sub report. London, UK. Available at: www.foodsecurity.ac.uk.

[43] Global Food Security Programme (2018b) Agriculture's impacts on water availability: Farming and water 2 sub report. Available at: www.foodsecurity.ac.uk.

[44] The future farming and environment evidence compendium - latest edition - GOV.UK (www.gov.uk)

[45] Agricultural facts: England regional profiles - South East (publishing.service.gov.uk)

taking the region's total food chain employment to just over 1.1 million. Post farm/factory gate food chain employment is the largest of any region in the UK.

Irrigated agriculture is modest in terms of area but significant in monetary value to the UK economy. In 2016, the estimated farm-level financial net benefits of irrigation in a dry year were more than £650 million.[46] In 2017, an estimated value of irrigated soft and top fruit to the UK economy was £711 million.[47]

6.1.1.2 Influence and control

The influence and control perspective on the agricultural system is shown on two maps. Figure 6.3 shows influences on farmer decision making leading to decisions about the implementation of sustainability measures with various environmental outcomes. Figure 6.4 shows the farm water use system.

The farming system map can be read from left to right. There is a cluster on the left around the node *Farmer willingness to change* representing the fact that agricultural strategy (such as family farms) are a function of social norms in addition to economic factors. The social and cultural dimensions to farm decision making is seen in the importance of farmer to farmer advocacy for new ideas and the significance of social networks. The *Farmer willingness to change* node is positively linked to the *On farm decisions towards sustainability* node in the next cluster to the right. Here we see the impact of food traders – which may be positive where the food value chain is demanding sustainability or may be negative where low cost food is prioritised. *Agricultural input and machinery providers* have a negative impact on decision making towards sustainability due to lock-in financial arrangements that constrain decision making. There is a complex two-way connection with *Farm financial resilience / profit* acknowledging that in the short term there may be a financial penalty in shifting to environmental practices whereas in the long term the benefits will be enhanced resilience. *On farm decision towards sustainability* influences a suite of farming strategies at the field level that influence environmental outcomes and food productivity.

The farm water use map is built around the node on *summer irrigation*. *Summer irrigation* increases *water in the soil profile - summer* and thereby *crop resilience* which is the key node for this sub-system. *Crop resilience* is also improved by *soil health*, both directly and through its influence on *water in the soil profile - summer*.

On the upper right side of the map issues around *water sharing / trading* indicate the potential for increasing *summer irrigation* through enabling water sharing and water trading. Where sufficient *farmer social capital* exists then water sharing may be more appropriate to water trading – noting the importance of social and cultural practices and decision making in the agricultural sector. Summer irrigation may be achieved as a result of an increased abstraction, which would potentially reduce availability of water to others upper; or could be achieved by increasing farm storage. Increasing *farm storage* has potential *biodiversity*, *amenity* and flood control benefits. Improving *soil health* is another means of enhancing *crop resilience*.

[46] Rey, D. et al. (2016) 'Modelling and mapping the economic value of supplemental irrigation in a humid climate', Agricultural Water Management, 173, pp. 13–22. https://doi.org/10.1016/j.agwat.2016.04.017

[47] UKIA (2018) Irrigators' Handbook. Edited by M. Kay. United Kingdom: UK Irrigation Association.

Figure 6.3: Farming and environment system map

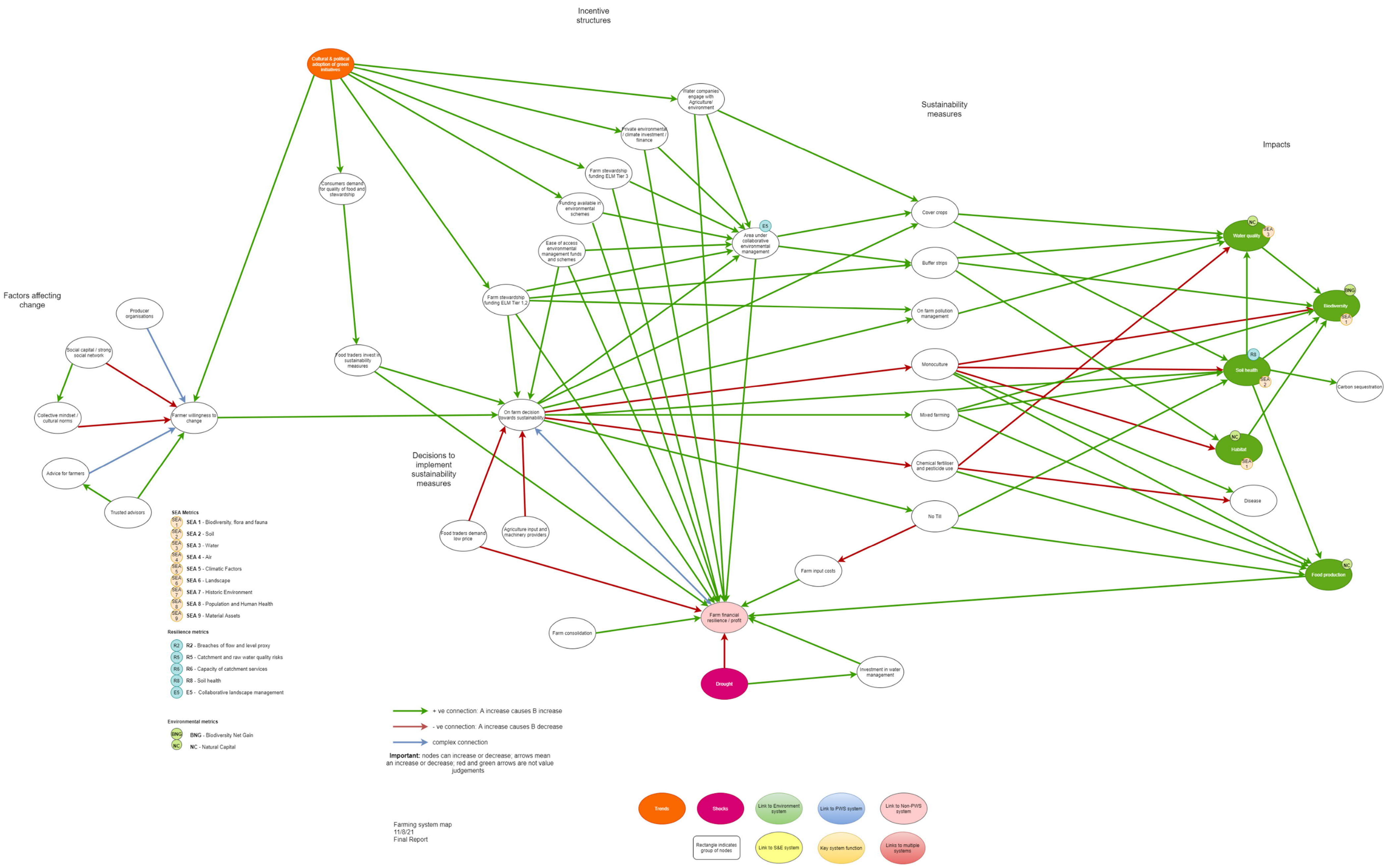
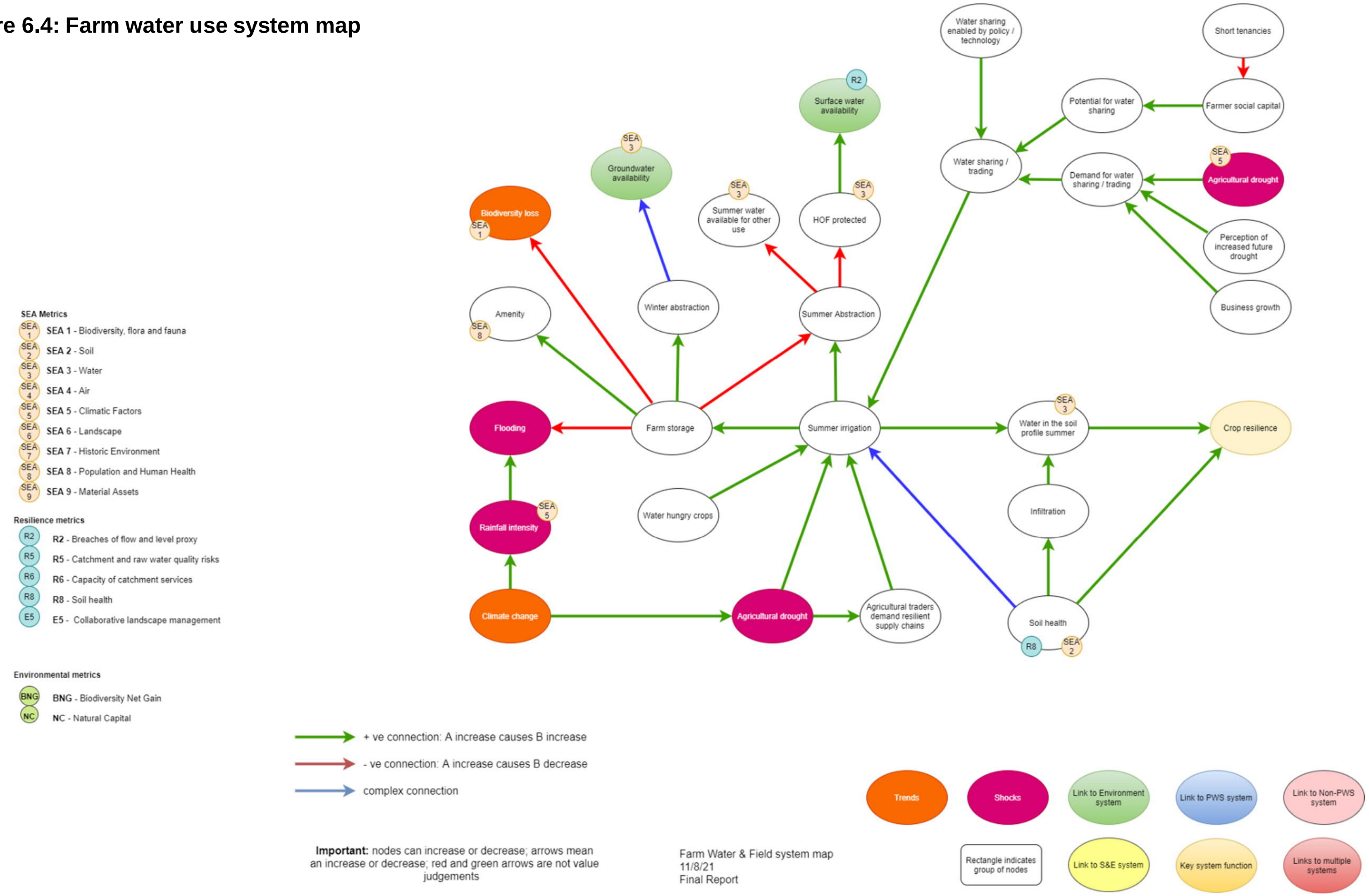


Figure 6.4: Farm water use system map



6.1.2 Agriculture in the South East

Agriculture and horticulture across the southeast are predominantly rainfed and diverse with significant arable and livestock farming. The region is also home to nationally significant irrigated fruit and ornamentals production, mostly located in Kent and along the south coast. The agricultural land and river catchments within in south east are shown on Figure 6.5.

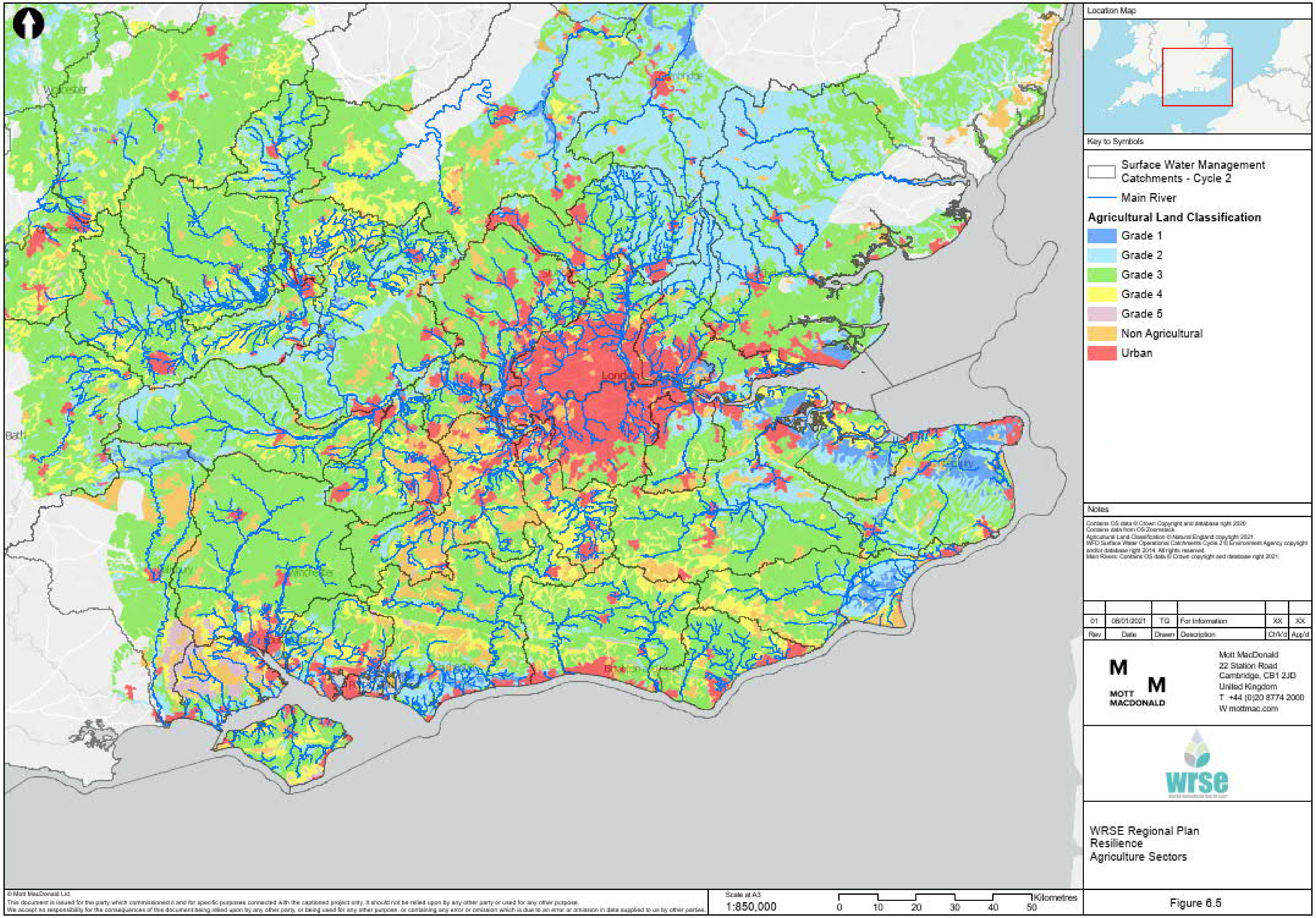
Available agricultural data from Defra for the 'southeast region' relate to government regional boundaries and differs from WRSE boundaries as they exclude parts of Gloucestershire, Essex, Hertfordshire, and Greater London. Nevertheless, these data demonstrate the importance of agriculture to the region's economy including employment, as shown in Table 6.1.

Table 6.1 South East agricultural output and value in 2018. Source DEFRA

Sub-sector	Area (ha)	% UK total	Value in 2018 (£ million)
Horticulture			
Field Veg & Salad	8,217	7%	74
Glasshouse crops	314	15%	124
Hardy Nursery Stock	1,082	11%	104
Top Fruit	9,211	38%	93
Soft Fruit	4,726	43%	226
Total			£621
Arable crops	**Area (ha)**		
Wheat	208,968	12%	249
Barley	110,710	10%	93
Oats	23,017	14%	15
Potatoes	3,262	2%	15
Sugar Beet	611	1%	1
Peas & Beans	32,230	17%	19
Oilseed Rape	77,938	13%	82
Maize	28,136	13%	30
Seeds & Straws	-	11%	87
Total			£591
Livestock	**Total herd**	**% UK total**	**Value in 2018 (£million)**
Dairy	63,138	3%	163
Beef	68,650	4%	148
Sheep	1,264,914	4%	54
Pigs	217,102	4%	54
Poultry	10,704,095	6%	198
Total			£617

Major rainfed crops include 13% of the nation's cereals and oilseed rape, and 17% of pulses. The region's livestock comprises only 4-6% of the UK total herds. Some 40% of the nation's top and soft fruit is produced in this region, particularly in Kent, which is renowned for its orchards and fruit. Field grown fruit is a mix of rainfed and supplemental irrigation, whereas protected cropping requires total irrigation.

Figure 6.5: Agricultural land and river catchments in the south east



Typical rainfall and evapotranspiration (ET) data for Manston in Kent illustrates the issues facing farmers. In most years, rainfall is evenly spread throughout the year. However, in the summer months, ET generally exceeds rainfall, and soil moisture deficits (SMD) build-up and peak in the autumn. In the winter months, rainfall generally exceeds ET and so runoff and infiltration occur providing freshwater for other users. Table 6.2 shows the rainfall and evapotranspiration for Manston Kent.

Table 6.2 Rainfall (RF) and evapotranspiration (ET) for Manston Kent (Ave 1962-2017)

Year	Summer RF (mm)	Winter RF (mm)	Summer ET (mm)	Winter ET (mm)
2015 (dry year)	147	393	397	176
Average	191	414	360	175

Most catchments in the South East are identified as over-licensed and/or over-abstracted, so there is often no new water available for direct abstraction in the summer months to improve or increase production. For example, in the River Medway, agricultural abstraction licences are placed under restriction in approximately four out of every five years, due to constraints on available resources. At a national level, this has been referred to as an emerging “critical irrigation geography” as some two-thirds of all agricultural holdings are located in catchments where no additional water is available for direct summer abstraction and competition for water is increasing. A potential means of addressing this problem is to increase winter abstraction and provide farm storage.

6.1.3 Risks and trends that affect the industry

The agricultural sector is facing a number of highly significant and concurrent processes of change. The rural economy is transitioning from one in which agricultural stewardship function was funded through the EU CAP scheme to one in which the new Environmental Land Management (ELM) scheme will be central. Farm payments are being phased out and the exact nature of the scheme to replace them is as yet still emerging. Agriculture is facing the prospect of increasing frequency and impact of drought, floods and high temperatures associated with climate change, calling for a response in terms of cropping patterns, irrigation, soil, and land management. The UK’s changing relationship with the EU is also affecting farming though changes to food export arrangements that mean additional bureaucracy at least. There are also potential implications for the availability of seasonal migrant labour as visa regulations change and as a changing exchange rate could make the UK a less attractive destination for seasonal labour.[48]

The key to understanding how these trends affect farmers is in the fact that they are all occurring together – a farmer therefore has to prioritise which adaptation strategies to adopt and where to accept risk. This complex decision-making process occurs in a context where traders demand reliable production and any breach in supply could mean a farm is excluded from future contracts. A survey of rainfed farmers in East Anglia produced a list of factors that farmers are facing shown on Table 6.3.

One of the means of coping with risk is to increase in scale. Small family farms growing rainfed crops and grass for livestock, typically around 85 ha (200 acres), are tending to be aggregated into larger business, usually because of limited profitability and heavy reliance on government payments which have an uncertain future. Farmers sell out to commercial companies and then

[48] The UK’s new immigration policy and the food supply chain - Environment, Food and Rural Affairs Committee - House of Commons (parliament.uk)

farms are often rented back to others coming into farming. This is expected to have little impact on overall rainfed production.

One of the means that farmers are using to improve financial and operational resilience is to improve soil health. In many cases this is done as part of a systemic change to farming that emphasises the biological activity in the soil and deemphasises the application of chemical nutrients. The approach, not to be confused with organic farming, is known as regenerative agriculture or no-till farming (and previously known as conservation agriculture). The uptake of regenerative agriculture is a global trend also evident in the UK.[49]

There are opportunities for change and growth in the irrigated sector. Despite the constraints on abstraction, the southeast has seen significant growth in soft fruit production, due to customer demand, improved varieties, better growing methods, and access to additional water from using trickle irrigation. This irrigation method was previously exempt from licensing and growers maximised this opportunity. Estimates suggest that in Kent, trickle irrigation increased substantially over the past 10 years indicating that where water was available, the sector has the capacity to innovate and grow to meet consumer demand.

Nationally, some 55% of food is imported. Growers see opportunities to expand home production of fruit and vegetables.[50] The government encourages this kind of thinking but the decision to increase production is a commercial one with many risks and uncertainties, of which water security is one of them. There is as yet no clear national policy on water for agriculture.

Table 6.3 What farmers worry about (ranked in priority)

Challenges	Mean score *(descending)*
Reduction in direct payments of the Common Agricultural Policy (CAP)	5.85
Persistently low market prices	5.77
Persistently high input prices (e.g. fertiliser, feed, seed)	5.76
Lack of appeal of farming as a career/profession	5.53
Strict regulations (e.g. environmental, animal welfare, or competition)	5.53
Market price fluctuations	5.31
Low bargaining power towards processors and retailers	5.27
Limited ability to work on the farm due to illness, divorce or other personal circumstances	5.25
Input price fluctuations (e.g. fertiliser, feed, seed)	5.12
Low bargaining power towards input suppliers (e.g. fertiliser, feed, seed suppliers)	5.12
Persistent extreme weather events (e.g. floods, droughts, frost)	5.04
Late payments from buyers	4.93
Public concerns for example about pesticide use, glycosphate and fertilisers, food safety etc	4.92
Uncertainty about the future UK agricultural policy	4.88
Low soil quality	4.76
Limited availability of skilled farm workers	4.04
Access to EU markets	3.90
Limited access to loans from banks	3.90
Pest, weed, or disease outbreaks	3.73

Source: SURE-Farm, 2017[51]

[49] Kassam, A., & Coates, D. (2019). The Global Uptake of Conservation Agriculture and the Impact on Water-Related Ecosystem Services. In Allan, T., Bromwich, B., Keulertz, M., & Colman, A. (Eds.). (2019). 'The Oxford Handbook of Food, Water and Society.' Oxford University Press. https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190669799.001.0001/oxfordhb-9780190669799-e-59

[50] https://www.gov.uk/government/statistics/food-statistics-pocketbook/food-statistics-in-your-pocket-global-and-uk-supply#origins-of-food-consumed-in-the-uk-2019

[51] Reidsma, P. et al. (2017) 'Resilience assessment of current farming systems across the European Union', (727520). Available at: https://www.surefarmproject.eu/wordpress/wp-content/uploads/2019/12/D5.3-Resilience-assessment-of-current-farming-systems-across-the-European-Union.pdf

6.1.4 Rainfed farming

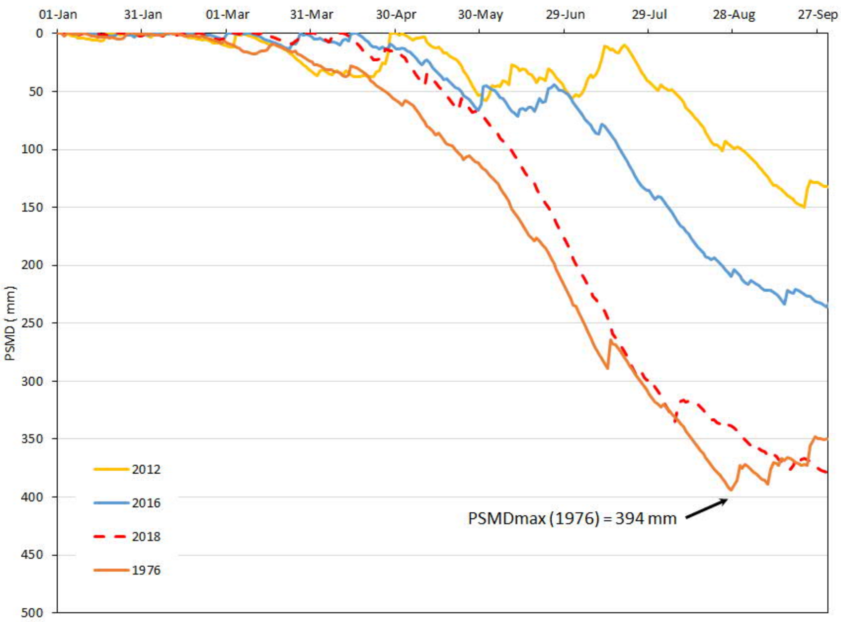
As listed in the concerns among Anglian farmers, those who farm in the southeast are also worried about water shortages during the growing season. This directly affects rainfed farming and irrigated farming where there is a direct abstraction from rivers and groundwater.

Cereals and oilseeds production in the UK are among the most efficient in the world. The water footprint for wheat of less than a third of the global average. Less than 0.3% of the cereal area is irrigated and this is usually for germination during a dry spring or late autumn sowing. Irrigation only benefits those with equipment and licences for abstraction that has been bought for other crops.

In future, the expected uncertainties over rainfall patterns may increase the demand for irrigation. Under optimum growing conditions average yields could reach 15 T/ha. Better water use can come from breeding varieties with improved water stress resilience and higher nutrient/water use efficiency.

In most years, the growing season starts with soils at field capacity following winter rain, but a meteorological drought can quickly turn into an agricultural drought if there is little rain in the spring and crops start to grow and use the stored water. An agricultural drought can occur in as little as 10 days without rain at critical times during crop growth. Potential Soil Moisture Deficit (PSMD) is a common agroclimatic indicator of aridity (Figure 6.6) illustrates the build-up of soil moisture deficits during recent agricultural droughts between 1976 and 2018. Within a matter of weeks after planting, the PSMD increased beyond 50mm and impact crop growth and eventually on yield. This level of drought would not normally impact public water supplies, but it would be the beginning of serious problems for farmers who do not have access to irrigation, and it is also likely to impact the aquatic environment.

Figure 6.6: PSMD as an agroclimatic indicator for recent droughts



Source: (J. Knox et al., 2020) [52]

[52] Knox, Jerry W. et al. (2020) 'The challenges of developing an irrigation strategy for UK agriculture and horticulture in 2020: industry and research priorities', CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 15(050). DOI: 10.1079/PAVSNNR202015050

Case study: Farm resilience against 2019 - 2020 shocks.

Arable farmers faced multiple shocks in succession during 2019 to 2020. Heavy rain made planting difficult in the autumn of 2019, and dry weather undermined yields in spring 2020.

The area planted with wheat was 24% less in 2020 than 2019 and yields fell by 22%, making an overall decline in production of 40% to 9.7 million tonnes in the UK, the lowest figure since 1981.[53]

The area of winter sown barley was down 31% on the previous year, but an increase in spring sown barley of 52% made an overall increase of 19%. Due to low yields, production increased by only 0.9%, but this was still a large harvest providing surplus for export.

When drought hit in May, then farmers with good soil health were in a more resilient position than farmers whose soils were less well able to capture and retain soil moisture. Given the combination of these impacts is a year of low profitability, then farmers with low costs – farmers practicing no-till / regenerative agriculture had improved financial resilience.

This case study shows that the output of rainfed crops is highly variable and that rainfed farmers tolerate an unusually high level of variable outcome compared with other sectors. Improving soil health and controlling input costs are means of improving the resilience of their business. Variations in international trade provide a buffer for domestic food security. The import of wheat increased by 72% between 2019 and 2020.

6.1.5 Livestock farming

Livestock farming requires water for drinking, washing animals, and cleaning yards and parlours. Water is required all year round and the amount depends on the numbers and size of animals and their diet as some drinking water requirement comes from moisture in food. The balance may come from natural sources (such as ponds and streams), private wells, or from mains water in drinking troughs.

The volume of water needed to produce meat at the farm gate is equal to 67 l/kg for beef and 49 l/kg for lamb. Dairy farms also use significant amounts of water for cooling and in total it takes about 8 litres of freshwater to produce 1 litre of milk at the farm gate. Although most livestock farms use mains water, nationally some 30% of water for livestock rearing is abstracted from surface and groundwater sources.[54]

Dairy, beef, and sheep farmers can improve their water use efficiency for grazing livestock, improving grass sward management can make better use of rainfall onto grass through improved soil nutrition, soil structure, and grazing management. With dairy, continuing efficiencies are being implemented for washing down and milk cooling, high-pressure low volume hoses, and recycling milk cooling water.

Drought tolerance comes from using deep rooting grass varieties and other forage crops which in some cases also improve soil structure and infiltration and soil water storage. Livestock can also benefit from using genetics and breeds from drier climates which can improve drought tolerance in beef and sheep.

For non-ruminants, such as pigs, the industry uses housed production systems and relies mostly on good quality mains water as the demand is for drinking and hygiene purposes. In recent years, the emphasis on hygiene, especially cleaning and disinfection means the sector is

[53] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004670/AUK-2020-22jul21.pdf

[54] Global Food Security Programme (2018b) Agriculture's impacts on water availability: Farming and water 2 sub report. Available at: www.foodsecurity.ac.uk.

more reliant on adequate and reliable supplies of water. The cost of water for livestock is a significant driver for optimising use.

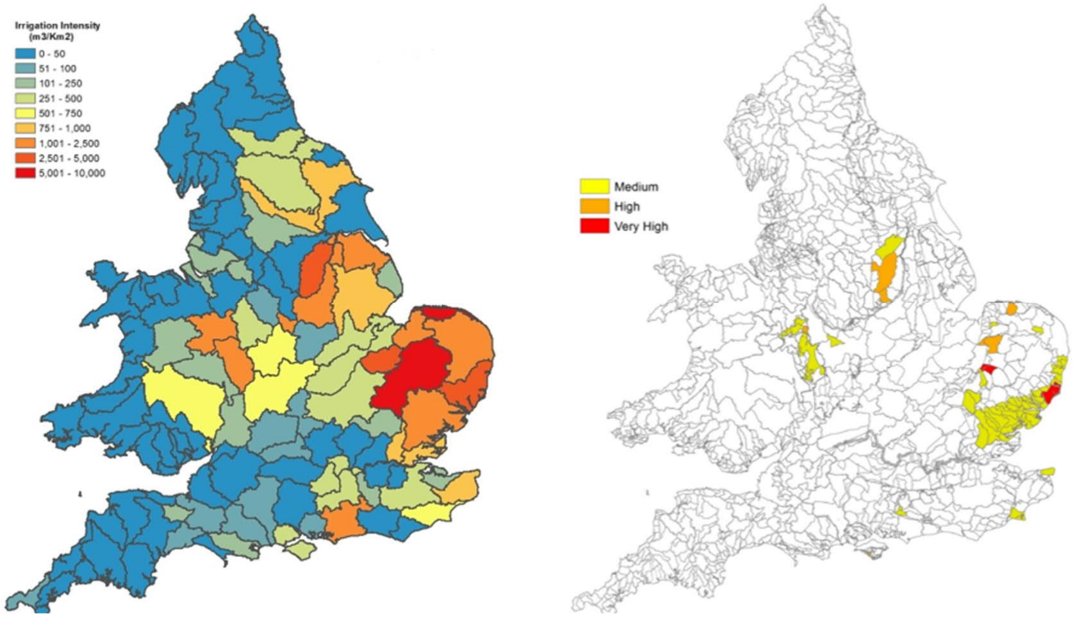
6.1.6 Irrigated farming

The EA National Framework indicates that the South East has an average of 41Ml/d direct abstraction for agriculture which is similar to the North (33Ml/d); the West (58Ml/d), the South West (43 Ml/d) but significantly less than the East at 202 Ml/d. The use of water is shown in Figure 6.2. Within irrigation, there are two distinct sub-sectors: outdoor field scale crops, and indoor (protected) horticulture producing edibles and ornamentals. The south east offers ideal growing conditions for both.

6.1.6.1 Outdoor field crops

High-value outdoor fruit and vegetables enjoy the light soils the mild and warm climate. But these are areas with the lowest rainfall and soils retain little moisture, and so irrigation is now essential to produce quality crops for the UK's sophisticated food markets. Maps are available of irrigation intensity in m^3/km^2 and identified vulnerable areas by combining maps of resource availability with irrigation abstraction (Figure 6.7). Although irrigation abstractions are highest in East Anglia, Lincolnshire, and the Midlands, there are pockets of high demand in the south-east. 'Hotspots' of vulnerability exist along the north east and south coast that highlight where competition for water and pressures on irrigation sustainability are most likely to emerge.

Figure 6.7: Irrigation intensity (m^3/km^2) (a) and irrigation 'hot-spots' (b) in England and Wales based on Environment Agency abstraction data (2010) and water resource availability (2002).



Source: (J. Knox et al., 2020)[55]

Irrigation farmers and growers in the region live with uncertainty. Most catchments that are over-licensed and/or over-abstracted are also areas where irrigated production is concentrated. Many

[55] Knox, Jerry W. et al. (2020) 'The challenges of developing an irrigation strategy for UK agriculture and horticulture in 2020: industry and research priorities', CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 15(050). DOI: 10.1079/PAVSNNR202015050

rely on direct abstraction from rivers and groundwater, but summer abstraction is perceived to be becoming less reliable as demand for water for agriculture and other sectors increases and drought risks are understood to be increasing. In contrast to the more predictable patterns from domestic demand, irrigation abstractions do not follow steady patterns. Direct abstraction is concentrated in the growing season from April to September and can vary throughout the season and from year to year depending on summer rainfall. Water supply is also not guaranteed. Many licences are now time-limited, headroom on licences is being reduced on the basis that abstractors are not regularly using their licensed volume, 'hands-off' flow restrictions are common constraints on licences, and the regulator can prohibit abstraction when they perceive a threat to the environment, using a facility known as Section 57.

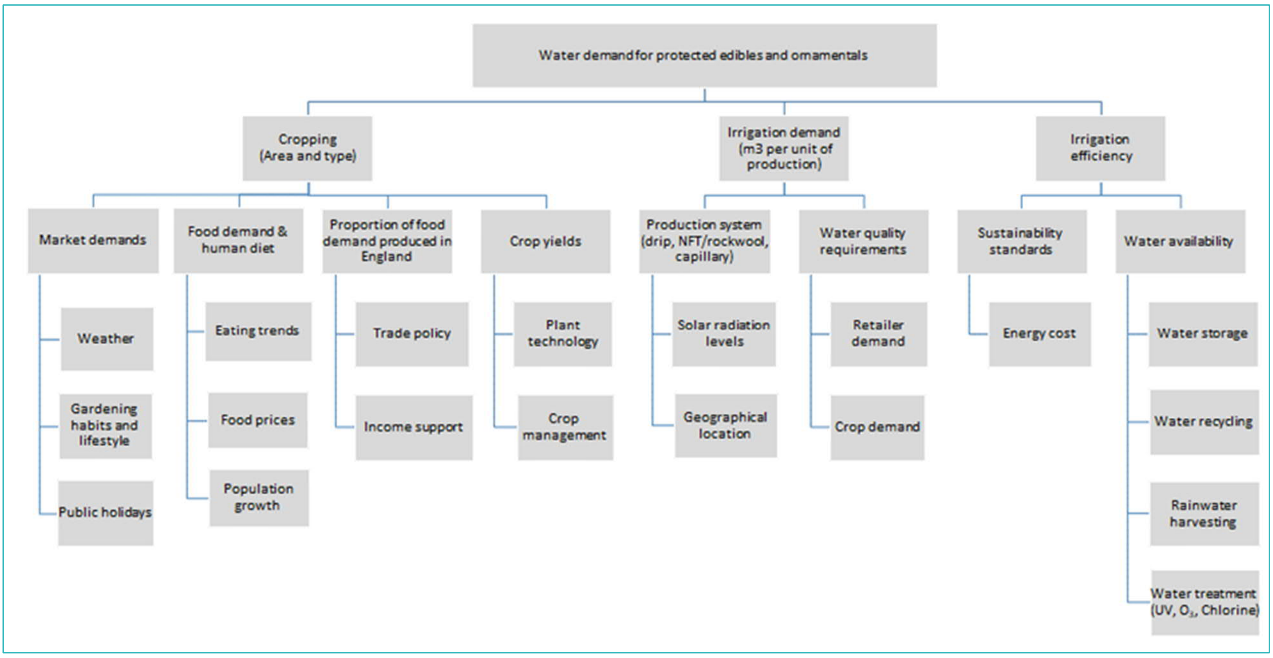
6.1.6.2 Protected cropping

Protected cropping for edibles (soft fruit and salad crops), and ornamentals (container pot plants, cut flowers) is a highly specialised activity with high investment costs and high returns. Figures for sales of ornamentals for example can be up to £1.5-2.0 m/ha of cropping annually. Most nurseries specialise in a few plant types but some supply over 1,000 different plant species.

Growers, mostly along the south coast, who produce crops under glass or polyethene are dependent on irrigation and are subject to the same regulations as field crop irrigators in terms of abstraction. Small growers and nurseries may rely on private boreholes and have some relaxation in their abstraction conditions compared with spray irrigators.

Nursery crops can use up to 8,000 m^3/ha/yr. Nurseries by their nature are intensive operations and have little room for winter storage. Most rely on groundwater and PWS. Many also collect water from roofs and store it in tanks, but this is limited by available land. The National Farmers Union (NFU) suggest that overall direct abstraction is reducing because of efficiency gains, but in some hotspots, it is increasing. Although assessing the magnitude and location of current and future water demand is essential for planning, forecasting demand in this diverse industry is hard. Within any subsector many factors influence demand, as illustrated in Figure 6.8 for indoor crops and ornamentals. The relative importance of these factors and how they are combined to impact water demand in complex. Changes in agro-economic policy and government decisions on trade policy and levels of self-sufficiency can have a dramatic short-term impact on water demand. It is unfortunate that much of these base data and equivalent analysis is not yet available for both indoor and outdoor cropping.

Figure 6.8: Factors affecting water use for indoor cropping protected horticulture.



Source: (J. Knox et al., 2020) [56]

Knowledge gaps and priorities for action for protected cropping include:

- Gather catchment data on cropped areas, water sources, and patterns of water use
- Information on 'drivers of change' and policy impacts, including effects of trade and tariffs on imports and sector expansion or contraction.
- Understanding the impacts of climate change on this subsector, and how this may affect production, plants offered, and target markets.
- Assess impacts of abstraction reform and investment options.

Similar gaps may be identified for outdoor cropping.

6.1.7 How the sector responds

6.1.7.1 Drought planning

There is as yet no universal definition of drought and so not surprisingly many farmers and growers differ in their understanding of drought and hence their reaction to it. Farmer perspectives often differ depending on whether they have sufficient headroom on their licence to carry them through a dry year and not suffer from restrictions. Consequently, irrigators may view drought as an opportunity rather than a risk, with scope to benefit from their competitive advantage over rainfed production systems.

In 2016, a survey of farmer reactions to drought in the Anglian region found that the percentage of irrigators affected by Section 57 restrictions has reduced in recent years and there was an increase in the proportion of growers that had agreed to voluntary abstraction restrictions earlier in the year, to avoid mandatory restrictions from rivers later in the season, when they needed it

[56] Knox, Jerry W. et al. (2020) 'The challenges of developing an irrigation strategy for UK agriculture and horticulture in 2020: industry and research priorities', CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 15(050). doi: 10.1079/pavsnnr202015050.

most.[57] The research did not address the frequency of Hands-Off Flow (HOF) restrictions. Short-term coping strategies from the farmer survey included:

- Making best use of available water relative to their water resource position and infrastructure constraints
- Liaising with the regulator (either directly or indirectly via Water Abstractor Groups) to either reduce the likelihood of abstraction restrictions and/or to obtain maximum warning and support from them
- Irrigating at night and crop prioritization to irrigate reduced areas (although it is noted that research in southern France suggests there is little water-saving irrigating at night, the only advantage being reduce wind speeds improving application uniformity (Molle, 2012).
- Coping strategies such as water trades or renegotiating existing contracts were less common.

The most common long-term adaptive strategies included:

- Securing alternative water sources.
- Investing in more efficient irrigation infrastructure.
- Investing in on-farm reservoirs to synchronise abstraction timing with water availability. This represents a major investment that not every farmer is willing or able to make in the uncertain climate around the future of agricultural production.

A general perception from the survey was that farmers and growers perceived that agricultural drought impacts have decreased over time despite little change in drought severity. This suggests that they are becoming more resilient to drought than a few decades ago. Growers identified improvements in drought management:

- A more collaborative approach exists now between the regulator and growers.
- Improved seasonal forecasting of water availability.
- Better water re-allocation within agriculture such as facilitating short-term water trading and increased flexibility around licence restrictions when water availability exists e.g. extending winter reservoir filling into April during winter droughts and extending the irrigation season to enable crops to be lifted easily.

Since the survey in 2016, additional issues that can exacerbate drought have come into play. Licences are now becoming time-limited which limits planning horizons, and there is pressure to reduce licensed headroom.[58] Headroom is seen by irrigators as their safety margin to cope with extreme years.

6.1.7.2 Potential actions to increase agricultural water resilience

Improve soil health and organic matter

Improving soil health benefits water resilience by increasing infiltration and water storage in the soil profile. There are additional benefits to other users such as downstream water companies who benefit for better and more regular water quality and flows. The essential measures of soil health are dry bulk density (to indicate good structure), organic matter and cover. There are other factors that can be measured but these three provide a good overview of the likely condition of the soil.

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[57] Rey, D. et al. (2016) 'Modelling and mapping the economic value of supplemental irrigation in a humid climate', Agricultural Water Management, 173, pp. 13–22. https://doi.org/10.1016/j.agwat.2016.04.017

[58] Headroom is the difference in water volume between what a farmer uses and what they are licensed to use.

There are numerous ways of improving soil health. A full range of interventions would be addressed in a regenerative agricultural approach. Regenerative agriculture is based on the following principles as articulated by the Groundswell agricultural show who champion these techniques in the Southeast (in collaboration with Affinity Water). [59]

Diversity of crops.

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

In combination, these techniques enhance soil structure, organic matter, infiltration, and soil retention thereby making the crops more resilient and improving the water quality and flow regulation of runoff. Soil health has been adopted a resilience indicator for WRSE.

Build more on-farm storage

This is the most common response to increasing water resilience on farms and is a strategy supported by the recent National Infrastructure Strategy.[60] More farmers are looking to secure water before the season begins by storing excess winter water. But recent winter droughts have highlighted that storage is not without risk. Currently, the common practice is to assess storage based on meeting the requirements based on water demand for the 5th driest year in 20 years on a given irrigated areas. This is of course is a simple design criterion and does not take account of how and when the water is used, the area irrigated from one year to the next, and does not define the level of inadequacy.

Reservoirs are costly to build and the returns, particularly in a run of wet summers, do not always immediately pay for the level of investment needed. Thus, the volume of storage is as much an economic decision as a technical one. Some farms, concerned about the combination of winter and summer droughts, like the pattern in 2011-2012, are now thinking about storage over 2 years rather than 1 and changing the design criteria to the driest year in 20 years. The risks would be reduced but not eliminated.

The high cost of storage, together with uncertainties over future abstraction rules, can inhibit long term investment. The government, with EU support, has stepped in occasionally with grants up to 40% to encourage reservoir construction but such grants come and go. There are also concerns that farmers are using public money for private goods. This is true but there are also public benefits as well both in securing home food production and making use of winter water which is usually more plentiful rather than summer flows. Farmers usually have to give up their summer licence for a winter licence when they want to store water. This has the benefit of reducing irrigation abstractions in the summer and leaving water for others to use for domestic, environmental, and amenities. Winter abstractions can also help to take the top off winter floods flows thus easing flooding downstream. Thus finance to support winter storage is potentially a public good as well as a private good and relevant to public financial support.

During the recent run of dry years, the EA has responded by allowing farmers to fill reservoirs outside the authorised winter filling times. Provided the river flows are adequate the regulator has allowed filling to continue into April and to take the top of excess summer flows resulting from high rainfall events. The latter works well on clay catchments but has little impact on groundwater-fed rivers. This has worked well but there are concerns that the regulator sees

[59] See Principles of Regenerative Agriculture - Groundswell Groundswell (groundswellag.com) Affinity Water are the headline sponsor of Groundswell.

[60] HM Treasury (2020) National Infrastructure Strategy (NIS). https://www.gov.uk/government/publications/national-infrastructure-strategy

such flexibility as a temporary measure to encourage farmers to take more permanent steps to secure their water supplies. Farmers argue that this should become a more permanent feature of agricultural water management practice.

Synergies are available with water companies where farmers can increase their farm storage and reduce their abstraction at times where demand from PWS is high. Where farmers forego abstraction at peak times, then there is potential for schemes that fund farm storage and create a win-win project.

Develop shared storage

This includes farmers sharing storage or storage for multiple use. An example of successful shared farm storage is in Holkham in Norfolk, where up to 15 farmers buy water from a common reservoir owned by the Holkham Estate. Shared storage among multiple uses, water supply, flood storage, irrigation, the aquatic environment, and amenity is gaining much favour, particularly for the larger reservoirs, driven primarily by PWS. Water Resources East is pursuing this strategy and has spent considerable time and effort in building social capital for such a venture. However, it is not clear yet how it will be funded and who will manage the water, particularly in drought periods, when there will be inevitable trade-offs needed.

Make better use of available supplies

Farmers are encouraged to make the best use of available water resources. However, there is as yet no clear definition of what water use efficiency means for irrigation. "More crop per drop" is often used but is this productivity in terms of income or the tonnage of cop produced. Although there will always be some who may waste water, it is not common because applying water to crops is expensive and the main cost is in energy, which can be as much as 70% of the total cost of irrigation. Thus, the need for energy efficiency and reducing costs tends to drive irrigation water use efficiency. The UK Irrigation Association (UKIA) recommends that farmers adopt the pathway to efficiency rather than worrying about putting a number on it. This involves optimising the use of irrigation equipment, scheduling water applications in line with crop and soil requirements, and adopting best practices.[61]

For livestock, there is little opportunity to reduce water consumption as most is used for drinking. However, there is scope to reduce water losses through maintenance, such as fixing leaks in water troughs, and good management, such as using trigger sprayers when washing down, or reuse of cooling water.

Improve water management

Improving data management and scenario planning is an important strategy for farm water management. There are web-based tools that support farmers in this endeavour.

UK Water Resources Portal

A wealth of information has come onstream to support agricultural drought planning from the UK Centre for Ecology and Hydrology following several years of research into drought precipitated by the 2011-12 drought which impacted water supplies as well as agriculture. Their water portal provides up-to-date data on river flows, rainfall, soil moisture, and groundwater levels from a local to a national scale, with users able to view measurements in any part of the country by clicking on an interactive map.[62] The portal is designed to help irrigation farmers better understand the current state of water resources in their local area and provide an early warning of potential droughts and floods. Historical records also help irrigation managers to compare current events with long-term averages and previous significant events from the past 50 years.

[61] UKIA (2018) Irrigators' Handbook. Edited by M. Kay. United Kingdom: UK Irrigation Association.

[62] https://eip.ceh.ac.uk/hydrology/water-resources/

The Portal brings together several data sets from the EA, the Met Office, COSMOS, and British Geological Survey all in one place in an easy-to-use format.

An innovative feature is near real-time access to river flow data directly from the EA. This means that farmers can see the same date the EA uses to make decisions about flow restrictions. Farmers can now look at the same data and make plans/adjust their management strategies accordingly when flows start to approach abstraction limits.

D-Risk

The D-Risk tool, developed by Cranfield University enables farmers to take more strategic approach to drought planning.[63] This allows farmers to evaluate their existing business models and align water resources availability with crop planting programmes to assess their resilience to water shocks, such as drought and changes in water allocation.

Rainwater harvesting

Harvesting rainwater from roof canopies and hard surfaces can help to increase resilience. This is mainly for those involved in protected cropping and harvesting water from runoff from plastic and glass coverings.

It can also benefit livestock farmers who have buildings and hard surfaces from which they can harvest rainfall. However, whilst this reduces farm water costs it does not create new water in a hydrological sense. Water captured may otherwise have contributed to streams or aquifers.

Where run off from farms would otherwise go into combined sewerage systems then there are additional potential benefits in reducing combined sewer overflow spills.

Besides, livestock farms and irrigators will still require an adequate water supply, often from the mains, to meet their water requirements during periods of low rainfall and drought.

Farm abstractor/water management groups: working together

Over the past 20 years, evidence has been growing that farmers working together and forming abstractor groups can encourage water-sharing and increase resource use efficiency. They usually form as a result of a crisis that needs combined efforts to resolve and then they gradually mature into organisations, formal and informal that sees merit in continuing to work together. They build social capital (trust) and become a useful resource for negotiating with the regulator when there are potential shortages. Many have been able to avoid Section 57 restrictions through this mechanism and have negotiated voluntary restrictions to avoid shortages later in the season.[64]

The Water for Food Group is another grouping around water management that encourages better use of water in agriculture. It is an informal grouping of many of the agricultural organisations who have an interest in water management, at present among those mostly working in the Anglian region.[65] It was formed after the 2012 drought by the UKIA and NFU to bring together those interested in working together to discuss, understand, and promote the wise use of water in agriculture and horticulture. Its membership is growing and now includes the EA, Defra, Water Resources East, the drainage authorities, and the Food and Drink Federation. Importantly the membership is among those who want to be at this table rather than formal representation.

[63] www.d-risk.eu,

[64] UKIA (2018) Irrigators' Handbook. Edited by M. Kay. United Kingdom: UK Irrigation Association.

[65] Water for Food Group (2017) The case for prioritising water for food production as an essential water need. London, UK. Available at: https://www.fdf.org.uk/responses/Essential-need-position-statement.pdf.

Water trading and sharing

Water trading (generally in terms of abstraction licence trading) is in its infancy. It is an option to move water to where it is needed but it is fraught with difficulties not least is the limitation imposed by catchment restrictions and abstraction regulations.

Water sharing offers a means of informal trading among say, members of an abstractor group. An example of sharing is the recent experience in the Lark Abstractor Group in the Anglian region which relies heavily on trust among those practicing sharing. Kent County Council have developed a pilot project to trade water in the Hacklinge Marsh area and are looking to scale this up to different parts of the county.

6.1.8 Need for an agricultural water strategy

The UK has a well-developed strategy for protecting public water supplies and is developing a strategy for water and the environment. But it has yet to develop a comprehensive water strategy for agriculture, horticulture, and livestock. The questions that are addressed for PWS, such as how much water is needed now and in the future, and what investment is required to increase water security, have not been asked about water needs for agriculture. Unlike PWS companies, which have statutory duties set by the government, agriculture is in the hands of smaller private sector companies whose water abstractions are also tightly regulated by the government. This is a fragmented industry with no focal organisation that has responsibility, resources, and capacity to collectively identify priorities and drive change. The industry urgently needs a strategy to ensure that agriculture receives a fair share of the nation's water resources as the UK government makes plans for an integrated approach to water resources management in line with the requirements of the 2030 UN Development Agenda for Sustainable Development.[66] So far, the UKIA has set out a document to begin this process for irrigated agriculture but the industry faces many unknowns, the most important of which is just how much water is needed now and in the future. Predicting this is fraught with many difficulties, not least of which is the question of who will gather the information needed and prepare the strategy.[67]

Water for agriculture also lacks the same level of security that public water supplies enjoy. All abstractions are licensed and the regulator has powers to stop irrigation when supplies are limited using a Section 57 notice. In the event of water shortages, this is a commercial risk that must be borne by the farmers.

6.2 Paper

Paper and pulp are the largest industrial user of water in the South East taking 64% of the region's multi-sector abstractions. A system map of the paper system is shown on Figure 6.9. The findings and key system health and resilience factors are summarised in this section.

6.2.1 The paper system

The paper system takes natural capital in the form of wood fibres and/or recycled fibres (manufactured capital) to produce paper, relying on the additional inputs of human capital (labour), intellectual capital (know-how) manufactured capital (factories, machinery, control systems and inputs) and social and relational capital in the form of markets and associations.

[66] United Nations (2018) Sustainable Development Goal 6: Synthesis Report 2018 on Water and Sanitation. New York. Available at: https://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/ .

[67] Knox, Jerry W. et al. (2020) 'The challenges of developing an irrigation strategy for UK agriculture and horticulture in 2020: industry and research priorities', CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 15(050). doi: 10.1079/pavsnnr202015050.

The purpose of the paper system is main value creation goal is to produce paper products of appropriate quality for multiple end-uses. The main end-uses identified that drive the demand for paper production are:

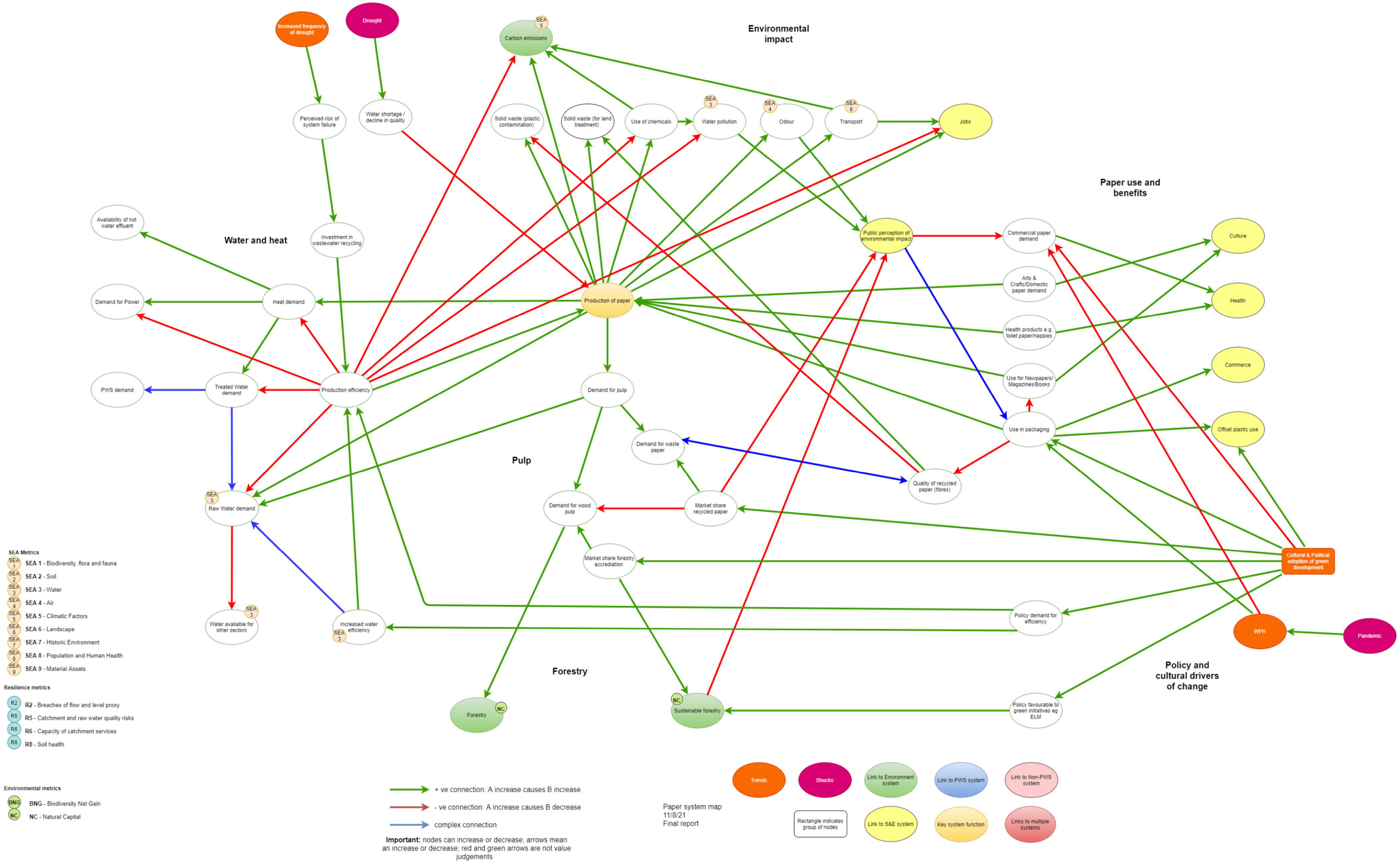
- *Commercial paper demand*
- *Arts & Crafts/Domestic paper demand*
- *Health products e.g. toilet paper/nappies*
- *Use for newspapers/magazines/books*
- *Use in packaging.*

These demands are indicated on the right hand side of the system map (Figure 6.9) and drive the central key node, *Production of paper*. Production of paper drives demand for pulp and the associated functions at the bottom of the map, heat demand and Raw water demand on the left of the map; and environmental impact nodes at the top of the map. Production efficiency on the left of the map creates a reduction in the environmental impact nodes which is likely, in some degree to be lessened by the opportunity to increase production that the efficiency creates.

The paper system has solid and fluid waste streams that need to be managed to either minimise negative impacts on external systems or provide additional value inputs to them. The sector also provides additional value beyond the production of paper, it directly employs 56,000 workers and supports a further 232,000 jobs through the supply chain. The products it produces support:

- cultural and knowledge sharing (books, newspapers, and magazines)
- other business to deliver their products to customers (packaging)
- health and wellbeing (health products, toilet rolls/nappies)
- the productivity of workers (commercial paper production)

Figure 6.9 The paper system

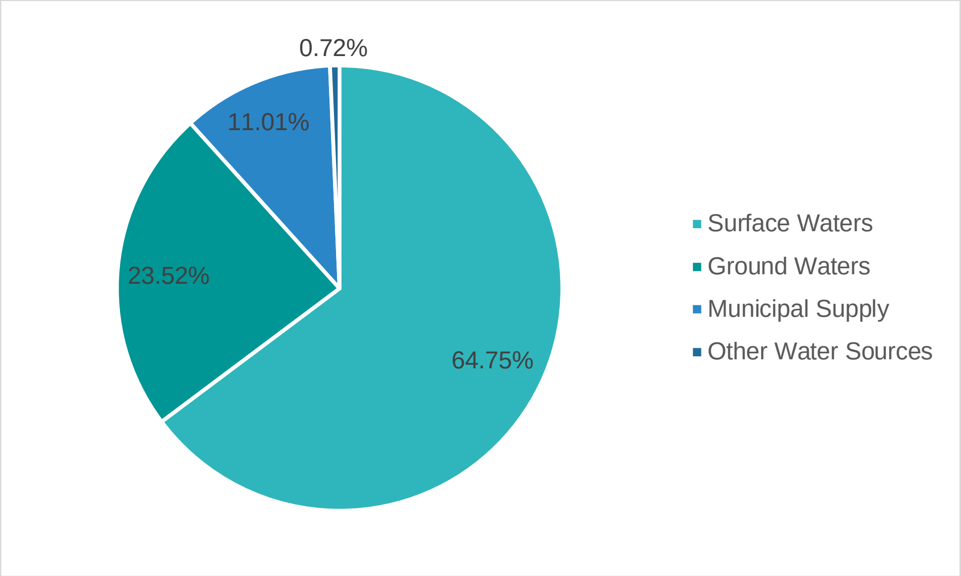


6.2.1.1 Demand for water

Paper mills require a significant amount of water throughout the paper production process both as part of pulp preparation, and for steam generation. Most of the water is non-consumptive use and is returned to the environment into surface waters.

Data from the Confederation of Paper Industries (CPI) shows that paper mills in the UK require over 170Ml/d of water demand.[68] Figure 6.10 shows how this demand is split between different source types, with 65% coming from surface waters, 24% from ground water and 11% from the public/municipal water supply.

Figure 6.10: Breakdown of paper mill water consumption by source



Source: CPI data - CPI_PAP_WaterAbstraction_2019.xlsx

The sector has already identified the need to improve water efficiency to maintain the resilience of mills with increased scarcity of water resources. Improvements in water efficiency are driven by requirements in environmental permits, which specify Best Available Technology (BAT), which outline water and energy efficiency best practice. Individual companies and mills also have internal targets to drive water efficiency targets, normally measured as volume of water per tonne of paper product produced.

The paper industry needs a consistent continuous supply of water. Mills operate production streams on a 24-hour basis. There are different factors that affect the availability and quality of this water supply and may impact system resilience. These include:

- Increased drought risk due to climate change.
- Reduced water quality during droughts.
- Increased competition for water resources from other sectors and PWS requirements.

6.2.1.2 Demand for pulp material

The other key value input for the paper system is the raw pulp material, this mainly comes from virgin wood pulp or recycled fibres. Most pulp material comes from recycled fibres. Of these

[68] CPI_PAP_WaterAbstraction_2019.xlsxutline

fibres they are mainly source from recycled packaging and household recycled waste as part of municipal collections. It is estimated that 75% of all pulp is sourced from recycled fibres, with some mills utilising 100% recycled fibres, and the remaining using virgin pulp materials. The general trend is towards increased use of recycled fibres rather than virgin pulp material from forestry, although the mix does require some virgin pulp rather than 100% recycled material

6.2.2 Attitudes to resilience

Whilst paper production peaked in 2000 at 6.6 million tonnes and produced 3.6 million tonnes in 2016, there has been significant growth in a number of areas.

The Covid-19 pandemic saw a rise in packaging from home deliveries thereby increasing demand. Office paper used declined. Health care and packaging continue to grow during the pandemic. Print media and commercial paper production have declined. It is not clear whether these trends will continue after the pandemic.

Additional risks include:

- Increased scarcity of water resources particularly during drought conditions.
- Fibre quality (plastic contamination) and associated waste processing costs
- Fibre volume availability
- Carbon tax and EUTS (Climate change mitigation policy/regulation).

The way these risks are viewed and managed by different actors within the paper system is considered in this section.

6.2.2.1 Water scarcity risk

The paper sector is tackling the water sector risk by ensuring sufficient resilience in the supply demand balance. Control of adequate consistent, continuous supplies is a key strategy. Increased treatment and use of recycled water addresses supply side resilience. The potential use of reverse osmosis has been identified as a measure for increasing the quality of wastewater to a point where it could be re-used directly, but this approach is costly, with high energy use. For now, water resource constraints are not severe enough to make this step necessary.

6.2.3 Potential options to increase paper sector resilience

The paper sector faces multiple challenges, primarily:

- Climate change impacting water availability
- Quality and quantity challenges with raw materials for pulping and paper production
- Drive to decarbonise power and heat demand

The paper sector adopts a risk control strategy with respect to water. This is evident in the focus on engineering technology to driving efficiencies, improve availability of water resources and longer-term options to implement advanced treatment processes to recycle more water.

There is potential to enhance collaboration and to harness economic opportunities such as trading water with the PWS (and other sectors) when excess is available or where additional water supply is required. The current attitude to this does not seem favourable for a number of reasons, these include:

- There is a lack of certainty that under a trading scenario that water will be available when needed and this could decrease the resilience of the sector. This uncertainty would be problematic for the water sector due to the need for a constant and reliable supply.
- The current legislative approach to abstraction licensing constrains how the water abstracted can be used and prevents the sector from exporting surplus water in its licence for profit.

Going forward if a more entrepreneurial approach were to be taken, involving water trading, these barriers would need to be resolved. This would likely require a strongly regulated or contracted system to trading that would provide confidence to all stakeholders that water would be available in the quantities and qualities required at any given time. The paper sector is concerned about the risks to a secure resource in the event of an increased focus on water trading.

Overall, the sector faces many challenges and its current approach to look to manage and control risks individually are justifiable. However, there are potentially opportunities to look to develop alternative approaches, particularly for the water scarcity challenge, to manage some key risks that may require more reliance, engagement, and trust in external sectors to deliver longer term resilience in a more cost effective way.

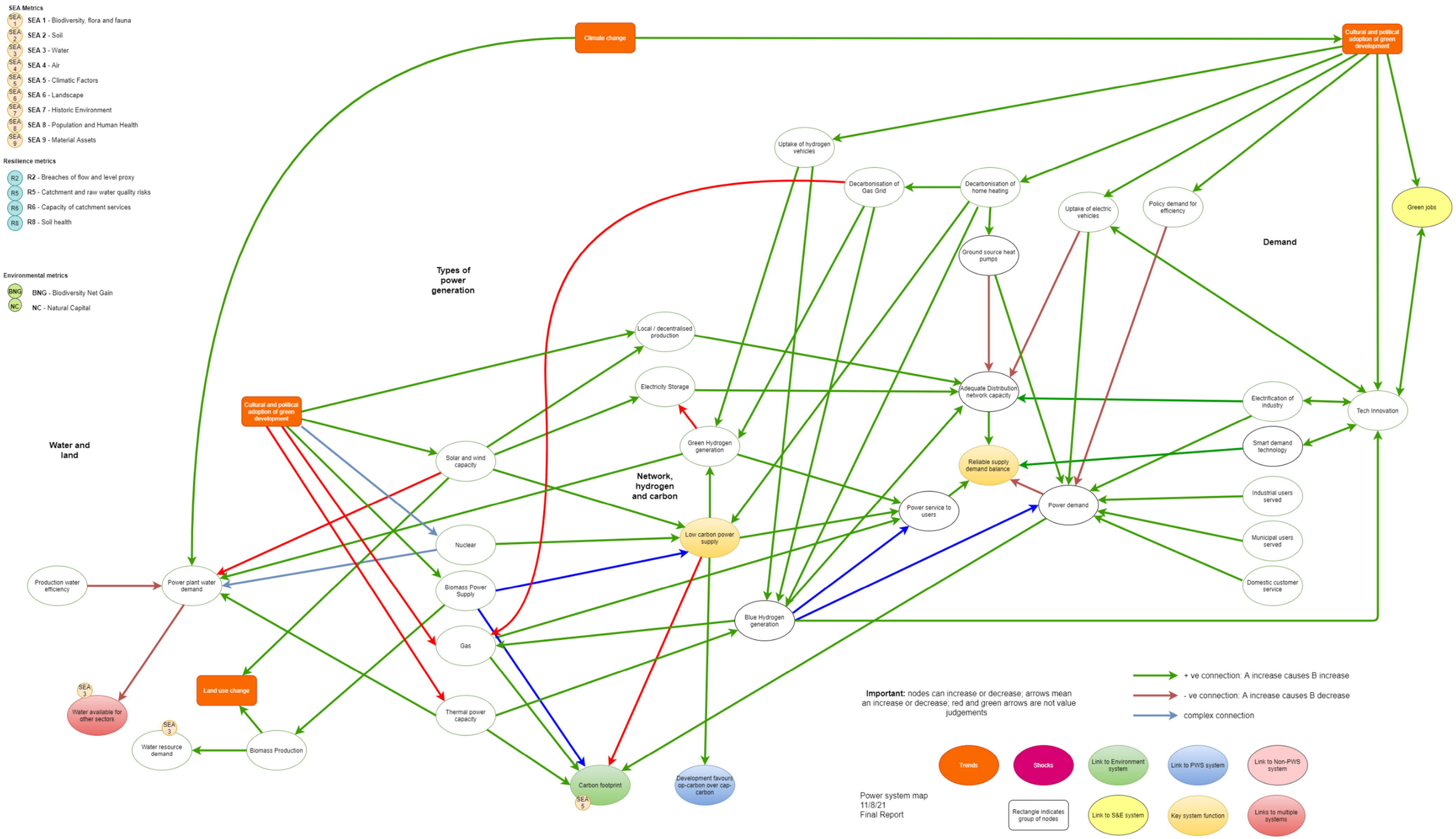
6.3 Power

The power sector is undergoing a major transformation to decarbonise. This transition is creating new water demands and new opportunities to interface with other water using industries.

6.3.1 The power system

The power system is shown on Figure 6.11. To reflect the importance of the shift to carbon net zero in the power sector, two key system functions are identified: *reliable supply demand balance* and *low carbon power supply. Reliable supply demand balance* is influenced by *power demand, adequate distribution network capacity* and *power service to users.* On the left side of the diagram the system map shows the different types of power generation, the role of hydrogen and the carbon footprint. On the far left of the diagram, *power plant water demand* is driven by the mix of different power generation technologies. At the top of the diagram different behavioural factors such as the uptake of electric or hydrogen vehicles, decarbonisation of the gas grid and home heating are shown to influence the supply network and power demand. These changes are driven by *cultural and political adoption of green development.*

Figure 6.11: The power system



6.3.2 Changes and trends

The power sector is undergoing a major transformation to net zero by 2050 in the context of rising demand. This is creating a market driven phase out of many current generation assets – such as coal powered power stations all due to close by 2025. Markets are changing and new assets are being developed.

The detail of the policy framework that will provide the market backdrop to this is unclear. The decarbonisation of transport and heating leading to increased electrical demand are two important high-level influences.

Renewable sources are undergoing a marked increase in capacity, driving investment in network connectivity, storage, and demand management to address the challenges associated with intermit supplies. Load factors on combined cycle gas turbine plants are likely to fall although this will mean they retain significance as firm power on demand. The duration of electricity storage is short term only – there is no apparent solution for seasonal electricity storage in the UK.

The carbon net zero target is driving new technologies for carbon capture and storage (CCS) such as hydrogen production, methane blending and hydrogen combustion. These will all affect the geography of the market, further driving infrastructure demand with implications for water supplies.

The magnitude of these changes is considerable. Investments in new power facilities are typically in the range of £1-3 Billion. This highlights two important features of the changes in the power sector: firstly, that the regulatory context is essential to determining what type of technology will attract the capital required to meet the challenge. Secondly, that the investments will not be made in the context of unacceptable or poorly defined water risks.

6.3.3 Implications for water use

There will be a continuing role for thermal (combustion) power plant in delivering resilient, affordable, and efficient electricity supply in combination with other generation sources renewables, nuclear, interconnectors etc). This implies a continuing economic role for use of water and water rights associated with sites hosting current assets and with potential to host future power market facing assets. Water rights are foundational for investment in the power sector. Power stations are water-dependent long-life nationally significant infrastructure assets.

It is important to recognise and distinguish the economic use of a water right from 'water use' (as interpreted as physical as abstraction of water at a given time). Water rights underpin the participation of water-dependent assets in power-facing markets years ahead (both capacity and electricity). Just because water is not abstracted under a particular water right at a particular time, that does not mean the water right is not used.

There has been a sector-wide trend in the reduction of freshwater consumptive use since 2010 that could level-off or continue to decline over the next five years. Thereafter a dramatic increase in sector demand for water is expected to underpin and supply new assets (CCS, hydrogen production etc). As yet there is a high degree of uncertainty over the timing and location of these demands[69].

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[69] See Gasparino & Edwards 2020 and successor publications (Gasparino & Edwards (2021), Moores (2021)) which will update to FES 2020 and CCC20 net zero scenarios.

As a result of the overall trends, each asset is facing changing operational modes (more start/stops & part loading). The introduction of new technologies, such as CCS cooling, is influencing internal energy consumption and influencing water-using processes. Water demands are increasing and site water efficiency (m^3/MWh) metrics are expected to decrease when compared with current and historic levels. This would not indicate worsening asset/operator performance[70]. Such metrics are useful for information but would be inappropriate in isolation as compliance targets. Each asset has a unique 'water story'.

For plant not located on the coast, the primary raw water source is direct abstraction from rivers and to a smaller extent boreholes. The scale of requirement for cooling water precludes the use of PWS for cooling on a cost basis. Some smaller plants have used sewage treatment works effluent for cooling.

Smaller volume use for steam cycle make up may come from the PWS (potable or raw) or private alternatives depending on cost, reliability, and quality considerations. The choice is typically made at project design stage and rarely changes since the very high-quality water treatment plant is designed for a very specific water quality 'envelope'.

Some plants have a backup supply for low volume high quality water be interrupted (either the PWS backed up by borehole or vice versa) though many do not, relying for a few days or weeks on site storage of suitable water.

6.3.4 Industry assumptions around drought planning

River abstraction plants are typically exposed to low flow risks not just drought. Risk often represented as Hands-off-flows/Hands-off-levels (HOF/HOL). In low flows, lowland river flow frequently contains a significant proportion of sewage treatment plant effluent constituting indirect water re-use in EU terminology. Power plants therefore rely on these flows and planning of future flows factors in these flows at historic quantities. A concern to the power sector exists over whether such flows would be re-directed (e.g. for transfers or direct re-use).

Water quality is a potential risk to operation in the context of drought or extended low flows. Decisions on operation would be made at the plant level if risks such as algal growth in eutrophic low flows emerge.

A concern exists over the EA management of river levels to maintain environmental and navigation objectives. The sector is keen to maintain engagement in river basin management to voice concerns over the risks to power supplies. They see inter-sector communication and coordination on water management as important – such as receiving prior information when changes are made that would affect water quality (such as switch from groundwater to surface water sourcing in the PWS network). Most plants have ability to withstand high quality water supply interruption of a few days or weeks. In some cases, additional water treatment and/ or groundwater blending can be used to mitigate water quality shocks. Sites have provision for sanitary requirements if the PWS is interrupted.

In a previous abstraction reform initiative Energy UK raised the possibility that water resource planning should presume that power sector HOF/HOL would be relaxed in a power system stress event. The interviewees report that this appeared to be received sympathetically but the initiative faded without resolution of this issue. The priority given to strict enforcement of HOF/HOL is perceived as a significant boundary on the resilience of electrical supplies. This may be the limiting constraint in periods at which water and power supplies were stressed. The

[70] See eg Booth & Edwards 2019

interviewees suggested that there may be societal benefits in revisiting the question around establishing protocols for short term relaxations of HoF constraints for major shock events.

6.3.5 Potential options for power sector resilience

Restrictions on consumptive use will impact operation at tower-cooled plants. A small reduction in gross abstraction permitted could be tolerated by many plants (tower-cooled and other) if some permit relaxation were given on discharges when required (in relation to chemical concentrations or temperature).

Smart and ramped HOFs are preferable to cliff edge HOFs since power generation companies would be trading changing plant position in fuel, energy, capacity, and grid service markets as views on drought/low flow change. Clarity on how HOF/HOL provisions would be imposed and relaxed in practice is important to the efficient management of these positions. Energy UK would expect to be engaged with EA on development of EA's digital platform which may offer more streamlining of this compared with historical practice which has varied significantly between EA areas.

Power generators would expect to liaise with water companies and the EA to mitigate mutual risks depending on geographic extent. Energy UK is represented on the EA's National Drought Group to provide and to understand a strategic overview.

6.3.5.1 Water efficiency

All power plant would be expected to have optimised site water use. This is not water use minimisation but rather optimisation in a multi-media BAT setting including consideration of materials choices, emissions, and chemical use etc.

The limiting constraint on efficiency is likely to be water consumption in cooling system which is constrained by the fundamental thermodynamics of evaporative cooling systems, allowing no further optimisation. Retrofitting dry-cooling is unlikely to be commercially feasible as a long-term option for an existing plant and not technically feasible as a short-term drought response.

6.3.5.2 Shared development of storage

Power Generator companies would be open to any such opportunity which enabled risk mitigation or opportunity in a cost-effective way. New storage facilities should be managed by system operators or potentially by water company non-regulated business to avoid locking resources into one sector for managing long duration risk at the expense of others who may be able to extract benefit from stored water over shorter time-scales. It may be helpful to review how PWS statutory duty considerations could be regarded in relation to management of reservoirs especially in low flow conditions outside of drought.

6.3.5.3 Water sharing and trading

The power sector is actively promoting dynamic water sharing as a proposition. A power plant could well act as source of supply for other sectors in drought conditions, subject to suitable commercial terms, when its power market position can be managed cost effectively through making use of the power sector market arrangements.

Power generators consider trading as an unreliable source of additional flows during periods of stress due to the fact that all water users are likely to be looking for more resource, rather than looking to trade excess. Their experience is that water companies are unwilling to sell reservoir water.

It is thought unlikely that development of a major new water-dependent power sector asset would take place without control of a water right of sufficient capacity and reliability i.e. owner/operator would not be willing to expose the asset to open water market risk ,even if such markets were to exist in relevant rivers.

6.4 Canals

The Canal and River Trust is a charity with responsibilities to maintain a network of some 2000 miles of assets that are around 200 years old.[71] The system relies on 53 hydrological units which are fed by groundwater or a combination of groundwater, reservoirs and other feeders or are navigable rivers as shown on Figure 6.12. The system uses 1300 Ml/d across England and Wales, predominantly in the Midlands and North of England. Public water supplies are not used for canals. In addition to the Canal and River Trust, there are other canal operators and restorers in the south east such as the Basingstoke Canal Authority and the Wey and Arun Canal Trust.

The canals have several sometimes-competing groups of users and stakeholders. A thriving canal system enables them to co-exist in mutually beneficial ways. Boating and fishing are potentially competing uses andboth produce revenues important to the overall operation of the system. Walkers and cyclists, who use the tow path, support businesses along the canal that also benefit boating and fishing communities, but do not provide revenues to canal operators directly. Safety for all users is a priority in the management of canals.

The Canal and River Trust use the term navigational drought to refer to the point at which navigation is constrained by water resources. They have an aspirational level of service of 1 in 20 years. This provides a framework for decision making around investment planning and potential restoration and development projects.[72]

6.4.1 Changes risks and trends

The canal system map is shown on Figure 6.13. The key node on the map is at the centre, *Canal network functions well*, and from this on the right the key amenity benefits are shown; *pedestrian, boating, cycling amenities* and *fishing.* Social and economic benefits of these amenities in the form of jobs, mental health, health, and social and relationship capital are indicated. There is a feedback loop from *social and relationship capital* through *participation in third sector groups* to the nodes representing the organisation, operation, and maintenance of the network on the lower left part of the map, and from there back to the key node at the centre. At the top of the map environmental benefits and the non-amenity related social and economic benefits such as *housing* are shown.

The Canal and River Trust have identified climate change; funding constraints; changing environmental legislation (likely reduction in abstraction volumes) and increased network usage as pressures affecting the canal system. On the map policy change represents both environmental legislation and the potential change in status of the Canal and River Trust.

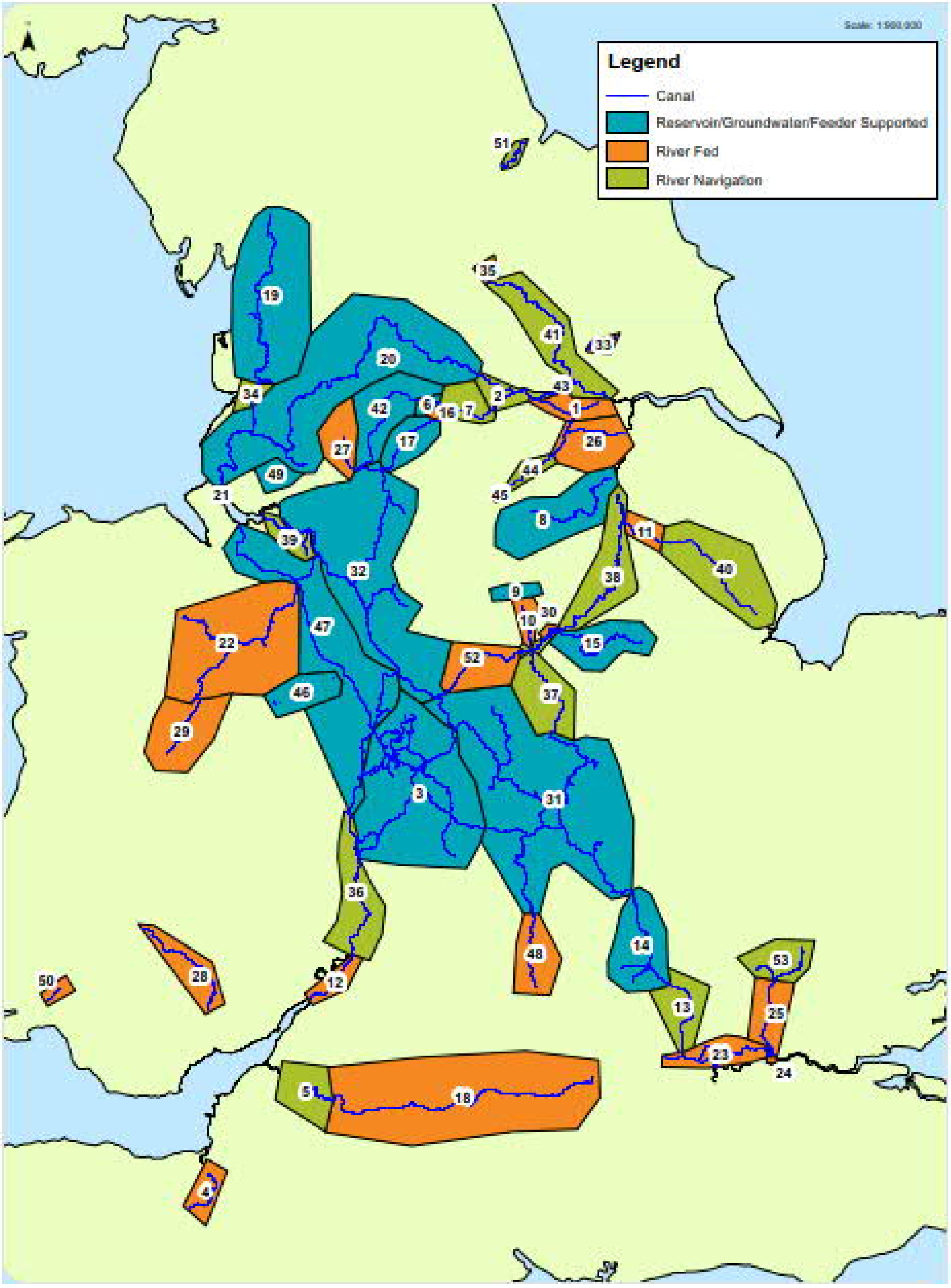
Climate change is a trend driving both flood and drought shocks. There are a large number of uncontrolled feeds into the canal system making flooding a problem. Drought has additional impacts over and above the need to close canals to navigation. Low water levels are problematic for boats. Low water levels may have environmental impacts such as fish kills caused by the low dissolved oxygen in the water, or long-term structural impacts if bank stability

[71] There are some canals in England and Wales that are not under Canal and River Trust management.

[72] https://canalrivertrust.org.uk/refresh/media/thumbnail/24335-water-resources-strategy.pdf

problems or soil shrinkage issues arise. The ecological problems with canal closure and low water levels may be significant. Some canals are designated sites e.g. SSSIs.

Figure 6.12: Hydrological units and water sources for canals and navigable rivers



The interviewees for this report described the policy change risk as relating to the status and funding of the Trust. This potential threat is being met with initiatives that demonstrate the plurality of benefits derived from the canal system such as well-being and is driving diversification of funding streams that the Trust draws on. Non-consumptive licensing of water to other uses such as heating and cooling water is an example of the type of new funding stream that the Trust is exploring. The next 15-year review of their status as a trust is due in 2027.[73]

Changes in environmental legislation are perceived as tightening restrictions on abstractions and the availability of water resources. Increased boating demands has potential to exacerbate tensions among different users and increase water demands. There is a demand for more marinas. Demand for residential moorings is also growing. The Trust models future growth scenarios as 0%, 1% and 2% annual growth to 2050.

The pandemic caused the Trust to restrict activities to essential work only, with 600 members of staff on furlough.

In a worsening drought context, the following steps would be taken:

a. More monitoring
b. More communications with bankside staff
c. Restrictions on hours of lock usage
d. Close the canal
e. Thereafter maintain the water level as far as possible to avoid longer term ecological and structural damage.

6.4.2 Potential options for canal resilience

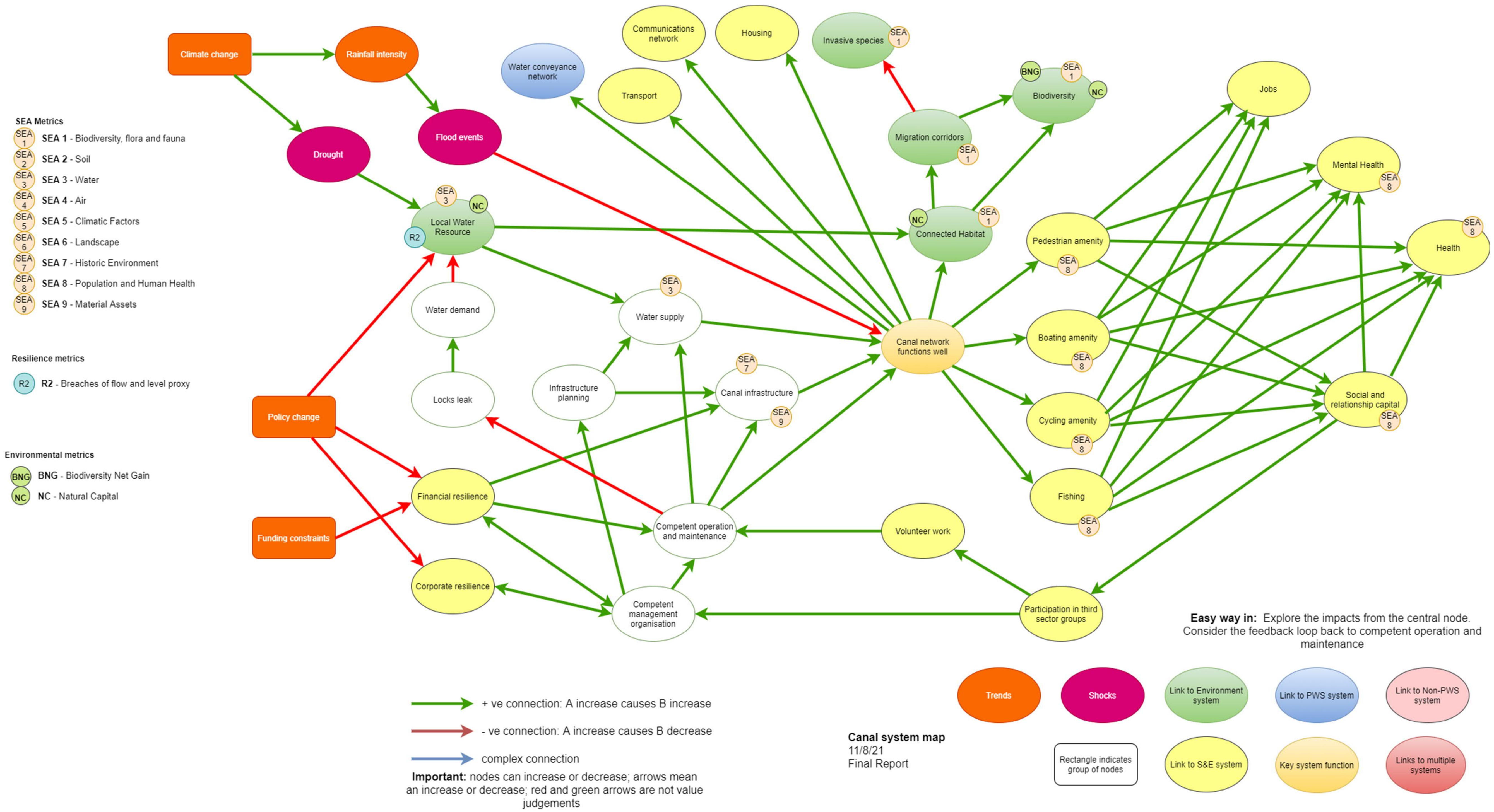
Enhancing financial resilience is a priority for the Canal and River Trust. Water may be traded on a take and return (non-consumptive) basis. This could be combined with marina and housing developments. Heating, cooling, and fire-fighting demands could take advantage of canal water. Commercial use such as data centres, printing or other industrial are markets for this type of water trade. The Trust has approximately 350 customers of this type.

Larger scale trades and transfers have been proposed such as conveying treated effluent from the Midlands to London in the Grand Union canal.

Leakage management in locks is an important water saving strategy.

[73] 42580-annual-report-and-accounts-2019-20.pdf (canalrivertrust.org.uk)

Figure 6.13 The canal system



6.5 Golf

Golf has the third largest multi-sector water demand in the South East after agriculture and paper. Irrigation of golf courses are not a priority in times of water stress when compared with critical services or domestic use. They are, however, an early contact point at which a relatively affluent public is likely to meet a tangible impact of water stress. As such they have relevance relating to drought awareness and cultural attitudes towards water saving.

Golf courses come under stress during periods of hot dry weather and put demand on public water supplies when the network is already under stress. Therefore, the challenge they raise for water companies is the management of peak demands rather than an overall water resource use.

There are actions that golf clubs can take to address their water demands through the provision of reservoirs, smart control of irrigation and improving soil health. In many cases, the key element will be for cultural change amongst players to tolerate a deterioration in the high qualities conventionally demanded for fairways and greens. Brown patches may become inevitable on fairways. Worm spoils associated with improved soil health may also become a feature of good golf clubs. This need for cultural change draws attention to the fact that customer behaviour is part of system resilience in multi-sector systems as in the PWS system.

A system map of golf is shown on Figure 6.14. The central node is '*Golf played'* and links to a number of social and economic benefits to the right of the map. The drivers for a growing demand for golf are on the lower right side of the map. At the top of the map, the process of cultural change that creates the conditions for the adoption of environmental management of golf courses are mapped. These link to the environmental factors around golf course management on the left of the map.

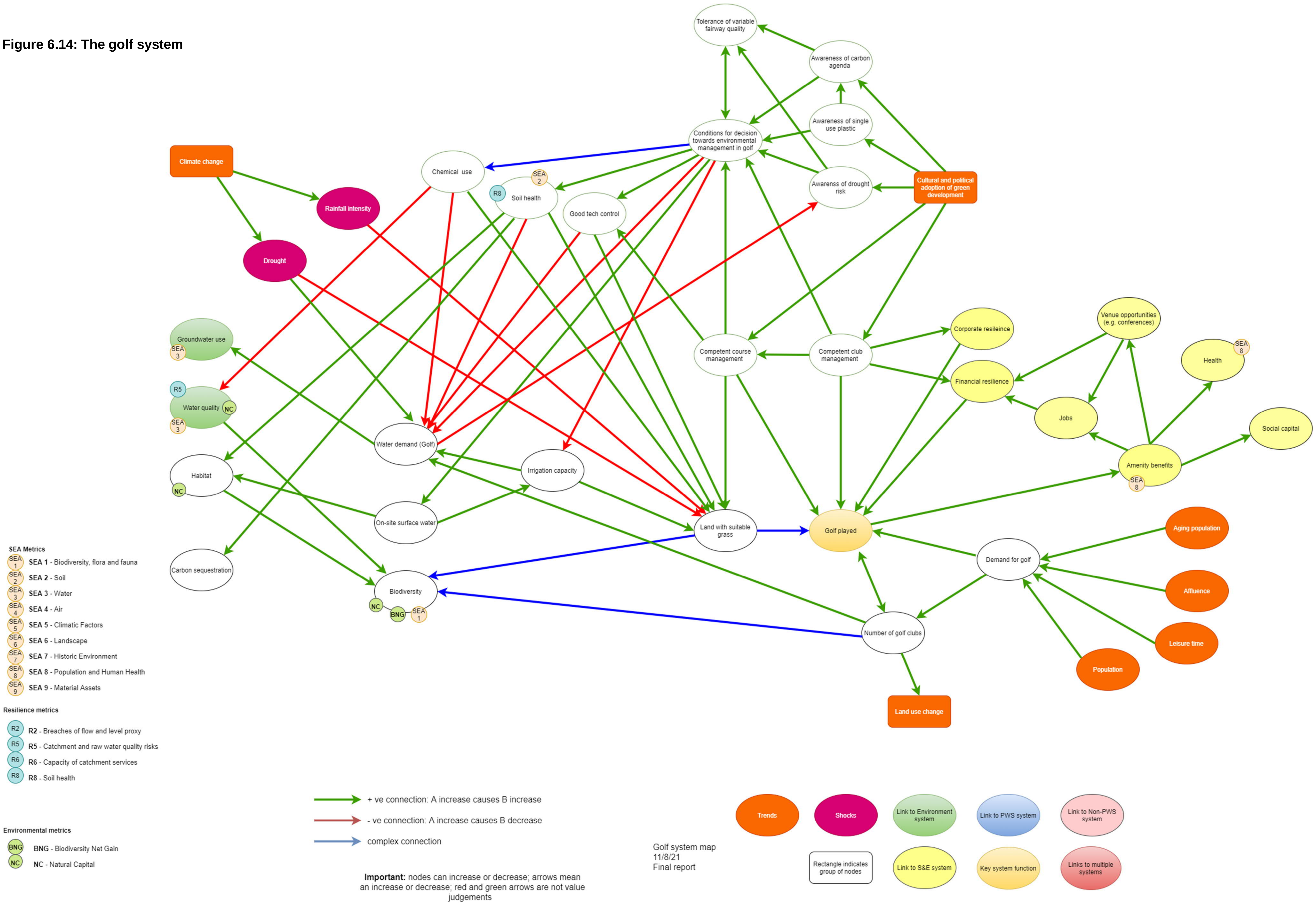
6.5.1 Changes, risks, and trends affecting the industry

There is an emerging awareness about the need for action on water management and drought resilience in the golf sector. The awareness is developing for four reasons, firstly as a spill-over from other environmental issues arising in golf; secondly as a result of dialogue and change within the industry; thirdly as water companies take action and finally as a result of awareness of the genuine threat to courses that drought poses. Awareness of environmental constraints on golf is occurring as one issue has a 'contagion' effect on other issues: awareness of the problems of single use plastic has led to the provision of reusable water bottles at some major events. This has prompted debate about other environmental issues.

A major step forward in driving cultural change in the sector occurred in July 2021 with the development of the Leisure Operator Water Charter. The charter raises awareness of water stress and commits leisure operators to work with water companies, regional planning groups and the Environment Agency to find solutions to the water challenges that the sector faces. Signatories to the charter commit to preparing water resilience strategies for their facilities by January 2022.[74]

[74] https://forms.office.com/pages/responsepage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAANAAb3w5UtUQVZDMFJZWVNUSzhLMlI3RDhWMjQyMkI2Mi4u

Figure 6.14: The golf system



A constraint to the uptake of good practice is often poor communication and conflicting incentive structures in the two branches of golf club management. The course manager will have a higher awareness of environmental risks and resilience strategies for the course than the club manager. The career path of the club manager involves bringing in results in a relatively short time frame, whereas the course manager needs to avoid difficulties impinging on the game over a longer term. Club managers have shorter periods of tenure and higher turnover than course managers. This undermines the ability of the sector to address long term sustainability issues.

There are examples where sustainability initiatives are being addressed, including the development of small reservoirs for courses, improved irrigation technology and improving soil health. Advocacy and advice on environmental aspects of golf is provided by the Golf Environment Organisation which advocates for:

- Fostering nature.
- Conserving resources.
- Strengthening community.
- Taking climate action.

In the UK, there have not been cases where drought has had a major impact on golf course although there are cases where this risk has been heightened. Water companies have communicated with golf clubs during period of peak stress. The impact of these communications has not been analysed. Examples of water company action that have triggered responses from clubs include changes to billing to reflect the impact of the peak demands rather than average water use.

Overall, there is a nascent awareness of environmental issues, but the interviewee for this project suggested that this has not yet been translated into substantive action in the industry. Other changes include the fact that golf is facing an aging population and a dip in funding due to the pandemic. This has delayed action on environmental issues.

6.5.2 Potential responses

Some 70% of water for irrigation comes from the PWS. The PWS is economically attractive because of the relatively small scale of the demand. The PWS is perceived to be cheaper than developing and maintaining private supplies. Potential interventions come in three categories: technology; environmental solutions and cultural change. Technological approaches to improving drought resilience include:

- “swishing” greens to improve infiltration
- Applying chemicals to greens to improve infiltration and soil water retention (surfactants used to prevent water budding on the leaf).
- Smart irrigation technology.

Environmental solutions have significant potential. As golf clubs engage with the environmental agenda then opportunities for developing schemes with significant co-benefits arise. For example:

- Reservoirs that store winter rains for summer irrigation and bring co-benefits for amenity use, biodiversity, and flood control.
- Soil health measures that improve drought resilience of courses and sequester carbon and improve biodiversity.

- The environmental benefits of environmentally planned and managed golf courses could be developed alongside new housing developments. Flooding, amenity and carbon sequestration and off-setting could be addressed together in new developments.

The major enabler of these changes would be cultural change in the golf sector. Initiatives include:

- Ongoing support to studies and profiling of results in golf clubs, conferences, and competitions.
- Pilot and demonstration projects.
- Advocacy and advice on the sources of environmental finance that could be relevant to golf courses.

6.6 Quarries

The mineral sector in the South East of England is made of quarries rather than mines and is focussed on serving the construction industry with building materials. Sand, gravel, clay and chalk are quarried. The time frames over which the industry operates are classified as medium term by the Ministry of Housing, Communities and Local Government. The industry does not have a vulnerability to drought because the principal water challenge is dewatering quarries – so drought is a benefit in this regard. Other water demands such as dust suppression are generally met from the dewatering process. There is a need, however, to ensure that polluted water is not returned to the environment after use. Water discharges are permitted with conditions usually for Total Suspended Solids (TSS) only. In most cases TSS can be controlled through the use of silt lagoons and similar measures.

The PWS is not used in quarries other than for sanitary/office use. The industry has a high degree of stability – impacts of Brexit and the pandemic do not appear to have created significant shocks to the minerals sector in the South East. Disused quarries provide capacity for water storage. The design of post quarry landforms considers factors such as groundwater and surface water management, safety and habitat creation. The quarry system map is shown on Figure 6.15.

6.6.1 Changes, risks, and trends affecting the industry

With a long planning process and an absence of significant short-term water related shocks, the principal challenge facing the industry is the long-term squeeze on land and resources in the South East, mediated to the industry via the planning process. Developing planning permission is a long-term exercise – taking up to 20 years before a quarry is operational. Land banks for mineral development exist in current development plans.

The squeeze on resources is expected to come as conditions for abstraction licences tighten. Quarrying is not a consumptive demand, but development of a new site does influence groundwater and surface water flow. Standards for emissions are increasing so dust suppression is increasing aided by technological improvements (finer sprays are more efficient). In remedial work on closed quarries, a focus on biodiversity is driving practice. Fewer closed quarries are being used for fisheries.

Currently some 85% of hard construction material is recycled and recycled as aggregate, a figure that is not likely to be increased.

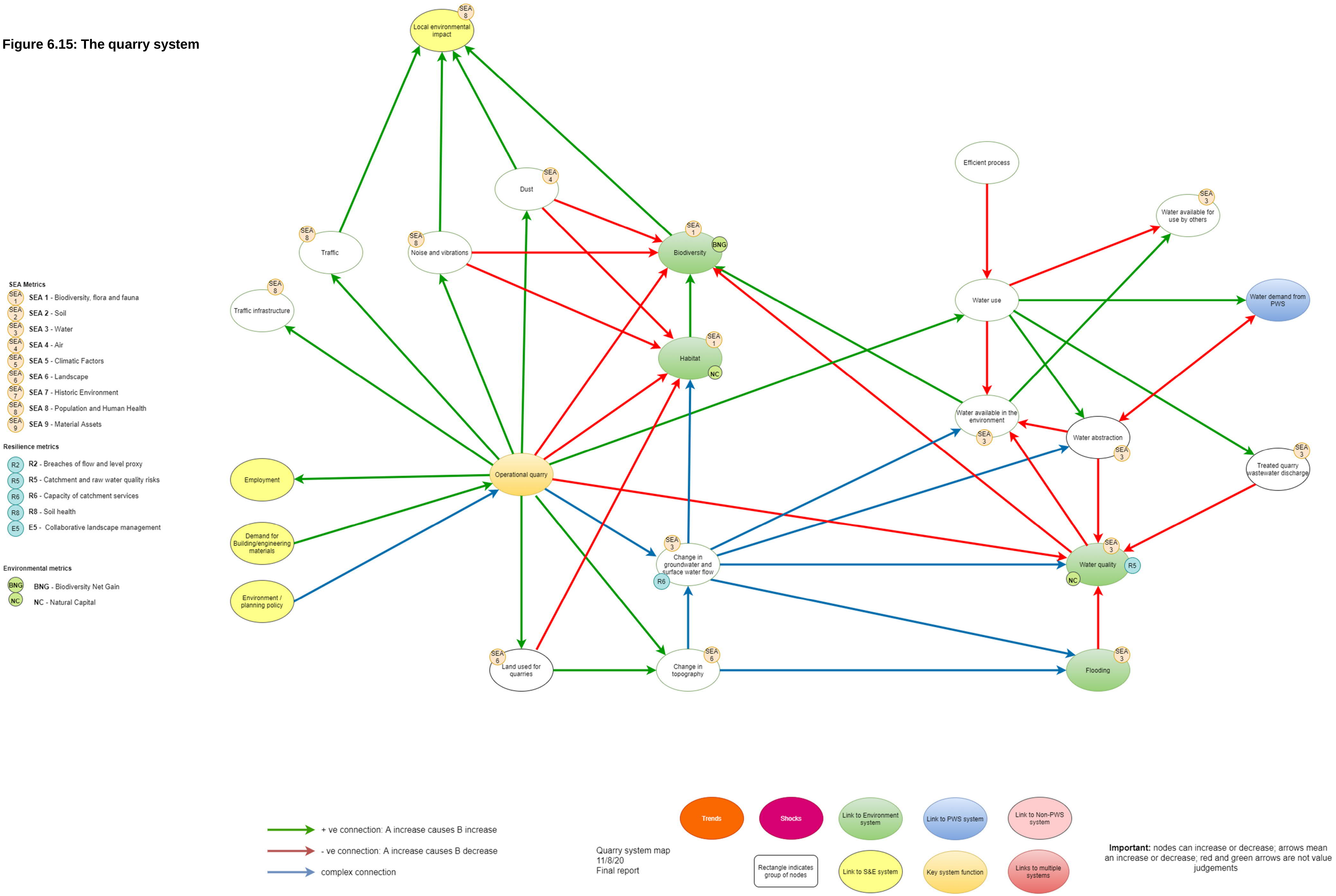
6.6.2 Potential options for quarry resilience

No significant work has been done on drought planning for quarries because quarries are not really affected by drought. The mineral sector interest in WRSE is to engage in the policy debate around abstraction licences as these are important for dewatering quarries.

There is potential for water from quarries to be used in other sectors, perhaps consumptive sectors like agriculture. Currently by returning water to the environment water is made available for indirect reuse. The complexity of licence arrangements is perceived as a barrier to more efficient forms of direct reuse.

Disused quarries do have potential as reservoirs and could be developed with multiple benefits including amenity and biodiversity.

Figure 6.15: The quarry system



7 The social and economic system

This section introduces approaches to the social and economic system, such as Public Value, social and relationship capital, Gross Value Added and some of the means by which these can be measured. A short introduction is provided to Ofwat's promotion of a social contract for the water sector. Then by means of a case study we consider approaches to understanding the social value contribution of access to water in an urban setting. The purpose of this Section is to introduce concepts relevant to applying social value in the evaluation of options for WRSE.

7.1 Value in social and economic systems

Perception and understanding of the value contributed by public and private sector organisations alike have expanded over the past two decades. They are no longer limited to the narrow conceptions of value characterised by the balance of financial benefit and cost, or the outputs delivered by infrastructure assets (whether it be kilowatt hours generated, cubic metres supplied, or procedures undertaken). In particular, the prominence of social value, and different ways of conceiving and measuring it has risen in the UK in recent years, particularly since the introduction of the Public Services (Social Value) Act 2012 ("the Social Value Act").[75] The Social Value Act requires relevant public bodies to consider how they can deliver social, economic and environmental benefits and has catalysed a response from both the public and private sector to consider how greater community benefit, and social value, can be realised from their activities. The form that this takes in practice varies, and organisations, both in the public and private sector, have often taken different paths in their interpretation of, and approach towards, 'social'. This section discusses some of the different ways in which social and economic systems can be considered and measured.

7.1.1 Six capitals approach – social and relationship capital

The Six Capitals framework was discussed in Section 2 comprising six categories of value that can be increased, decreased or transformed by the outputs and activities of an organisation.[76]

Traditional business decision making tends to focus on financial and manufactured capital as these are tangible, quantifiable and monetizable assets. However, value creation is increasingly looking at the more intangible capitals such as social and relationship and intellectual.

Social and relationship capital is valuable to individuals, organisations, and communities. For individuals, this form of capital allows them to access information, enhances their skills, and provides job opportunities. For organisations, social capital can add value in terms of efficiency, market share and performance. With communities, social capital can improve community health and sanitation, reduce crime rates, and encourage economic growth.[77]

The concept of social capital has been categorised according to three key dimensions:

- **Social networks and their structure:** the structure or pattern of personal and social networking relationships and connections people develop with one another. There is a focus

[75] Public Services (Social Value) Act 2012, Available at: http://www.legislation.gov.uk/ukpga/2012/3/enacted

[76] The capitals are: financial, manufactured, intellectual, human, social and relationship and natural

[77] Network for Business Sustainability (2014): 'Measuring and valuing social capital'. Available at: https://static1.squarespace.com/static/5d5156083138fd000193c11a/t/5d62101f45c94900018d0563/1566707797443/NBS-SA-Social-Capital-SR.pdf

on who an individual communicates with, how they reach them, and the frequency with which the individual shares information and resources with them.

- **Trust and reciprocity in relationships:** the kind of connections people develop with one another through a history of interactions. This looks at the quality of relationships and the resources that are shared during interactions.
- **Shared norms and values:** what people feel, and the values and perceptions individuals have of each other as they interact. It represents a shared goal and vision.[78]

Despite much work taking place around the six capitals, there is still uncertainty around how social capital can be measured reliably and consistently by organisations, to show the value that has been added.

According to the IIRC, quantitative indicators such as KPIs and monetised metrics can be important in demonstrating an organisation's use of the various capitals. However, it is not practicable to expect organisations to quantify all capitals, and this is not the purpose of the capitals approach. Measuring the effects of some capitals (including social) may in fact be best reported by narrative rather than by metrics.[79]

7.1.2 Public Value and Gross Value Added

Public Value has become one of the ways in which organisations, particularly in the public sector, define the way in which they contribute to society. It can be difficult for public sector organisations to assess their productivity or 'value', as traditional value measurements have focussed on the quantification of inputs (typically expenditure) and outputs (typically the services provided to the public), which are often hard to define and measure.

The Public Value Framework [80] offers a way of defining public sector productivity performance. It does so by defining everything that a public body should be doing to maximise the likelihood of delivering optimal value from the funding it receives. The main criteria that contribute to public value under the Framework are grouped into four sections, or pillars:

- **Pillar one: pursuing goals** focuses on what overarching objectives the public body is aiming to achieve and how it is monitoring the delivery of them.
- **Pillar two: managing inputs** tests the public body's basic financial management.
- **Pillar three: engaging citizens** and users highlights the need to convince taxpayers of the value being delivered by spending and importance of engaging service users.
- **Pillar four: developing system capacity** emphasises the long-term sustainability of the system and the importance of stewardship.[81]

Each pillar is then broken down into a set of further areas to consider (13 in total across the Framework). Within each of these areas to consider there are a series of headline questions (35 in total) designed to explore a specific element of departmental performance. Underneath each question there are then a series of prompts: these are designed to be a guide for the type of material that a good response to the question might cover.

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[78] Network for Business Sustainability (2014): 'Measuring and valuing social capital'. Available at: https://static1.squarespace.com/static/5d5156083138fd000193c11a/t/5d62101f45c94900018d0563/1566707797443/NBS-SA-Social-Capital-SR.pdf

[79] International Integrated Reported Council (IRC), (2013): 'Capitals: Background paper for <IR>'. Available at: https://integratedreporting.org/wp-content/uploads/2013/03/IR-Background-Paper-Capitals.pdf

[80] HM Treasury (2019), 'The Public Value Framework: with supplementary guidance'. Available at: Public Value Framework with supplementary guidance (publishing.service.gov.uk)

[81] HM Treasury (2019), 'The Public Value Framework: with supplementary guidance'. Available at: Public Value Framework with supplementary guidance (publishing.service.gov.uk)

The framework can be used in a variety of ways, including establishing understanding of a policy or programme's performance, informing future policy design, or considering how different parts of an organisation currently fit together.[82]

Gross Value Added (GVA) is a more tightly defined economic measure than public value. The Office of National Statistics defines GVA as is the value generated by any unit engaged in the production of goods and services.[83] As such measuring the contribution of an option or portfolio of options to GVA is more focussed on issues related to job creation and economic activity, than the broader perspective of public value.

7.1.3 The Sustainable Development Goals, and Environmental, Social and Governance measurement

The Sustainable Development Goals (SDGs) were adopted in 2015 as an urgent call for social, economic and environmental action, specifically to improve health and education, reduce inequality and spur economic growth, all while tackling climate change and preserving the environment.[84] The SDGs are increasingly being viewed as a key framework though which governments can drive the delivery of affirmative environmental and social action across all high-, middle- and low-income countries.

Drawing on the SDGs and other movements in how value is created and measured, a range of additional frameworks have begun to emerge, aimed specifically at measuring 'value' in terms that are not just financial or monetary.

In particular, the pace of evolution in several emerging systems for understanding and reporting on crosscutting environmental, economic, and social standards is quickening. For instance, Environmental, Social and Corporate Governance (ESG) benchmarking is used in capital markets and by investors to understand corporate behaviour regarding standards such as resource use, health and safety, community engagement, social safeguarding, and ethical standards. ESG benchmarking can be used as a key measure in determining the future financial performance of organisations. ESG frameworks can be built on a sector, asset, and territory basis, often taking into account multiple elements, including social and natural capital, governance, and business models.

7.1.4 Benefits framework considerations

Value can also be conceived in terms of benefits and beneficiaries. Benefits and investment appraisal frameworks are sometimes used by organisations to inform investment decisions and drive investment effectively to deliver intended objectives/outcomes while at the same time achieving value for money. These have been applied in a range of sectors in the UK, including transport and housing, as well as the water industry.

Best practice suggests that a robust evidence-based benefits framework considers a wide range of economic, environmental, and social factors when evaluating strategies, programmes, and projects. In the water sector, the Canal and River Trust in England and Wales and Scottish Canals in Scotland have developed methodologies to estimate and value the impacts of their networks and investments, including the consideration of economic, social and environmental goals.

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[82] HM Treasury (2019), 'The Public Value Framework: with supplementary guidance'. Available at: Public Value Framework with supplementary guidance (publishing.service.gov.uk)

[83] Gross Value Added (GVA) - Office for National Statistics (ons.gov.uk)

[84] UN Department of Economic and Social Affairs, 'the 17 Goals', Available at: THE 17 GOALS | Sustainable Development (un.org)

The benefit frameworks developed by water companies often include both quantitative and qualitative benefits and use a range of metrics to capture the benefits of, in this case, the canal network, and assess social benefits such as social capital, wellbeing, heritage value as well as health and education.

7.2 Value creation in the water sector

The supply of safe and reliable water is essential for every aspect of life, and as such the water sector has a critical role in society. An ineffective or unaffordable water market can have adverse social consequences. Because of this, and their close integration into the communities they serve, water companies have a unique potential to deliver social benefits in their areas of service coverage.

In recent years, water companies have been faced with several challenges and public trust in the water sector has been declining. The Consumer Council for Water's 2019 'Water Matters' report showed that customer satisfaction with water and sewerage companies has declined for the fourth year running[85], driven by value for money and affordability concerns. Trust in water companies has not been helped by recent criticism; for example, in 2018 the EA called water companies' efforts to protect the environment 'simply unacceptable', with nearly every major company failing to meet expectations after serious pollution incidents increased.[86]

Driven by Ofwat, the water sector has set out a programme of reform to rebuild public trust. Critical to this is for water companies to demonstrate how they are and will continue to deliver greater public value, delivering more for customers, society, and the environment.

While there is no comprehensive analysis of how UK water companies report on their public value, and how if at all, they embed it within their culture, some good practice examples exist and are discussed in more detail in the next sections.

7.2.1 The social contract

In recent years, it has become clear that the reliable and safe supply of drinking water and wastewater services at a reasonable price is no longer sufficient from a water customer's perspective. In 2018, Rachel Fletcher, CEO of Ofwat, recognised that customers are taking a greater interest in where money is being invested, and want more information and accountability of water companies' contribution to society while also protecting the environment.[87]

From this, the idea of a 'social contract' defined as 'a circular arrangement between service providers on the one hand and customers or a community on the other'[88] has emerged. Rachel Fletcher of Ofwat defined the key elements of the Social Contract as the following:

- The company is doing the basics right based on deep understanding and feedback from the customers it serves.
- The company examines its own corporate behaviours to ensure that these withstand scrutiny in all respects. The company upholds the highest levels of corporate governance.

[85] Consumer Council for Water (2019) 'Water Matters Highlights Report 2018/19'. Available at: https://www.ccwater.org.uk/wp-content/uploads/2019/07/Water-Matters-Highlights-Report.pdf

[86] Utility Week (2019), online article: 'Water sector criticised for 'unacceptable' performance last year'. Available at: https://utilityweek.co.uk/water-sector-criticised-unacceptable-performance-last-year/

[87] Fletcher, R. (2018) 'A "social contract" for the water sector.' Social Contract Summit, County Hall, Westminster, 6 November 2018, https://www.ofwat.gov.uk/wp-content/uploads/2018/11/Speech-from-Rachel-Fletcher-A-social-contract-for-the-water-sector.pdf

[88] INDEPEN, 2019 Social Contract Summit: Value for all, Tuesday 5 November 2019.

- The company has links into and an understanding of the community it serves, and it is looking to benefit or support that community (via procurement, employment, expenditure, and investment).
- The company doesn't limit itself to simple compliance with environmental regulations. It understands the impact it is having on the environment and is constantly looking for new ways to improve the ecosystem it is built on. [89]

The introduction of the 'social contract' has meant an increased focus on delivering for customers first and foremost, considering the wider impacts of the company, while also improving public value in all decision making. This has and will require a cultural change for many companies as well as increased partnership working within and beyond the sector. Section 8.2.1.1 below provides an example of Social Contract development in practice.

7.2.1.1 Example: Bristol Water Social Contract

Bristol Water included a social contract as a fundamental part of its business plan from 2020, making it the first company in the UK water industry to do so. The social contract will act as a framework to help the company have a positive impact on society and to provide assurance of how it delivers services that go beyond the basic business requirements of competitive markets, regulation, and corporate social responsibility. The social contract was developed over the course of a year through discussions with customers by means of local engagement groups, and within the industry.[90]

The aims of the social contract delivered by Bristol Water are as follows:[91]

- Delivery of wider societal benefits in a way that contributes to resolving key issues in society
- Framework for engaging with local communities to understand their needs and to assess where and how they can add social and economic value through their services.
- Transparent mechanisms through which customers and stakeholders influence decisions affecting local communities.
- Process that ensures board level decisions focus on wider societal impacts and benefits of their activities.
- Fair and transparent polices and ways of working which boost customer trust.
- Approach that promote innovation in response to social challenges.

Delivery of the contract will be overseen by the Bristol Water Challenge Panel, independent to the company. Community stakeholders, employees, and customers will also have a role in holding the company to account through engagement forums and judging the outcomes of community initiatives. There will be financial consequences related to customer cost if Bristol Water fail to perform on this contract.[92]

7.3 Reviewing the system map outcomes

There is evidence to suggest that there are strong links between the use and management of natural resources and social outcomes. As a case study of this type of analysis we consider social outcomes from blue and green infrastructure. Quality green and blue spaces that are accessible to all, especially in urban areas, can help to deliver positive social outcomes such as

[89] INDEPEN, 2019 Social Contract Summit: Value for all, Tuesday 5 November 2019.

[90] https://www.bristolwater.co.uk/bristol-water-publishes-the-water-industrys-first-social-contract

[91] Bristol Water (2019) 'Bristol Water for All: Our purpose and social contract to build trust beyond water', Available at: Bristol-Water-our-purpose-and-social-contract-to-build-trust-beyond-water.pdf

[92] Bristol Water (2019) 'Bristol Water for All: Our purpose and social contract to build trust beyond water', Available at: Bristol-Water-our-purpose-and-social-contract-to-build-trust-beyond-water.pdf

improved physical and mental health and well-being.[93] Conversely, poorly designed and maintained green and blue spaces can have significant negative impacts on communities, from poor access to services to concerns around safety (and perceptions thereof).[94] The potential link between natural resources and how they can deliver benefits (or, in turn, create challenges) for communities and the delivery of social outcomes, is briefly discussed below.

7.3.1 Defining the links between social outcomes and green and blue infrastructure

7.3.1.1 Physical health effects

Green and blue space can provide attractive and accessible ways of encouraging people to spend time outside and undertake physical activity, creating active, healthier, and more liveable communities.[95] Research also suggests that exposure and access to nature is as important as exercise or diet in terms of maintaining healthy lifestyles.[96]

This can impact on all parts of a community but can particularly affect certain groups. For example, access to green and blue space can be of particular benefit to the physical health of children and young people. Provision of and exposure to green and blue space can improve children's cognitive development and function[97] and encourage the uptake of physical activity, [98] which in turn can contribute to a reduction in childhood obesity (including predisposition).[99] This is particularly important as nearly a third of children aged between two and 15 in the UK are currently overweight or obese.[100] This impact is also likely to disproportionally benefit children living in deprived neighbourhoods, as childhood obesity rates are typically highest amongst those in deprived areas. According to the Department for Health and Social Care, children aged five from the poorest income groups in the UK are twice as likely to be obese compared to their most well-off counterparts, and children aged 11 are three times as likely to be obese.[101] Green and blue space has the potential not only to improve children's physical health in general but can also help to reduce health inequalities more widely.[102]

7.3.1.2 Well-being effects

Since the late 1980s, when the first research on nature and mental health emerged, it has become more widely accepted that spending time in green and blue space can reduce stress, restore thought processes, improve attention, initiate reflection, reduce mental fatigue and improve cognition.[103]

This can impact on all parts of a community, but can, again, have a positive differential effect on people with existing mental health conditions. The benefits of green space in improving mental

[93] Department for Health (2010): 'Healthy lives, healthy people: Our strategy for public health in England'; Joseph Rowntree Foundation (2007): 'The social value of public spaces'
[94] Burgess, J. Harrison, C.M. and Limb, M. (1998): 'People, parks and the urban green: A study of popular meanings and values for open spaces in the city'; Walker, G. (2012): 'Environmental justice: Concepts, evidence and politics'
[95] DfT (2016): 'Cycling and walking investment strategy'
[96] Pretty, J.N. Griffin, M. Sellens, M. and Pretty, C.J. (2003): 'Green exercise: Complementary roles of nature, exercise and diet in physical and emotional well-being and implications for public health policy'
[97] Dadvand, P. Nieuwenhuijsen, M.J. Esnaola, M. Forns, J. Basagana, X. Alvarezpedrerol, M. Rivas, I. Lopez-Vincente, M. De Castro Pascual, M. Su, J. Jerrett, M. Querol, X. and Sunyer, J. (2015): 'Green spaces and cognitive development in primary school children'
[98] Davidson K and Lawson C (2006): 'Do attributes of the physical environment influence children's level of physical activity?'
[99] WHO (2011): 'Health co-benefits of climate change mitigation: Transport sector'
[100] Department for Health and Social Care (2017): 'Childhood obesity: A plan for action'
[101] Department for Health and Social Care (2017): 'Childhood obesity: A plan for action'
[102] DfT (2016): 'Cycling and walking investment strategy; WHO (2019): 'Health and sustainable development'
[103] Hartig, T. Mang, M. Evans, G.W (1991): 'Restorative effects of natural environment experiences'; Hartig, T. Mitchell, R. De Vries, S. and Frumkin, H. (2014): 'Nature and health'; Herzog, T. Black, A.M. Fountaine, K.A. Knotts, D.J (1997): 'Reflective and attentional recovery as distinctive benefits of restorative environments'; Kaplan, R and Kaplan, S (1989): 'The experience of nature: A psychological perspective'; Ulrich, R.S, Simmons R.F, Losito B.D, Fiority, E, Miles, M.A and Zeison, M. (1991): 'Stress recovery during exposure to natural and urban environments'

well-being are now often included as part of a green agenda in some mental health treatment programs, known as ecotherapy.[104]

In addition, access to green and blue space can differentially benefit women experiencing prenatal and postnatal depression by reducing blood pressure and depression.[105]

7.3.1.3 Access effects

The ability to access green and blue spaces can have benefits of its own. Access to green and blue space plays a fundamental role in facilitating and promoting social interaction,[106] which in turn can support belonging, community spirit[107] and improve happiness.[108] This is likely to benefit groups such as older people as they are often more vulnerable to loneliness and social isolation compared to other age groups.[109]

In addition, the quality of green space and the availability of specific amenities, such as toilets, can play a significant role in the accessibility of green spaces for older people.[110] Similarly, evidence from Age UK suggests that although older people are generally at a lower risk of crime compared to other ages, they are often more fearful of crime[111] and fear of crime and concerns about safety can undermine their use of green space.[112] If green spaces are poorly designed and maintained they can increase the incidents of crime and anti-social behavior.[113]

7.3.2 The importance of social outcomes

As set out above, green, and blue infrastructure can have significant impacts in delivering both positive social outcomes, and the social outcomes experienced are likely to vary depending on the user group and their individual characteristics. As a result, it is vital to consider the impact of any change to green and blue infrastructure on all groups of people within society.

7.4 Mapping impacts and baselines

The social outcomes achievable through the delivery, safeguarding and opening up of green and blue space, will also depend on the makeup of the communities in which those spaces are delivered. If the makeup of a community includes a higher-than-average proportion of people with a particular social or demographic characteristic, or if people from a particular segment of a community are the primary users of an affected resource, changes to provision are likely to disproportionally affects these people.

In order the understand the disproportionate impacts of a change in green or blue infrastructure it is important to identify and understand the social and demographic characteristics and composition of an area. This includes, but is not limited to, analysis of age, gender, disability,

[104] Mind (2019): 'Nature and mental health'

[105] Grazuleviciene, R. Dedele, A. Danileviciute, A. Venclovine, J. Grazulevicius, T. Andrusaityte, S. Uzdanaviticute, I and Nieuwenhuijsen, M.J. (2014): 'The influence of proximity to city parks on blood pressure in early pregnancy'; McEachan, R.R. Prady, S.L. Smith, G. Fairley, L. Cabieses, B. Gidlow, C. Wright, J Dadvand, P. Van Gent, D and Nieuwenhuijsen, M.J. (2016): 'The association between green space and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity'

[106] Kim, J. and Kaplan, R. (2004): 'Physical and psychological factors in sense of community: New urbanist Kentland's and nearby orchard village'

[107] Pinder, R. Kessle, A. Green, J. Grundy, C. (2009): 'Exploring perceptions of health and the environment: A qualitative study of Thames chase community forest'

[108] Alcock, I. White, M. Wheeler, B.W. Fleming, L.E. and Depledge, M.H. (2014): 'Longitudinal effects on mental health of moving to greener and less green urban areas'

[109] NHS (2018): 'Loneliness in older people'; WHO (2016): 'Urban green spaces and health: A review of evidence'

[110] Aspinall P.A. Thompson C.W. Alves S. Sugiyama T. Brice R. Vickers A. (2010): 'Preference and relative importance for environmental attributes of neighbourhood open space in older people'

[111] Age UK (2006): 'Crime and fear of crime: Help the aged policy statement 2006'

[112] Walker, G. (2012): 'Environmental justice: Concepts, evidence and politics'

[113] Houses of Parliament, Parliamentary Office of Science & Technology (2016): 'Green Space and Health'

ethnicity, religious and deprivation profile of residents, both within a given area and against comparators such as regional and national profiles.

Understanding the context of a study area where change in green or blue infrastructure is proposed, by mapping impacts and identifying baselines, is pivotal in delivering outcomes that are appropriate and accepted by the local community.

8 System synthesis and analysis

This section provides analysis of the system maps and of the intervention types proposed in the interviews.

8.1 Analysis – system maps

System maps can be presented and manipulated in different ways for different purposes. The influence and control maps have been developed and presented so far in this report in a format that makes them easier to read. The influence can be tracked through different clusters of nodes. However, to undertake analysis of the maps, rather than follow them visually, a different approach is required. We took the visual maps, entered the nodes and links in a spreadsheet and reproduced the maps for analytical rather than visual purposes, using an application in R script for network analysis. The analysis we have prioritised is as follows:

- **Selection of sub-maps**: parts of the system can be selected for presentation. This allows for, say, the PWS and river health systems to be shown and analysed together. Any combination of the component system and sub-system maps may be shown.
- **Metric identification**: the location of a metric can be highlighted on the system maps. This method is important in assessing gaps and overlaps in metric coverage.
- **Upstream and downstream analysis of a node**: a node can be selected and the nodes that have connections to it or from it can be shown. We have allowed for 1, 2 and 3 step upstream and downstream analysis to be undertaken.
- **Upstream and downstream analysis of a metric**: like the upstream and downstream analysis of a node, this tool allows for upstream and downstream analysis of all nodes with the same metric to be analysed.
- **Addition of an option**: a node may be added to the map that represents a new option and connections made that explore how the option will interact with the system. Network analysis may then be performed with the addition of this option.

The entire network is shown on Figure 8.1. The network comprises 331 nodes and 797 connections. The most significant nodes in terms of connections are identified in Table 8.1 and Table 8.2. The following observations are made from the numerical analysis of the nodes:

- The factor with the broadest influence on the system is '*Cultural & political adoption of green development*.' This is not a surprise given the fact that this node represents behavioural change at scale and drives decision making across the system. The nodes have the most links and appears in the largest number of sub-system maps.
- 'Competent company' comes second on the rank of influence and second on the overall number of connections. This expresses the significance of water company strategy and effective implementation of that strategy on the water system, and our interest in that part of the system. It only appears on one system map.
- Climate change has the third highest influence and appears on the equal highest number of maps.
- Soil health is notably high impact appearing on 7 maps and having 16 different outgoing connections.
- Water quality is notable for being influenced, with 9 incoming connections across 6 maps.

Figure 8.1: WRSE - all systems combined

- Farm financial resilience / profit has the highest number of incoming connections reflecting its central role in the agricultural system and the significance of that system overall.
- Important system outcomes include biodiversity, carbon sequestration, carbon footprint, resilient water source, catchment functions well, natural capital and water quality. Jobs also features highly.
- Other important influences are production efficiency, on farm decision towards sustainability and soil health.

There has been some cleaning of this data to screen out nodes that where heavily connected such as production of paper. Overall, this introductory analysis shows that there is a need to look at the breadth of connections (number of maps) as well as the number of connections.

Table 8.1 Influential nodes

Connections out	Nr	Connections in	Nr	Total Connections	Nr
Cultural & political adoption of green development	36	*Farm financial resilience / profit*	15	*Cultural & political adoption of green development*	40
Competent company	16	*Carbon footprint*	12	*Competent company*	23
Soil health	16	*Biodiversity*	10	*On farm decision towards sustainability*	16
Climate change	13	*Water quality*	9	*Farm financial resilience / profit*	15
Production efficiency	9	*Resilient water source*	9	*Good regional & national collaboration including water sharing*	15
On farm decision towards sustainability	9	*Healthy rivers*	9	*Biodiversity*	14
Shocks	9	*Catchment functions well*	9	*Water quality*	13
		Natural capital	9	*Resilient water source*	13
		Jobs	9	*Urban runoff*	13
		Carbon sequestration	9	*Climate change*	13

Table 8.2 Breadth of relevance of node

Node	Sub-systems in which this node appears	Rank	Links out	Links in
Cultural & political adoption of green development	7	1	36	4
Soil health	7	1	16	2
Climate change	7	1	13	0
Water quality	6	4	4	9
Rainfall intensity	5	5	0	6
Biodiversity	5	5	4	10
Drought	4	7	3	2
Rural pollution	4	7	7	0
Urban runoff	4	7	6	7

8.1.1 Analysis of a node: soil health

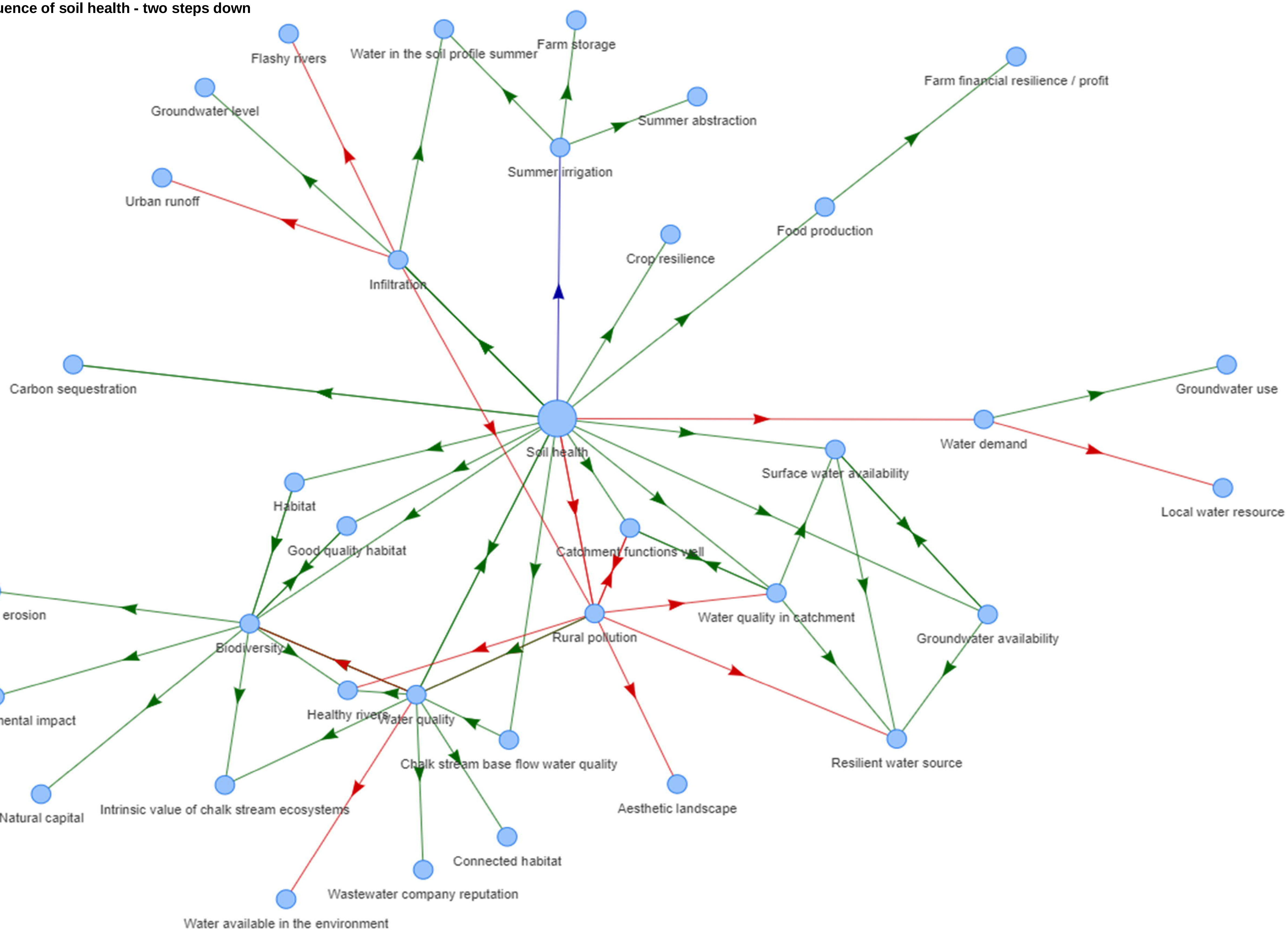
The one step and two step influences of soil health are shown on Figure 8.2 and Figure 8.3. Soil health has 13 positive downstream connections, two negative and one complex. The negative connection is to rural pollution which good soil health reduces. The complex connection is to summer irrigation. Good soil health has potential to reduce irrigation demand because more water is held in the soil profile. The overall impact of improving soil health may lead to greater ambition from farmers rather than water savings overall.

Figure 8.2: Influence of Soil health - one step down

Figure 8.3 (on the following page) indicates shows the two-step influence of soil health. The following observations may be made, taking a clock face to navigate around the diagram.

- The main benefits to the PWS are in the lower right side of quadrant including quality and availability of water producing a more resilient water resource.
- The negative link to Rural pollution (5 O'clock) has significant benefits to the PWS related cluster and the environmental clusters (lower left quadrant).
- At 11 O'clock infiltration increases water in the soil profile and brings other benefits such as less flashy rivers and higher groundwater levels.
- Benefits to the environmental system occur in the lower left quadrant via water quality and biodiversity.
- At 2 O'clock, improved farm financial resilience / profit is achieved, via food production. See also improved crop resilience.
- Carbon sequestration is shown at 9 O'clock.
- At 3 O'clock benefits relating to golf result in less water demand and therefore more local water resource (for others).

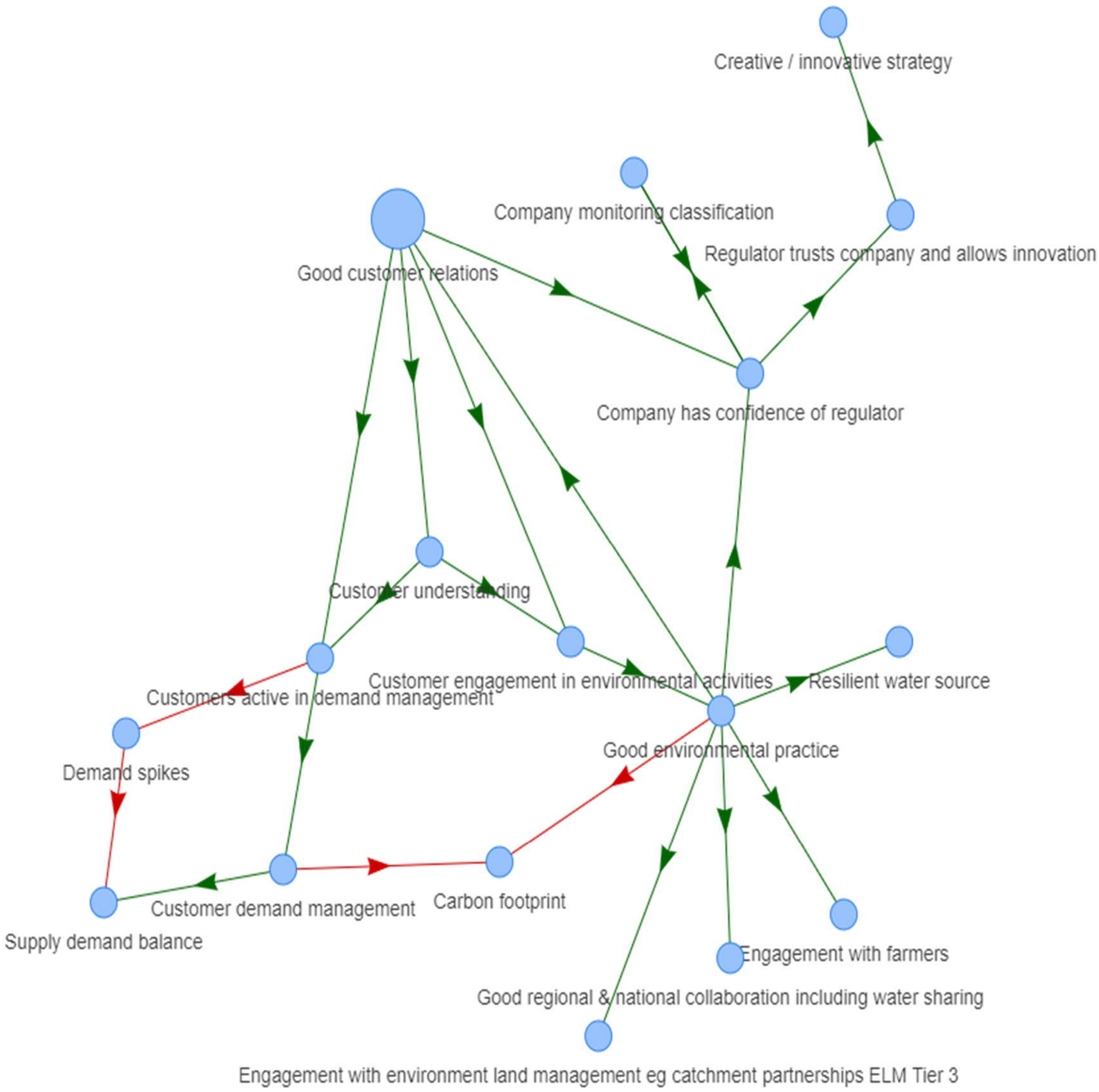
Figure 8.3: Influence of soil health - two steps down



8.1.2 Analysis of a node: customers active in demand management

Influence of the node *Good customer relations* is shown in Figure 8.4. The causal pathway to supply demand balance is to the lower left side of the diagram, passing through Customers active in demand management. Benefits derived from *Company has confidence of the regulator*, are shown to the right. Benefits derived from Customer engagement in environmental activities are on the lower right – including a feedback loop to good customer relations.

Figure 8.4: Two step influence of customers active in demand management



8.1.3 Additional analysis and next steps

The soil health example gives a good indication of the potential of this analysis. It provides a method for identifying complex linkages across systems and provides an auditable analysis of the significance of the node. The tools listed above (analysis of metrics, options etc) are available for further analysis and development of the WRSE options and portfolios. They will be significant in the following ways:

- Analysis at the catchment level needs to be downscaled, democratised and contextualised to be made catchment specific. The larger scale generic picture has been made available here. By using the mapping technique and the analysis app at the catchment level specifics of each catchment will be added.
- Multi-sector options and catchment level interventions can be identified and developed with this approach. For example, if a catchment has a problem with, say, water quality, then this approach may be used to identify interventions that would address that problem. The app may then be used to identify which other benefits, such as flood regulation or carbon sequestration, could be derived from those interventions. This analysis provides a platform for identifying other partners to join the initiative and develop a more comprehensive multi-benefit project with a number of co-benefits at the catchment level.
- The tool has potential use in work on environmental destination as downscaled analysis at the catchment level is used to explore impacts of different strategies in the catchments.

8.2 Analysis systems and interviews

The diversity of the potential interventions to enhance resilience in the different sectors is considerable. However, by categorising the different strategies identified in this report then potential synergies and enabling factors may be identified. The strategies and interventions may be categorised and compared in the following ways:

- **Categorisation by sector**.
- **Resilient system attribute: Reliable, adaptable, evolvable.** For measures that provide resilience to short term shocks, they either do so by maintaining system function without active change of the users enhancing *reliability*; or by enabling short term change in system operation enhancing *adaptability*. For measures that enable long term refocussing of the system function to cope with the impacts of a trend then the measure is said to enhance *evolvability*.
- **Time scale**: some resilience measures address only short-term shocks (reliability and adaptability), others address long term trends (evolvability).
- **Risk strategy: control, capitalisation, collaboration/coordination, and acceptance**. Different measures have different rationales relating to risk management. As identified in Section 2.4 there are three key categories of active risk strategy and one passive
  - **Control and influence**: through establishing control systems through regulation, technology or infrastructure, control is applied to the system to manage risk and enhance resilience.
  - **Capitalisation of risk:** enabling entrepreneurs to find innovative solutions that address risk. Risk is capitalised and traded, being sold by an organisation that wants to address its risk and purchased by an organisation that believes it can handle that risk and make a profit in doing so.
  - **Collaboration – pooling risk**: at grass roots level this approach may be a matter of mobilising collective action as would be the strengths of local environmental NGOs in addressing catchment or landscape level risks. Over a wider geographical remit with larger organisations, this approach is coordination as evidenced by regional planning of water resources. In our case, six water companies are collaborating in drought risk management by developing the WRSE regional plan and creating the regional water sharing that it envisions.

  – **Acceptance of risk: t**he report has identified varying levels of acceptance of risk. The canal system has an aspirational level of service of 1in 20 years. The PWS plans on the basis of 1 in 200 or 1 in 500 years accepting a lower level of residual risk. Rainfed farming tolerates a high degree of weather-related failure. Accepting risk is a passive risk management strategy.
- **Geographic and investment scale:** some interventions are at field level; others relate to strategies for development of major infrastructure such as power stations.

A review of the different types of option identified in the interviews undertaken for this report is given in Table 8.3.

A categorisation of interventions by risk strategy and resilience attribute is shown on Table 8.4.

Table 8.3 Review of potential multi-sector option types

Resilience measure	Sector	Resilience – system attribute	Risk strategy	Scale	Improves drought resilience	Water resource available for others	Water quality	Flooding	Amenity	Biodiversity	Carbon	Offsetting PWS peak demand	Enhance water users engage in demand management
Efficient use	All	All	Control (Collective)	User / collective	1	1						1	
On farm practices	Farmer	Reliability	Control	Farm	1	1	1	1	1	1	1	1	
Obtain secure resource	Power, Paper, Golf, Canals, Farming	All	Control	Organisation / sector Policy	1								
Irrigation	Agriculture, Golf,	All	Capitalisation / control	Farm / enterprise	1				1				
Seasonal storage	Farmer, Golf, PWS, closed quarries)	Adaptability, evolvability	Control	Farm	1	1		1	1	1		1	
Wastewater treatment and recycling	Paper, PWS	All	Control	Organisation	1	1	1					1	
Improved absorption / active infiltration	Golf	Adaptability, evolvability	Control	Enterprise	1				1			1	
Improving soil health	Farmer, Golf, PWS	Reliability evolvability	Collective/ control	Farm / catchment	1	1	1	1	1	1	1	1	
PWS connection	Agriculture,	Adaptability, evolvability	Capitalisation	Farm / enterprise	1								
Water sharing	Agriculture	Adaptability, evolvability	Collective	Catchment	1	1						1	1
Water trading – purchasing peak demand	Agriculture, PWS	Adaptability, evolvability	Capitalisation	Catchment	1	1							1
Sale of peak water	PWS	Adaptability, Evolvability	Capitalisation	WRZ/Hydrological unit	1								
Sale of non-peak surplus	Agriculture, canals	Evolvability/ adaptability	Capitalisation	WRZ/Hydrological unit		1						1	
Sale and return for non-consumptive use	Canals	Evolvability/ adaptability	Capitalisation	WRZ/Hydrological unit		1							
Co-benefit natural capital schemes	Agriculture, canal, golf, quarries	All	Collective	Catchment / landscape	1	1	1	1	1	1	1	1	
Billing arrangements to enhance efficiency	PWS	All	Collective (control)	Customer	1	1							1
Good customer relations	PWS, paper, canals	All	Collective	Wide scale	1								1
Cultural change among users	PWS, agriculture, Golf,	All	Collective	Wide scale	1	1						1	1
Tolerance of variable outcome	Agriculture, canals, golf	Adaptability (Evolvability)	Acceptance	Farm / sector / society	1	1							

Table 8.4 Analysis - risk strategy and resilience attribute

	Reliability	Adaptability	Evolvability
Control	Efficient use Farm practices Obtain secure resource Irrigation Wastewater treatment and recycling Soil health Improved absorption/active infiltration Billing strategy	Obtain secure resource Irrigation Seasonal storage Wastewater treatment and recycling Improved absorption/active infiltration Billing strategy	Efficient use Obtain secure resource Irrigation Wastewater treatment and recycling Soil health Billing strategy
Collaboration	Co-benefit natural capital schemes Good customer relations Cultural change among users Billing strategy	Water sharing Co-benefit natural capital schemes Good customer relations Cultural change among users	Co-benefit natural capital schemes Cultural change among users Good customer relations Billing strategy
Capitalisation	Purchase of water Connection to PWS	Irrigation PWS connection Sale of peak water Purchase of peak water Sale of non-peak surplus	Sale of non-peak surplus Purchase of water Connection to PWS
Acceptance		Tolerate variable outcomes and intermittent service failure	Tolerate increasingly variable outcomes and increasingly frequent service failure

8.2.1 Discussion

The following observations may be made on the findings of this report including the analysis shown in Table 8.3 and Table 8.4.

Enhancing resilience

The following types of scheme are potentially beneficial to all system resilience attributes:

- Co-benefit natural capital schemes. This has a diverse range of benefits as resources are used more efficiently on a permanent or responsive basis.
- Good customer relations and billing arrangements to enhance efficiency and cultural change among users. This group engages water users to reduce demand in on a permanent or responsive basis.
- Efficient use, and wastewater treatment and recycling. This improved the demand on a permanent or responsive basis (responsive in the case where there is capacity to recycle that may be more expensive, so it gets used more at times of system stress).
- Obtaining a secure resource, and providing irrigation improve the security of supply (to the organisation or to the crop). It may be that they may are secured at this stage and used responsively to shocks and long-term trends to increased demand.

The following types of intervention are beneficial to responsive strategies – adaptability and evolvability.

- Seasonal storage which allows for irrigation as an effective drought response and resilience against an increasing trend in drought.
- Improved absorption and active filtration in soil which allows for effective drought responses and an increasing trend in drought.
- Adding a backup PWS connection; water sharing; water trading, allow access to additional resource when it is needed (within limits). Sale of peak water supplies provides this opportunity to other organisations. Sale of non-peak water provides water to others for different types of resilience need (e.g. firefighting).
- Sale and return of water for non-consumptive needs may provide a useful back up supply for other organisations.
- The sale of water provides increased financial resilience to the vendor organisations.

Soil health provides reliability in that crops become more resilient to shocks, and evolvability in that over time different types of drought resistant crops may be grown.

Scale and cost

Scale and cost are significant in understanding the cost effectiveness of drought strategies. The perspective from golf is that the PWS is a cost-effective resource, but the power sector and canal system perceived it to be expensive. In agriculture it is perceived to be useful as a back-up supply for high value crops because of the high potential costs of losing the harvest if short term spikes in demand cannot be met. For lower value crops no irrigation is used and a passive strategy of accepting risk is taken.

Resilience and risk management strategies

1. ***Control of risk***

Control strategies are relevant to organisational strategy, policy, and infrastructure. At the organisational level, power generators and paper mills are seeking secure water rights rather than accommodate the risk associated with traded supplies. Policy actors such as Defra exert control over risk through measures such regulation of on farm water practice.[114] Investing in infrastructure, such as farm storage to retain water resources over summer periods, is another form of controlling risk.

All sectors saw improving efficiency of use as a means of enhancing the resilience of the resource they currently have. Increasing the margin by which they have a positive supply demand balance increases the reliability of their operation.

2. ***Capitalisation of risk***

Market orientated organisations are able to trade risk on the basis of a good understanding of variability and its financial consequences. The clearest articulation of capitalisation of risk came in the power sector who reported that the emerging policy context around security of water supplies is a factor in the attractiveness of the UK market to financial capital flows as the sector responds to the decarbonisation agenda. If water security can be assured for new plants, they are more likely to attract the investment needed for profitable projects.

The power sector is also keen to engage in water trading as a vendor. Selling surplus water incentivises resource efficiency and produces a better overall use of the resource. Canals are increasing their financial resilience by selling surplus water or selling water on a use and return basis, often enabling resilience of other systems such as by providing firefighting water.

[114] Rules for farmers and land managers to prevent water pollution - GOV.UK (www.gov.uk)

For high value agriculture, the ability to purchase of water from a reliable supplier, such as the PWS, is an important resilience strategy because it could save valuable harvests and thereby maintain important long term supply chain relationships.

All these approaches rely on generating a financial return based on trading between organisations that have different strategies for enhancing the resilience of their water supplies.

3. Pooling risk: Collaboration and coordination

At smaller scales, risk pooling is achieved by collaborative and collective action. At the catchment and landscape level improving natural capital is often best achieved through collective action. Examples include interventions coordinated by CaBA groups for environmental improvements in a catchment. At higher levels risk is pooled through more formal arrangements such as regional coordination – like WRSE.

Among farmers the distinction between water sharing and trading is important. Water sharing relies on local coordination among farmers building on social capital networks. Trading in competitive markets may cut across the grain of social networks on farmers, where they need to compete to engage in an activity. Each arrangement has its place, but the degree to which mutual social obligation or market forces are mobilised is an important consideration in a strategy to achieve desirable outcomes at the catchment level.

The importance of customer engagement in maintaining supply demand balance in the water sector has emerged as a priority (see Appendix A). Where water companies are seen as socially and environmentally responsible by customers then customer willingness to comply with drought restrictions is enhanced. By contrast where water companies are not well trusted then customers will be less inclined to act on the basis of collective obligation around water saving in times of drought.

4. Acceptance of risk

Tolerance of variable outcome is included in Table 8.3 to reflect a strategy of accepting a residual risk. The most striking example of a tolerance of risk is in the rainfed agriculture sector, which operates with a high degree of variability in output from one year to the next. There are no comparable examples of a sector dependent on climatic variability from one year to the next. The effect is mediated to downstream sectors by international food trade, but this itself is currently facing a degree of uncertainty as the UK reorganises its international trading relationships in the post EU era. There is little scope for irrigation in this sector due to the scale of the sector and the costs involved. A more beneficial approach is to improve soil health retaining water in the soil profile and increasing reliability of retention of rainfall for plant use.

The canal sector had the greatest clarity around a tolerable level of risk as a target in their strategic planning. The paper sector explained that when severe drought takes place then if needs be one or more process streams may be closed. They are working on strategies to reduce the likelihood of this event occurring. The power sector, as discussed above, were clearest in their unwillingness to tolerate a level of residual risk in the security of water supplies.

8.2.2 Conclusions – water and resilience for multi-sector systems

Water is a critical connecting theme running through diverse multi-sector systems. As such it provides a convening theme for broader analysis of resilience. However, water is relevant to differing degrees and in different ways in different sectors. Therefore, it is necessary to contextualise the relevance of water to resilience of different systems according to the perspectives that different organisations have on water, resilience, and risk. Most obviously, the tolerance of residual risk varies from one system to another – observe the 1 in 20 year service level of canals, but higher tolerance of failure in rainfed agriculture and lower tolerance of failure in the power sector.

The categories of risk (controlling, capitalising, pooling, and accepting) are useful in understanding different sectors and organisations approaches to resilience, noting the power sector's capacity and expertise in capitalising risk; small scale efforts to control risk through on-farm water storage.

- Control is attractive to organisations managing risks within their jurisdiction, and to regulators seeking to set boundaries on behaviour of organisations operating within the system they regulate.
- Some organisations can benefit from capitalising risk, but this may not be an option open to smaller organisations.
- Pooling risk happens in different ways at different levels. At grass roots levels collective action is mobilised such as through catchment-based solutions. At higher levels risk a degree of risk sharing occurs through coordination, as exemplified by regional coordination in strategic planning.
- Acceptance is adopted to different degrees by different organisations.

9 Conclusions

9.1 The resilience framework – a systemic framing with appropriate metrics

This report has reviewed the systems of interest to WRSE, the shocks and trends that affect those systems and the metrics used to assess resilience. It has endorsed the adoption of metrics in three categories: reliability, adaptability and evolvability and reviewed the distribution of metrics against the systems of interest. Three new metrics were added, and others were re-organised with more logical definitions.

- Soil health has emerged as a highly influential factor in the overall system resilience, benefitting resilience against agricultural drought, and with improved water quality and resources for the public and non-PWS systems.
- Customer relations are important in enabling short-term system adaptation to drought conditions and long-term evolution of the supply-demand balance in more resource-constrained circumstances.
- Collaborative land management such as ELM schemes are set to enable a more integrated approach to resource use that are better and potentially more equitably adapted to the long-term resource constraints we face.

This project has set a precedent in turning the ambition for a systems-based approach laid out in the 25YEP, Resilience in the Round and the EA's National Framework into a workable approach.

The report has developed proof of concept for the assessment and validation of resilience metrics by using system mapping. This sets a precedent for mapping the impact of complex investment strategies on the pre-existing systems that they are designed to enhance.

This approach has further potential application, such as articulating the WRSE contribution to public value or environmental resilience. The system maps could be used to assess in-combination impacts of options. Downscaling the system maps to individual catchments has potential to enhance option identification at the catchment level and to develop evaluation frameworks for catchment interventions.

9.2 A context of change and opportunity

A common theme across the discussion and interviews that informed this report was an awareness of the need for a step change towards a more comprehensive, integrated approach to the stewardship of our shared natural resources. There is a sense of collective urgency in the need to adapt to the impacts of climate change; mitigate the causes of climate change; to reverse the loss of biodiversity; and to respond to stresses associated with the post-COVID, post-Brexit economy. These major challenges are reflected in strategic business documents such as the WEF Global Risk Report[115] and the Royal Society's Resilience to Extreme Weather[116] and were reflected in the interviews held for this project. Resonant of the framing of interconnected systems in Resilience in the Round, the need for a holistic, integrated systemic perspective was reasonably well perceived. The interviewees, however, were all engaged with WRSE so would all be early adopters of this new way of thinking.

[115] https://www.weforum.org/reports/the-global-risks-report-2021

[116] https://royalsociety.org/topics-policy/projects/resilience-extreme-weather/

Water is the great connector running through the major systems that society needs to thrive; our natural environment, agriculture, business, government and society as a whole – they are all interconnected by aquifers, rivers, reservoirs, pipes, soil moisture, floods, droughts and drains. Water, therefore, runs right through any comprehensive analysis of the type of system-wide approach society needs for resilience to major threats like climate change, biodiversity loss and pandemic. The elements to enable the water sector to meet this challenge are coming into place and include the following: regional coordination that balances national objective setting with local contextual relevance; an emerging response to the call to think systemically; increasing interest in multi-benefit and multi-sector collaboration.

Most notably, the power sector and the agricultural sector are undergoing periods of considerable reorientation and reorganisation. Canals and quarries are preparing for the risk of change, and new opportunities. Golf is lagging behind with only an emerging awareness of the need for change.

The power sector is facing the transition to carbon net zero and is engaging in the discourse around emerging regulatory framework that will determine the context of risk and consequently strategies for capital investment during this period of change. Agricultural is facing an overhaul of the rural economy. Since agriculture comprises a larger number of small enterprises, it does not have the economies of scale or the unified voice that power companies can achieve.

The key elements of emerging policy in the environment, water and financial sectors have the right elements to enable a transition to systemic integrated approaches. The cultural change needed for this integration to take place has begun but has further to go. The following policy and practical steps need to be deployed in mutually beneficial and synergistic ways.

- **The 25 YEP and the Natural Capital approach** provides the vision and the tools for a comprehensive approach to the environment.
- **ELM and the emerging collaborative landscape management methods** provide a means of implementing the vision in the 25YEP. ELM operates at three tiers. The lowest level provides approaches that require compliance on a local basis. The second tier is a mid-level collaborative approach. The third level is a widespread landscape-based collaboration. Emerging approaches such as LENs and Local Area Plans are providing practical examples of how to implement collaborative multi-benefit action.
- **Resilience in the Round** set out a strategic vision for holistic, systemic approach to resilience followed up in subsequent Ofwat strategy documents. This is matched by the establishment of regional water resource planning which enable implementation of an integrated approach. The region is a scale at which grass roots and local initiatives can be integrated, by being nested, with major private sector collaborations. The importance of collaboration has been re-emphasised in Ofwat's (2019) strategy report '**Time to act, together**' with their key objective: "To drive water companies to meet long-term challenges through increased collaboration and partnerships"; and to seek a broader range of benefits: "For water companies to provide greater public value, delivering more for customers, society and the environment."[117]
- **TCFD** provides a driver for private sector engagement with environmental systems.

Fortunately, these policy driven responses are matched with practical innovation in systems thinking that will enable their delivery. One of the success criteria for new approaches is an interoperability across initiatives. The following approaches are significant in enabling joined-up approaches:

[117] Ofwat (2019) Time to act, together: Ofwat's strategy https://www.ofwat.gov.uk/publication/time-to-act-together-ofwats-strategy/

- **Multi-capital thinking,** as embodied in the six capitals framework, has provided a breakthrough in plural understanding and communication of value. The widespread adoption across business and increasing interest in the water sector makes this framework important as a common language on value.
- **Systems mapping similarly** provides a breakthrough in communicating complex problems and interventions with a valid audit trail and a manageable level of detail. In the UK environment sector, the approach is under development rather than widespread adoption. The approach in this project improves on the proof of concept achieved in the preceding catchment project run by Defra. This approach, participatory systems mapping, has benefits over more linear system maps by embracing the need to consider complex feedback loops and multiple interactions.
- **Resilience frameworks** are emerging. This work is based on 'Resilience by Design'.[118] The three-fold categorisation is presented as a potential simplification that may enable a greater engagement with resilience planning and analysis.
- **Systemic approaches to infrastructure and digital twins** as articulated by the Centre for Digital Built Britain in support of the National Digital Twin in their report "Flourishing systems" which states: "the central ideas are simple and radical: that the purpose of infrastructure is human flourishing, therefore infrastructure should be viewed and managed as a system of systems that serves people and the environment."[119]
- The **Cultural Theory of risk** has a long pedigree, rather than widespread adoption.[120] Its contribution is important in bridging diverse and unarticulated assumptions about systems that frequently lead to siloed approaches amongst system operators and managers. For example, where engineers look for more formal system design, environmental NGOs benefit from broader perspectives; the cultural theory perspective enables these divides to be bridged, drawing on the strengths of each perspective.

9.3 System operation

The call for a systems perspective has been accompanied with a debate on how such systems should be operated[121]. One aspect of the debate relates to the appropriate geographic scale of managing water resources. A comparison of work in this report at the regional level with Defra's 2020 report 'Systems Analysis for Water Resources', at the catchment level is informative.[122] At the catchment level greater granularity was achieved that reflected the distinctive contexts of the two case studies: the Medway in Kent and Sussex and the Eden in Cumbria. However, the work did not attract engagement from larger scale operators such as the power sector, paper and quarries who have been willing to engage at the regional level with WRSE in this report. This endorses the position in the Defra report that a nested approach to understanding water resource systems is needed. Catchments are important for water resources management but are just one element of a multi-layered and integrated system. A regional perspective provides

[118] 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

Brown, C., F. Boltz, J. Tront, D. Rodriguez, and S. Freeman. 2020. Resilience by design: a deep uncertainty approach for water systems in a changing world. Water Security 9: 100051 https://doi.org/10.1016/j.wasec.2019.100051

[119] Flourishing Systems - Re-envisioning infrastructure as a platform for human flourishing | Centre for Digital Built Britain (cam.ac.uk)

[120] Thompson, M., Ellis, R., & Wildavsky, A. (2018). Cultural theory. Routledge.

[121] See Helm (2019) http://www.dieterhelm.co.uk/regulation/regulation/the-systems-regulation-model/#_ftnref1, Balance et al (2017) hat role for System Operators in the water sector? https://www.unitedutilities.com/globalassets/z_corporate-site/about-us-pdfs/looking-to-the-future/what-role-for-system-operators-in-the-water-sector-november-2017.pdf

[122] Defra (2020) Systems Analysis for Water Resources http://sciencesearch.defra.gov.uk/Document.aspx?Document=14947_WT15121.FinalReport.pdf

the scale needed to engage larger organisations with greater financial and geographic scale than regularly engage with catchment management groups.

There is evidently a need to coordinate activities at numerous levels. The following nested perspective on systems, governance arrangements and coordination mechanisms emerges.

- Social and economic system – culture, economy and society driving the layers below.
- National policy – governance
- National water resource coordination – regulators
- Regional water resource planning – coordination mechanism
- Multi-sector organisations – systems with their own governance and coordination arrangements
- Water companies and WRZ systems with their own governance and coordination arrangements
- Local government – resilience forums to coordinate emergency services, NHS, the EA transport and other categories of resilience related service at the local level.
- Catchments – systems with their corresponding governance/collaboration mechanisms
- The natural environmental system – as a foundation to everything above

9.3.1 Recommendations

1. The resilience framework should be promoted for wider uptake and further development. The collective work across the six WRSE water companies, their consultants, the multi-sector, and environment working groups has enhanced the framework, which can now be used as a platform for further development in similar planning processes. The key features of the framework to build on are:
   - The clear categorisation of resilience attributes in terms reliability, adaptability and evolvability relating to passive and active responses to shocks and trends.
   - A set of metrics scalable by deployable output in a way that reduces subjectivity of weighting between metrics.
   - The validation of the metrics with participatory system mapping, providing an audit trail for the selection of metrics.
   - The clear framing of public and private water systems that are reliant on the environmental system, interface with multi-sector systems and serve the social and economic systems.
2. The metrics developed in this report should be evaluated, managed, and developed to ensure that they bring the right balance of incentivisation across the systems of interest to WRSE. By maintaining the link between the system mapping and the metrics, then the system mapping may be updated, and the metrics revised over time as required. Suitable governance arrangements are required for the metrics to ensure ongoing implementation and relevance beyond the PWS system alone.
3. The metrics need rigorous baselining as part of the planning cycle to inform option development and prioritisation. This need now informs the next round of planning. Identifying where the system has weaknesses would allow targeting of effort in option development, in addition to providing a platform for investment modelling.
4. The system maps need to be reviewed, integrated, shared, developed, and democratised. The insights that come from them must be made available for planning processes, stakeholder engagement and option development at the catchment level.

  – Approaches to collaborative option development should be explored, developed and adopted. These would use maps to investigate problems, identify interventions and identify co-benefits of those interventions with a view to generating more integrated interventions with more partners to influence system change. This type of exercise would provide the basis for developing multi-benefit schemes with blended finance and collective implementation and monitoring.
  – Work on the catchments should be downscaled to be made catchment specific so that they inform planning at that level.
  – Insights from the maps should be used for other objectives. Implications for a regional carbon net zero strategy should be explored using the systems mapping presented in this report.

5. The role of water as a super-connector of systems and a central focus in resilience planning gives regional water resource organisations a significant role in regional multi-sector resilience planning in the management and coordination of resilience and systems management. The benefits of this perspective should be taken forward through liaison with other resilience planning mechanisms and objectives.
6. The insights on risk culture should inform the development of coordination and governance structures, with each organisation playing to its natural strength or strengths in a framework that reflects the respective benefits that each risk culture brings.
7. The systems perspective should be developed as a management tool over time. The addition of real-time monitoring would be added as the system maps are used over time. In combination with a GIS, this then creates the basis of a digital twin for the regional water resource system. A digital twin of this type would allow integrated systemic planning of the regional water resources, with plans then transformed into monitoring and management tools as they are implemented. This live tool would also be used as a scenario analysis tool, enabling further development of strategic interventions.

A. Metric revision

MOTT MACDONALD

WRSE Resilience metrics review

Project:	Water Resources South East (WRSE)		
Our reference:	412624-RES-701	**Your reference:**	
Prepared by:	Brendan Bromwich	**Date:**	30/11/20
Approved by:	Paul Chadwick	**Checked by:**	Nick Rhoden, Karen Treherne
Subject:	Revision of metrics for the WRSE resilience framework		

1 Summary, draft framework and scope

1.1 Summary

This technical note proposes changes to the metrics used in the WRSE resilience framework. It is based on:

- Feedback on the first draft of the framework;
- Early results from the work on WRSE systems mapping; and
- Experience of developing and scoring the metrics in the draft framework.

The following changes to the metrics are proposed:

- R3: *Vulnerability of infrastructure to other hazards* is split into two metrics: R3 *Risk of failure of planned service due to other physical hazards* and R7 *Risk of failure of supporting services due to exceptional events.*
- R8: *Soil health* is added as this indicates resilience of the water quality and water resources in face of intense rainfall and drought associated with climate change. Soil health provides resilience for the public and non-public water supply systems; and for the availability of soil moisture for field-based farming.
- A7: *Customer relations enhance engagement with drought demand management measures* is added. This metric reflects the fact that some options enhance company reputation with customers but others are neutral or unattractive to customers. Where a customer is confident that the company is taking all reasonable measures to manage leakage, then the customer will be more inclined to engage in demand management themselves.
- E6: *Collaborative landscape management*. Collaborative approaches that reflect multiple interests and manage the landscape for multiple benefits are well placed to evolve over time to enhance resilience in the environmental system. This will benefit the public and non-public water supply systems.

This technical note is issued as part of a review of the WRSE resilience framework. Feedback is sought on the following areas, which are subject to ongoing discussion and development:

- Differentiation between scores of 4 and 5 on the soil health metric;
- Differentiation between scores of 4 and 5 on the collaborative landscape management metric; and
- Other feedback as appropriate.

This technical note is issued on 30/11/20 and feedback is requested by email to Brendan.c.bromwich@mottmac.com by 7/12/20 or at an online meeting to be scheduled in the same week. A png file of the system map is available on request.

1.2 The draft framework

The draft framework comprises four inter-dependent systems as indicated in Figure 1.

- The public water supply is a core system;
- The non-public water supply is a core system and is also referred to as the multi-sector system.
- The environmental system is a core system;
- The wider south-east system includes society and economy; is not a core system and is not well defined.

The resilience metrics are shown in Figure 2 and are described in Annex B.

Figure 1. Four inter-dependent systems in the WRSE resilience framework

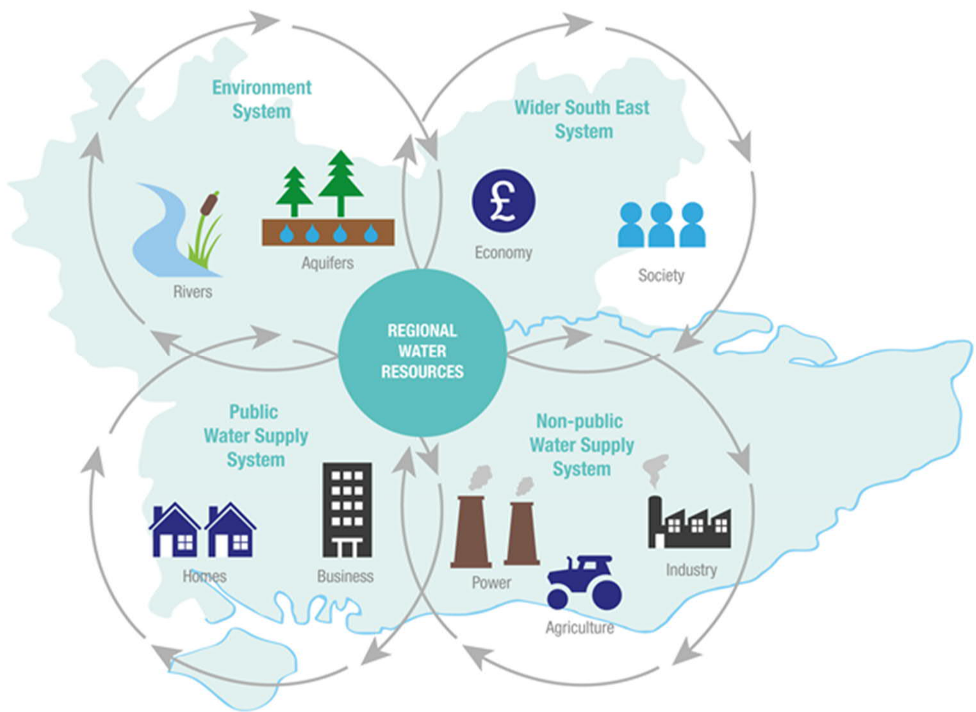
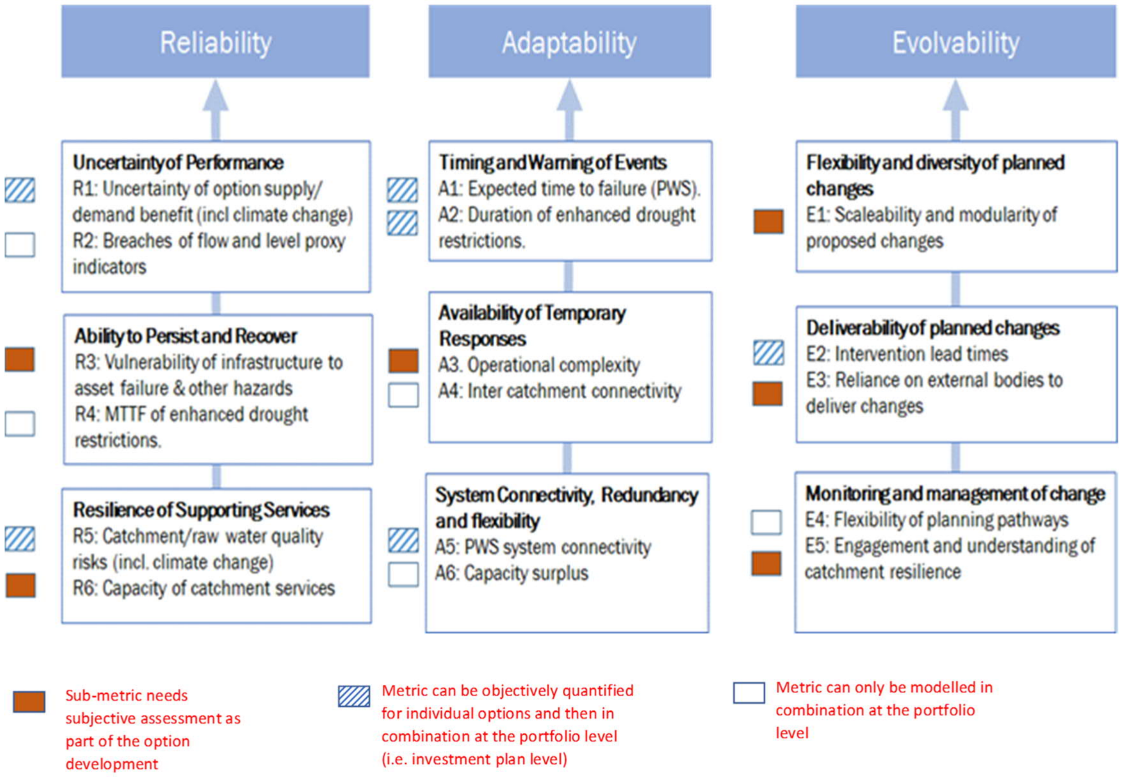


Figure 2. Resilience metrics in the draft framework (Refer to WRSE Resilience Assessment Technical Guidance V2)



1.3 The scope of this work and organisation of this note

This technical note is issued ahead of the final report on the revision of the resilience framework in order to elicit feedback on the proposed new metrics.

In order to address the need for greater clarity about the rationale for the metrics and the interconnected nature of the systems, a systems-mapping exercise is in progress. In line with the feedback on the draft framework this technical note retains the four component systems as reflected in the following system maps:

- Environmental system: flooding, catchment health (including rivers, chalk streams and waste-water systems), land use and natural capital;
- Public water supply system, (wastewater considered in outline in the catchment system map);
- Non-public water supply or multisector system: Farming (including decision making, environmental management and water management); power; paper; canals; quarries, golf; and
- Social and economic system.

The social and economic system is considered in terms of the outcomes and feedbacks from the three "core" systems. In this technical note:

- The drivers for change to the draft framework and the proposed changes described in Section 2.
- The reorganisation of metric R3 is described in Section 3.
- The new metrics on customer relations, soil health and participation in collaborative land management are show in Sections 4,5, & 6.

A system map of the Public Water Supply is shown in Annex A.

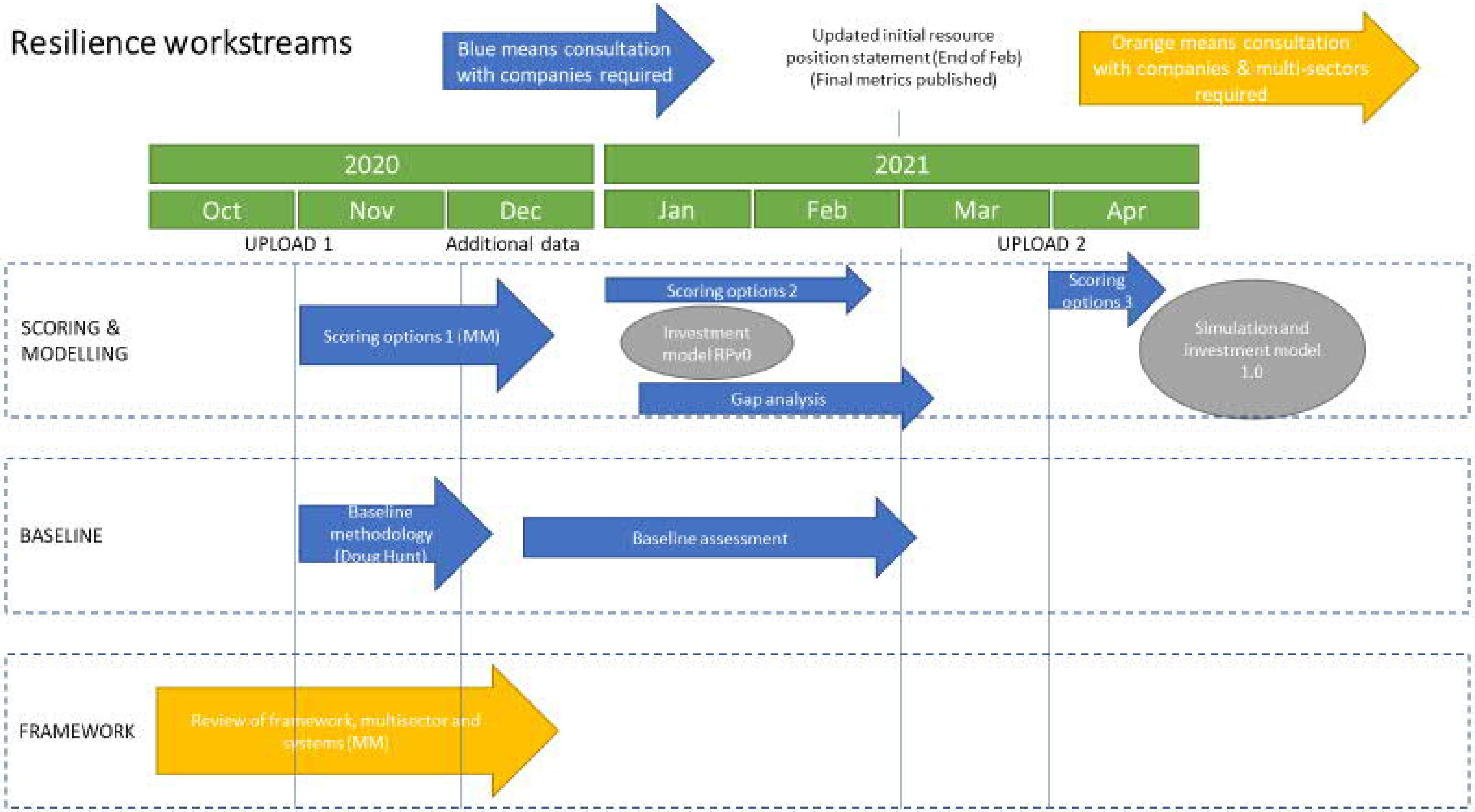
A detailed description of the metrics used in the draft framework is given in Annex B.

1.4 Resilience workstreams

There are a number of active workstreams on resilience as indicated on Figure 3.

- This piece of work, comprising the update of the resilience framework, is shown in orange.
- The scoring of the options from the first upload against the original schedule of metrics is ongoing and due for completion in December 2020 (by Mott MacDonald).
- Work is ongoing on the design of the baseline assessment methodology (by Doug Hunt).
- Following acceptance of the revised metrics proposed within this technical note then a revision to the scoring of the options would be made (Scoring options 2). Some further option scoring would be needed after the second upload in early April 2021 (Scoring options 3).
- The baseline assessment will be done following finalisation of the methodology and acceptance of the new metrics.
- A gap analysis of the range of options uploaded will be undertaken following the scoring of the options in January and February 2021.

Figure 3 Resilience workstreams



2 Feedback on the draft framework

2.1 Drivers of change to the schedule of metrics

2.1.1 Priorities identified in the feedback on the draft metrics

The consultation feedback on the draft framework[1] broadly endorsed the framing of four interconnected systems noting the underpinning role of the environmental system. With respect to the resilience metrics, the headlines in the response were:

- Greater coverage of the non-public water supply/multi-sector system resilience is required, rather than being too focussed on the public water supply system.
- The resilience of the environmental system needs to be covered.
- Greater clarity around rationale for the metrics is required.
- The framework omits response and recovery (one of the cabinet office 4 Rs).

Response

- Metrics added on soil health and collaborative land management increase attention to non-public water supply system (farming) and environmental systems. The role of the environmental system as foundational to the other systems is reflected.
- The system mapping supports explanation of the rationale for the metrics. The mapping is not presented here in full but will be presented in more detail in the main report.
- Response and recovery will be discussed in the main report.

Additional detail on the feedback will be added in the main report.

2.1.2 Review from the systems mapping

This analysis is undertaken on the basis of the system map of the Public Water System (PWS) and part of the environmental system as shown on Figure 4 in Annex A. The following features are evident:

1. There is a degree of crowding of metrics around infrastructure. This is reasonable given the primary purpose of the metrics is the development of an investment plan in which infrastructure features highly.
2. There is a lack of attention to customer service.
3. The component parts of metric R3 reflect a diverse range of issues.

Response

- A metric on customer service has been added in relation to the way that it enhances customer engagement in demand management during drought.
- Metric R3 has been disaggregated into R3 and R7.

2.1.3 Feedback from the metric scoring

The metric scoring is ongoing. At this stage it is understood that there a number of minor revisions to the metric scoring approach but just one substantive change to the metrics themselves. A difficulty arose in the aggregation of the broad range of issues covered in metric R3.

[1] See: https://www.wrse.org.uk/media/qybbxsqw/resilience-framework-response-to-feedback-03-august-2020_final.pdf

Additional issues have arisen from working with the metrics including the following:

1. Inconsistency in the use of the terms metrics, sub-metrics, indices, system attributes and characteristics.
2. Unavailability of data needed for the scoring of metrics R1, R5 and A5.
3. Adaptability and evolvability need clarification.
4. There have been difficulties with the aggregation of the elements scored under a metric. Consistency is needed in addressing the approach to aggregation. If aggregation is not appropriate, then there is inadequate differentiation between options.

Response

- A consistent approach to aggregation is proposed in Section 2.2.1.
- Terminology is clarified in Section 2.2.2
- Current modifications to the approach adopted for R1, R5 and A5 are indicated in Annex B. This work is still ongoing and there are some issues that are yet to be resolved.

2.2 Modifications to the framework

2.2.1 Priorities for the selection of metrics

Through the course of the review the following priorities for the development of metrics were identified:

1. The metrics must enable differentiation between the options at the investment modelling stage. If the scores are too close together then they do not provide differentiation.
2. The metrics must reflect the key function of the overarching WRSE system which is the provision of water. Therefore, while the systems need to be understood in the broader terms demanded by the feedback on the draft framework, there is a need to provide a rationale for the metrics that shows their relevance to the provision of water.
3. There must be a clear logic to the selection of system attributes combined into a single metric.
4. The resilience scoring of elements that are combined into a single metric must be aggregated based on the lowest score going forward where the elements are scored at 1 or 2. This reflects the fact that a system attribute is only as resilient as the weakest element under consideration. To achieve this system for aggregation, the scoring of each component part, must reflect a combination of likelihood and impact of system failure against a given shock. In this way the most relevant vulnerability will influence the resilience score of that option.
5. Where the elements of a composite metric are scored 3, 4 and 5 then a judgement is made to the relative weighting of 4s and 5s, based on whether the option makes a significant contribution to the resilience of the system.

The proposed revisions to the metrics are shown in Table 1, giving the revised schedule of metrics in Table 2. The relevance of the metrics to the different systems is indicated on Table 2. The principal link with the systems is indicated and in some cases secondary links are indicated in brackets – the links are indicative and will be confirmed in the final report when the systems mapping is complete.

2.2.2 Clarification of terms

The lack of clarity around the use of the term metric and sub-metric is resolved in a way that reflects the practical usage of the term metric to apply to the level that is scored (R1, R2, A1 etc.). The metrics come under headings (such as Uncertainty of Performance) relating to different system characteristics and attributes as Table 2. Reliability, adaptability and evolvability are system attributes.

2.2.3 Revisions to the schedule of metrics

The revisions to the schedule of metrics are summarised on Table 1 and the new overall schedule is presented on Table 2. The revisions to the metrics are shown on Figure 4 in Annex A. The gold coloured circular metric labels indicate the reorganisation of R3, becoming R3 and R7. The new metrics A7, R8 and E6 are shown in pale pink. The unchanged metrics are shown in blue.

Table 1 List of metric revisions

Revision	New metrics	Resilience rationale	Additional benefits
R3 disaggregation	Risk of failure of planned service due to other physical hazards.	Physical hazards are considered together.	Clarity
R3 disaggregation	Risk of failure of supporting service due to exceptional events.	Resilience to extreme events are clustered together.	Clarity
Addition of R8	Soil health	Improves resilience of water quality, crop access to water and water resources.	Biodiversity, carbon sequestration.
Addition of A7	Customer relations enhance engagement with drought demand management measures	Supply demand balance requires participation of customers – which is enhanced when a relationship trust of the company is greater.	Furthers the social contract for the water sector.
Addition of E6	Collaborative landscape management	Significant co-management of landscape objectives enable ecosystem service benefits to be developed at scale and enhanced over time.	Multiple benefit landscape management schemes, create a range of economic, environmental and amenity benefits.

Table 2 Revised schedule of resilience metrics

System attribute	RELIABILITY		ADAPTABILITY		EVOLVABILITY	
System characteristic		**UNCERTAINTY OF PERFORMANCE**		**TIMING AND WARNING OF EVENTS**		**FLEXIBILITY AND DIVERSITY OF OPTIONS**
Metric	R1 PWS	Uncertainty of option / supply demand benefit	A1 PWS	Expected time to failure (PWS)	E1 PWS (Non-PWS)	Scalability and modularity of proposed changes
Metric	R2 Non-PWS	Breaches of flow and level proxy indicators	A2 PWS / (Non-PWS)	Duration of enhanced drought restrictions		
System characteristic		**ABILITY TO PERSIST AND RECOVER**		**AVAILABILITY OF TEMPORARY RESPONSES**		**DELIVERABILITY OF PLANNED CHANGES**
Metric	R3 PWS	Risk of failure of planned service due to other physical hazards	A3 PWS	Operational complexity	E2 PWS / (Non-PWS)	Intervention lead times
Metric	R4 PWS	MTTF of enhanced drought restrictions	A4 All	Inter-catchment connectivity	E3 (PWS)	Reliance on external bodies to deliver change
			A7 PWS	Customer relations enhance engagement with drought demand management measures		
System characteristic		**RESILIENCE OF SUPPORTING SERVICES**		**SYSTEM CONNECTIVITY, REDUNDANCY AND FLEXIBILITY**		**MONITORING AND MANAGEMENT OF CHANGE**
Metric	R5 Env	Catchment / raw water quality risks	A5 PWS	PWS system connectivity	E4 PWS	Flexibility of planning pathways
Metric	R6 Env / All	Capacity of catchment services	A6 PWS / Non-PWS	Capacity surplus	E5 Env/All	Engagement and understanding of catchment resilience
Metric	R7 PWS	Risk of failure of supporting service due to exceptional events			E6 All	Collaborative landscape management
Metric	R8 Env/ All	Soil health				

3 Reorganisation of R3: Vulnerability of infrastructure to other hazards

Metric R3, *Vulnerability of infrastructure to other hazards* is the key metric that describes the resistance of the PWS and non-PWS systems to hazards other than the 'primary' meteorological shock (drought) hazard. The hazards that have been used in the scoring of the draft framework are:

1. Flooding
2. Physical damage: Extreme weather - excessive cold and ice/ snow or prolonged hot/dry weather
3. Physical damage: Terrorism / vandalism
4. Physical damage: Geological - Earthquakes, landslides
5. Physical damage: Internal - Fire
6. Physical damage: Internal - Asset deterioration / failure
7. Power supply loss - power failure
8. Communications loss - cyber-attack/solar flare/ space weather/ telecoms failure
9. Supply chain loss - materials shortages e.g. chlorine, fuel, strikes, commodity price change
10. Shortage of staff – epidemic/ pandemic, civil unrest, skills crisis, national strike
11. Other

These hazards are treated reorganised into two metrics as follows:

- Hazards 1-5 remain as R3 as Risk of failure of planned service due to other physical hazards.
- Item 6 is deleted as it is not a hazard but would be addressed as asset health and covered under outage.
- Hazards 7-10 are included in the new metric R7: *Risk of failure of supporting service due to exceptional events.*
- Power failure is included in R7 in as much as the power failure is an exceptional event such as major power network failure over a wide geographical area. Localised power failures at individual sites is addressed within the outage allowance and are not considered here. This metric covers events that are not represented in the historical record of power failures that are generally used for the statistical derivation of outage allowances. Such occurrences may be prompted by extreme events such as severe drought, wide-area flooding, hurricane winds, etc
- The other category, Hazard 11, is not taken forward.

These changes are summarised Table 3 and shown on Figure 4 (see gold coloured circular metric labels.)

Table 3 Reorganisation of R3

Component	Destination	Reason
Flooding	Remains R3	Physical hazards are aggregated and retained
Physical damage: Extreme weather - excessive cold and ice/ snow or prolonged hot/dry weather	Remains R3	
Physical damage: Terrorism / vandalism	Remains R3	
Physical damage: Geological - Earthquakes, landslides	Remains R3	
Physical damage: internal - Fire	Remains R3	

Component	Destination	Reason
Physical damage: internal - Asset deterioration / failure	Deleted	Not appropriate for inclusion – this is an asset health issue rather than a resilience issue
Power supply loss - power failure	R7 Risk of failure of supporting service due to exceptional events	
Communications loss - cyber-attack/solar flare/ space weather/ telecoms failure	R7 Risk of failure of supporting service due to exceptional events	Exceptional hazards. Site specificpower failure covered in outage.
Supply chain loss - materials shortages e.g. chlorine, fuel, strikes, commodity price change	R7 Risk of failure of supporting service due to exceptional events	
Shortage of staff – Epidemic/ pandemic, civil unrest, skills crisis, national strike	R7 Risk of failure of supporting service due to exceptional events	
Other	Not used	

4 New metric: A7 Good customer relations enable collaborative drought management

Table 4 New metric A7 Customer relations and drought management

Score	Description	Example
5	Benefit visible to customers relating directly to drought, water supply or customer service	Demand management, leakage control Customer service improvements
4	Benefit visible to customers but not relating directly to drought, water supply or customer service	Environmental benefits
3	No noticeable change for customers	Pipeline
2	Disbenefit visible to customers but not relating directly to drought, water supply or customer service	Environmental detriment
1	Disbenefit visible to customers relating directly to drought, water supply or customer service	Change in taste in water, unattended visible leaks

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 active in demand management. Conversely where companies have lost the confidence of customers then they will be less inclined to implement demand management.

The metric works by having two steps up or down from the central score of 3. A score of 3 applies to an option that does not influence customer perception of the water company and its attention to drought management. One step up (score 4) is achieved by an option that is visible to the public and likely to enhance the perception of the company – such as catchment management scheme. Two steps up (score 5) would be achieved by an option that is visible to the public, likely to enhance the perception of the company and relates directly to leakage control, demand management or customer relations. Conversely, one step down (score 2) is applied to an option that is visible to customers and likely to be detrimental to the perception of the company – such as a scheme with environmental dis-benefits. Two steps down (score 1) is applied to an option that is visible to customers, likely to be detrimental to the perception of the company and relates to drought management, leakage, water supply to customers such as options that cause a change in taste of the water.

Additional benefits of this metric are that they support the 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 implementation of demand management 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. The same attribute is also relevant under the evolvability category of E metrics in enabling a longer-term process by which customers reduce their demands. The same social contract will be underpinning the lowering of the per capita demand at which the supply demand balance is reached and reliably maintained.

5 New metric: R7 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.

Table 5 New Metric R7 Soil health

Score	Description	Example
5	Improved to water quality and infiltration: additional measures in addition to cover cropping	Regenerative Agriculture
4	Improvement to water quality from cover cropping	Reverse auction for nutrient loading
3	No change to soil	Pipeline
2	Detriment to water quality	Unlikely to occur at scale
1	Severe detriment to water quality and infiltration	Unlikely to occur at scale

The metric works by allocating a score of three 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 5 is allocated to options that enhance soil structure, organic matter and infiltration in additional ways over and above the use of cover crops.

The definition of step 5 is currently under discussion. It 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[2] identify 5 principles of regenerative agriculture as follows:

1. Diversity of crops.
2. Armour soil surface – protect from heat and rains.
3. Minimise soil disturbance.
4. 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.

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

MOTT MACDONALD

6 New metric: E6 Collaborative landscape management

Table 6 New Metric E6 Collaborative landscape management

Score	Description	Example
5	Large scale multi-benefit landscape restoration with multiple revenue schemes.	LENs style, ELM Tier 3; blended finance
4	Single domain medium scale catchment interventions.	Catchment partnership
3	No noticeable change for catchment stakeholders	Pipeline
2	N/A	
1	N/A	

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 3 for options that do not involve collaborative land management. A one step increase to a score of 4 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.

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.

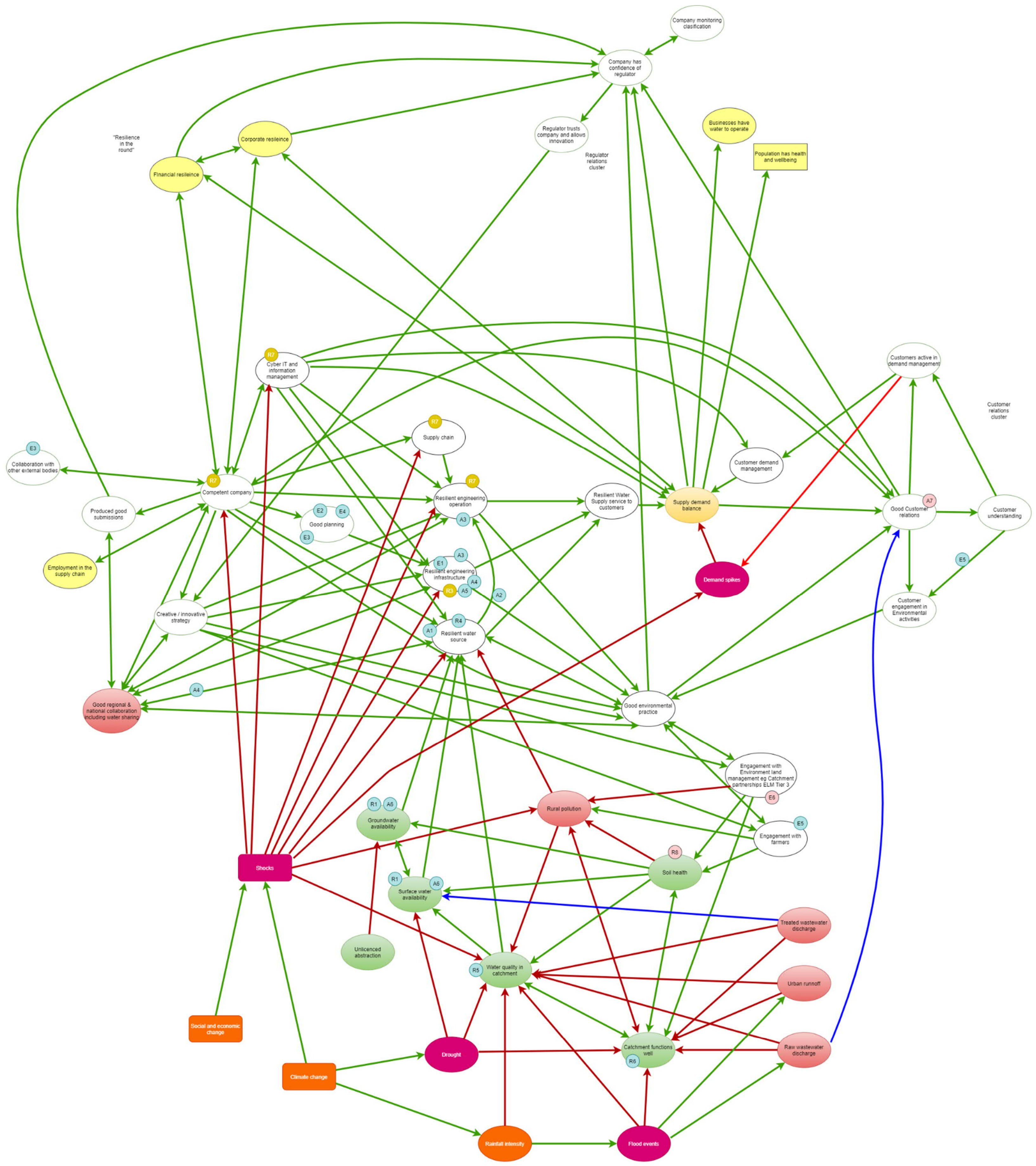
Examples of major, multi-benefit initiatives, that would score 5 in this metric include:

- 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.

Annex A: Public water supply systems map

Figure 4 PWS system map indicating original R3 and location of three proposed new metrics



Important: nodes can increase or decrease; arrows mean an increase or decrease; red and green arrows are not value judgements

+ ve connection: A increase causes B increase
- ve connection: A increase causes B decrease
complex connection

DRAFT Public Water Supply system map
30/11/20 Brendan Bromwich
Map currently a work in progress

Rectangle indicates group of nodes

Revision Control

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Annex B: Public water supply systems map

Table 7 Overview table of metrics in the draft resilience framework

Sub-Metric	Metric assessment	Why it is Included	Main hazard types linked to the attribute	*Comment*
R1: Uncertainty of option supply/demand benefit	Quantitative – option and portfolio	Key metric describing the reliability of the interventions in the face of climate change and other uncertainties associated with the primary (drought) hazard.	Drought, possibly societal where there are significant licencing uncertainties.	*Modelled variation in DO – there is a lack of data on DO uncertainty, therefore this metric is being scored on an option type basis in line with headroom methodology.*
R2: Breaches of proxy flow and level thresholds	Quantitative – portfolio	Provides a high level description of the frequency at which non-PWS abstractors could have to plan for and manage abstraction constraints as a result of meteorological (drought) hazard.	Drought.	*Modelled breaches of Hands off Flow in water courses. This is a useful direct indication of system failure resulting from unmatched SDB in the non-public water supply sector.*
R3: Vulnerability of infrastructure to other hazards	Subjective - option	Key metric that describes the resistance of the PWS and non-PWS systems to hazards other than the 'primary' meteorological shock (drought) hazard.	Physical and adversarial hazards, including flood, fire, storms, cyber-attack, civil unrest, large scale accident/explosions. Only consider hazards that can cause long term failure due to damage. loss of power etc. Events such as forest or heath fires that could prevent access for repairs are particularly significant.	*This is a major catch-all metric for non-drought shocks. In its current form there are too many factors aggregated together without clear rationale for the weighting between the factors.* *ACTION – requires disaggregation*
R4: MTTF of enhanced drought restrictions.	Quantitative – portfolio	For both PWS and non-PWS systems there will be operational stress during periods where drought restrictions are in place. It is important that time is allowed between such conditions to allow learning and preparation to improve.	All hazards described under other metrics.	*Modelled for PWS and n-PWS*
R5: Catchment/raw water quality risks (incl. climate change)	Quantitative – option and portfolio	Raw water quality represents one of the most significant hazards that can combine with meteorological stress events to worsen the risk of failure of service. Reliability of systems reduces as water quality risks increase.	Raw water quality hazards that lead to sustained loss of supply, particularly during drought or demand shock events[3].	*This is being scored on an option type basis: (1) new supply side options that do not impact on catchment water quality will have scoring based on the inherent water quality risk of the catchment; (2) new supply side options that do impact on inherent water quality risk of the catchment will have scoring based on the shift (improvement or detriment); and (3) new options that on the demand side have a default score*
R6: Capacity of catchment services	Subjective - option	This is a key metric that seeks to identify the capacity of the catchment services themselves to persist during shock events, which will affect recovery times and the damage that the event causes to the system.	Primarily drought/low flows, although could relate to water quality hazards.	*OK - This is being scored on an option type basis*

[3] 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.

A1: Expected time to failure (PWS)	Quantitative – option and portfolio	Key response/recovery metric – the longer the drought takes to materialise, the more adaptive measures such as customer messaging, operational preparedness etc can be put in place.	Drought	*OK*
A2: Duration of enhanced drought restrictions.	Quantitative – option and portfolio	As above – these events place stress on operations and prolonged periods increase the chance that operational response (staff, monitoring etc) will start to fail as a result of that stress.	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).	*OK*
A3. Operational complexity		Common resilience concept – the more complex the system, the less reliable it will tend to be during shock events, and the more difficult it is to recover if it fails.	All hazards described under other metrics.	*OK - This is being scored on an option type basis.*
A4: Inter catchment connectivity		Measures the ability of water to be transferred between catchments and thus help to alleviate drought stress within the catchment (either virtually through abstraction changes, or direct augmentation).	Drought	*OK*
A5: PWS system connectivity	Quantitative – option and portfolio	Common resilience concept – the greater the connectivity the more likely it is that operational 'work around' can be found during service failures.	All hazards described under other metrics.	*Data on single points of failure is lacking. Information/advice requested from companies to assess options that have a benefit to improving system connectivity. It is assumed that the majority of options will not have a score.*
A6: Capacity surplus		'Capacity' in this sense relates to the availability of raw water sources in the face of meteorological or demand stress - having redundancy promotes resilience when there are localised variations in outage, demand, availability etc outside of planned expectations.	Drought or demand shocks	*OK*
E1: Scalability and modularity of proposed changes		Relates to investment planning – the more modular and scalable the investment, the easier it is to flex the investment	Planning hazards (multiple long term reasons, including climate change beyond expected ranges, societal changes leading to widespread, unexpected behavioural change etc).	*This is being scored on an option type basis.* *Relates to the infrastructure rather than the planning process. The infrastructure is to be designed and built in a way that is scalable e.g. land procured and space available for additional treatment streams.*
E2: Intervention lead times	Quantitative – option and portfolio	Relates to investment planning – the longer an intervention takes to implement, the more likely it is that supply and demand conditions or economic/societal changes will make that intervention inadequate or superfluous.	Planning hazards – as above	*OK, data has been provided to inform scoring.*
E3: Reliance on external bodies to deliver changes		Reflective of the fact that such investments are more liable to be unsuccessful and more difficult to predict that failure in advance.	Societal hazards – change in expectations, governmental support, civil society etc.	*OK - This is being scored on an option type basis.*

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E4: Flexibility of planning pathways		Although adaptive planning is a fundamentally resilient approach to investment, if the differences between the adaptive planning branches are too large and require too much in the way of policy/direction change, then there is a risk that decisions will be deferred and choices left until it is too late, despite adaptive monitoring.	Societal hazards – change in expectations, governmental support, civil society etc.	*OK*
E5: Engagement and understanding of catchment resilience		There is a lack of understanding of what drives resilience within catchment services. Any initiative that improves this understanding will improve subsequent rounds of resilience planning.	All hazards that could affect the water environment.	*OK - This is being scored on an option type basis.*

B. References

Books and peer reviewed papers are listed here. Other material is referenced as footnotes through the document.

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