

Influencing policy development: Safe & SuRe responses to recent consultations

(2015)

Context

Resilience and sustainability are key concepts receiving increasing global attention. In the wake of the enactment of the Water Act (2014) for England and Wales, which included a Resilience Duty, a number of organisations issued consultations on resilience and related topics during 2015. The Safe and SuRe (S&S) project has reliability, resilience and sustainability as core concepts in its conceptual and analytical frameworks. Consequently, responses were formulated and those herein were compiled by the Safe and SuRe (sustainable, resilient) project research team from the Centre for Water Systems, University of Exeter, led by Professor David Butler (coordinated by Dr Sarah Ward).

For further information about this project, please refer to the website (safeandsure.info) and/or contact Professor Butler (d.butler@exeter.ac.uk). Key references are:

- Butler, D., Farmani, R., Fu, G., Ward, S., Diao, K., Astaraie-Imani, M. (2014) A new approach to urban water management: Safe and SuRe. *Procedia Engineering*, 89 (C), 347-354, DOI:10.1016/j.proeng.2014.11.198
- Butler, D., Ward, S., Astaraie-Imani, M., Diao, K., Sweetapple, C., Fu, G. and Farmani, R. (submitted) Reliable, resilient and sustainable water management: the Safe & SuRe approach. *ASCE Journal of Water Resources Planning and Management*.

Please ensure to reference these papers or this document where any information is used.

Responses to the following consultations are summarised in this document:

Section	Consultation Title	Issuing organisation	Pages
1	Ofwat Resilience Consultation	Ofwat	3-10
2	Resilience Task and Finish Group Questionnaire	Severn Trent Water	11-14
3	Lloyd's Register Foundation Resilience Engineering Priorities	Lloyd's Register Foundation	15-21
4	Environment Agency Water Company Drought Plan Guidelines Consultation	Environment Agency	22-24

Ofwat Resilience Consultation Response

The underpinning aim of the consultation seems to be to articulate Ofwat's definition of resilience, so that service providers can interpret it and apply it to assess their resilience and report back to Ofwat. This will allow Ofwat to provide support where needed and determine whether the resilience duty is being met and furthered. Key focuses are also trust and confidence. Trust and confidence are built through clarity and transparency. At present there is a lack of both in Ofwat's articulation of how they understand resilience and will undertake their resilience duty. Through our responses to the questions posed in the consultation, we aim to help improve this clarity and transparency to build trust and confidence between Ofwat, the service providers and customers. Before responding in detail to the questions posed in the consultation, our main comments are:

1. Reliability, resilience and sustainability are conflated in the consultation document. Additionally, when a definition is posed, its concepts are usually elaborated upon directly afterwards. The concepts within the proposed working definition are currently not clearly explained. We provide guidance on the differences between the concepts and how to elucidate them in response to Q1;
2. A number of different types of resilience are referred to throughout the document (we list them in response to Q1), but without clearly articulating to service providers whether each type could or should be addressed in their actions to build overall resilience. A summary of these types and how they could be addressed is warranted (we help with this in response to Q3);
3. Responsibilities for delivery are implicit rather than explicit, with a certain amount of reading between the lines required. We encourage greater clarity on this and make suggestions in this regard in response to Q2;
4. A much clearer distinction needs to be drawn between building resilience and achieving resilience. Service providers will be responsible for delivering, assessing and reporting on resilience (potentially via independent audit). Monitoring the achievement of resilience is, in our opinion, the role of Ofwat based on a set of resilience indicators or standards. It is presumed that Ofwat's indicators will be clearly and transparently made available to service providers. This will enable them or their independent assessors to consistently apply a common set of indicators and also allow Ofwat to undertake cross-comparisons. We provide guidance on potential indicators and methods of assessment in response to Q3.

Q1 Is our basic understanding of resilience aligned with your own – are we addressing the right things in the right way?

Despite best efforts, concepts and terms are conflated and used incorrectly throughout the document. It is important to get these right the first time in order to address the right things in the right way. Reliability is not equal to resilience and thus the very title of the document is misleading: 'reliable services' are equated to 'resilience', which is incorrect. To clarify, we

contend reliability pertains to minimising level of service failure frequency under normal conditions (i.e. maximising compliance), but resilience pertains to minimising level of service failure magnitude and duration under extreme conditions. This is reinforced by the ‘Keeping the Country Running’ report (2011), which is quoted (but seemingly misunderstood), which highlights that reliability is one of the foundations of resilience (along with redundancy, resistance and response/recovery) and therefore the two are not the same thing. The S&S way of illustrating the relationship between reliability, resilience and sustainability is shown in Figure 1, emphasising that reliability is the foundation for resilience and resilience the foundation for sustainability. The current proposed Ofwat definition of resilience includes an element of sustainability (“now and in the future”), which is understandable due to the way the Duty is described in the Water Act. However, the temporal element should be acknowledged as a feature of sustainability that converges with, rather than is part of, resilience. This will help service providers better consider how sustainability and resilience relate to each other. Park et al (2013) provide more guidance on this.



Figure 1 The relationship between reliability, resilience and sustainability (the Safe & SuRe pyramid (Butler et al., 2014))

Whilst the proposed definition of resilience given on page 10 broadly aligns with well-established grey literature and academic definitions of resilience, it is not the only definition given in the document. There are other definitions peppered throughout the document. Aside from the proposed working definition (pg 10/14, given here first), the following alternative meanings are also offered:

- Pg 10/14 - “Resilience is the ability to cope with, and recover from, disruption, trends and variability in order to maintain services for people and protect the natural environment, now and in the future.”
- Pg 5 - “They [customers] may not call this resilience, but resilience is reliability in the broadest sense, and that is the way in which we are using ‘reliable’ in this consultation.”
- Pg 22 - “But resilience is not just about disruptions. It is about maintaining a quality service for the long term at a price that current and future generations can afford.” This

definition of resilience includes affordability and is phrased very similarly to existing definitions of sustainability.

- Pg 24 - “And resilience – what customers want and rely on - will mean different things to different customers; and different things at different times; as well as in different places.” This definition effectively implies resilience is anything!
- Pg 27 – “Resilience is about deviations from standard service for any reason, not just loss of service for extreme reasons.”
- Pg 28 – “Resilience means the need to seek to avoid service disruptions as well as to bounce back from them if they do happen.”
- Pg 28 – “resilience as efficiency.” Resilience is not efficiency. However, improving resilience may facilitate improved efficiency and vice versa.

This is an issue of clarity and any documentation produced on resilience should be consistent in the words and phrases it uses to describe types of resilience, resiliency and resilient systems or services. To facilitate this, the words (concepts) within the proposed definition need to be explained in turn and then used consistently throughout any associated guidance. Here we propose definitions using S&S terminology as a guide (Butler et al., 2014). Please note that in the descriptions below the term ‘system’ could apply to any type of system (e.g. infrastructural, financial, organisational):

- Sustainable – the degree to which the system maintains levels of service in the long-term whilst maximising social, economic and environmental goals;
- Resilience – the degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional conditions [extremes];
- Reliability – the degree to which the system minimises level of service failure frequency over its design life when subject to standard loading [normal conditions];
- Threat (‘disruption, trend, variability’) – any actual and/or likely event with the potential to reduce the degree to which the system delivers a defined level of service. Can be internal or external to a system and includes knowns and unknowns;
- Impact – the degree of non-compliance with the defined level of service [results from a threat];
- Consequence – any outcomes and effects of the impacts (i.e. non-compliance with a level of service) on each pillar of sustainability;
- Cope – any preparation or action taken to reduce the frequency, magnitude or duration of an impact on a recipient (society, economy, environment);
- Mitigate - reduce the threat;
- Adapt – efforts to increase system reliability and resilience;
- Learn – embed experiences and new knowledge in best practice;
- Recover – regain the ability to deliver and comply with a defined level of service.

The relationship between these concepts is illustrated in Figure 2.

In addition to these concepts and definitions, the types of resilience hidden throughout the document need to be more clearly summarised and articulated. We found the following types of resilience mentioned:

- Water sector resilience (page 9) – this will be the culmination of all stakeholder efforts, not just service providers;
- Service resilience (throughout);
- System resilience (throughout);
- Asset resilience (page 12, 23);
- Ecosystem resilience (page 10);
- Customer resilience (page 11, implied throughout);
- Market resilience (page 16);
- Planning resilience (page 16);
- Corporate (organisational) resilience (page 7, 16, 19);
- Financial resilience (page 7, 19)
- Water resource resilience (page 27);
- Water environment resilience (page 27)
- Skills resilience (page 28).

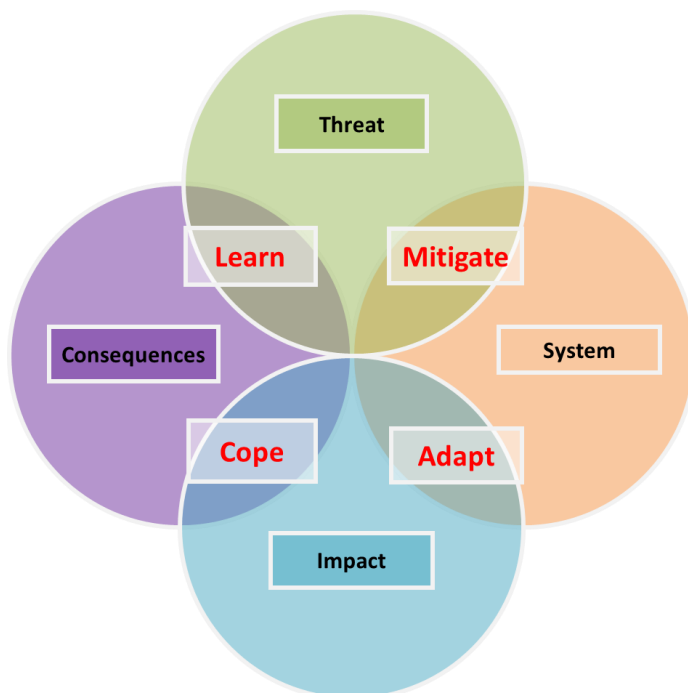


Figure 2 Building reliability, resilience and sustainability - the Safe & SuRe conceptual framework

Approaching resilience assessment by focusing on an impact to a service, system or other type, rather than the actual threat, means that unknowns can be included. We agree that it is impossible and inappropriate to identify all threats (or 'risks'), therefore identifying the ways in which a component or system or service may react to a threat (e.g. a pipe fails; the

impact of which affects water pressures throughout the network) negates the need to identify the actual threat causing the failure (Mugume et al., 2015a, b). Assessment should focus on the ability of the existing system or component to cope and recover from failures, impacts and consequences (through quantification of stress via measuring magnitude and duration). If they are deemed not resilient enough, mitigation, adaptation, coping and learning interventions will need to be modelled to determine their effect on resilience (how magnitude and duration of stress vary), before interventions are then implemented. This will help Ofwat, service providers and customers better understand how each aspect of the sector is dealing with resilience. Use of the concepts, their definitions and the types of resilience listed, will help make more transparent how each of the case studies included in the consultation document is actually 'resilience in action'; currently this is not at all clear. As an example, we have taken the first case study (page 6) and shown how the types, concepts and definitions map to it:

Affinity Water's Resilience in Action

Type of resilience: ecosystem, customer

Threat: relieving pressure on the environment

Failure mode: reduced abstraction based on environmental need and customer motivation

Impact: deficit of 42million litres a day by 2020

Consequence: social - reduce customer demand and leakage; economic – keep bills below rate of inflation; environment – ecosystem pressure relieved

Cope: work with customers to enable them to use 10l less per day

Adapt: improve infrastructure reliability to reduce leakage by 14%

Learn: embed and share cope and adapt actions in general practice

Recover: demand can be met with a reduced volume of supply

Finally, "resilience risks" is a confusing term given the variety of existing approaches to risk ('uncertainty') management. Based on the S&S terminology perhaps "threats to resilience" would be a better phrase to use in relation to 'what-if' scenarios, as risk assessment and management is usually based on probability estimations. Resilience can focus on whether systems can overcome failure (or not), whether that failure is predicted or not (i.e. not probability-based).

Q2 Do you agree with our view of what Ofwat should deliver, including where we might step in, and what is for others to deliver?

There is a hidden emphasis on the assessment, delivery and reporting of resilience by service providers in collaboration with its customers, including community groups, local authorities, business partners and linked sectors. However, it is unclear as to exactly what these non-service provider partners are to deliver. We agree that, due to the individual nature of each service provider and their 'knowing their patch best', service providers should be responsible for delivering and assessing their own resilience. However, to avoid a mere re-branding of everything they do as 'resilience' due to a lack of clear definition with poorly elucidated concepts and loosely defined assessment methods, we encourage Ofwat to provide substantially more detail when they are compiling their final document and the

proposed framework for assessment that they will use (page 20). We provide information that may be useful in this respect in response to Q3. At present it is implicit rather than explicit that service providers should assess, deliver and report on resilience building and that Ofwat will provide guidance where needed and report on achieving resilience across the water sector. This needs to be clearly stated in a single paragraph, rather than hidden in different sentences throughout.

There is an emphasis on meeting the levels of service customers expect, but also recognition that the cost of meeting higher expectations may not be realistic. It is not clear whether acceptable levels of service under normal and extreme conditions have been elucidated by service providers through engagement with customers. As acknowledged by the proposed resilience definition, coping with and recovering from threats, impacts and consequences is key to resilience. Resilience is not about eradicating all threats, therefore levels of service will be affected under certain conditions/failure modes. The consultation says “Customers themselves are part of this system” and as such they need to be resilient too. That is they need to be able to cope with and respond to impacts and consequences of varying frequencies, magnitudes and durations.

Ofwat should emphasise the need to work with CCWater, service providers and customers to increase awareness of the role residential and business customers play in contributing to the types of resilience listed and the levels of service they find acceptable. If this is not undertaken in a comprehensive way, Ofwat and service providers may alienate customers from the decision-making process, which is counter-productive to building trust and confidence.

Q3 What views do you have on how the water and wastewater sector might measure its performance in delivering resilient services – and the best way for us to demonstrate that we are carrying out our role?

To create a framework that encourages, incentivises and enables the sector to deliver resilience Ofwat needs to formulate guidance on indicators and assessment based on the responses to this consultation. The current ‘resilience principles’ given in the consultation document are not strong enough to guide service providers to assess, deliver and report on resilience. These resilience principles relate to Ofwat duties wider than the resilience duty and should therefore not be called ‘resilience principles’, as this is confusing. Perhaps renaming them something along the lines of ‘Principles to Build Trust and Confidence’ would be more appropriate. The seemingly under-used 2012 document “Resilience – outcomes focused regulation: principles for resilience planning” (Ofwat and Mott MacDonald, 2012) provides a tighter set of 9 principles, to which Ofwat should refer back to and consider operationalising. To be outcome-focused, there needs to be a method of objectively assessing outcomes, which the methodology provided in that 2012 report could facilitate.

Whilst understanding the need for a flexible approach from Ofwat (to ensure service providers act creatively rather than just doing enough to comply), we believe there is currently inadequate guidance on indicators for assessing resilience. Unless provided with an assessment framework with which to work, independent assessment could lead to an

inability to undertake cross-comparisons, which would hinder Ofwat's furthering of its resilience duty. For Ofwat to carry out its role it should benchmark how service providers and others are assessing and operationalising the resilience definition. To enable this, Ofwat needs to provide a clear approach to assessment that need not include targets or a standard or be intervention specific, but should show that there is a common methodology to be used by partners across the sector. Otherwise a range of different methods could be developed across the sector by service providers and independents. If this happens, how will Ofwat ensure that the methods developed are comparable?

There are a number of starting points for resilience indicator and assessment development. For example, resilience could be assessed for each of the types of resilience outlined in response to Q1 across the three primary tasks of service providers, those being provision of:

- Water supply and distribution;
- Drainage and flood control;
- Wastewater treatment and disposal.

We suggest that both qualitative and quantitative indicators may be required. This type of framework is specific yet flexible enough for service providers to apply it to doing ".....different things in different ways" (page 19).

The consultation also asks for guidance ".....including any useful stress tests they may perform." In response to Q1, we briefly touched on the idea that threats (disruptions) need not necessarily be identified. Instead the focus becomes how the system fails in order to assess how it can be made 'safe to fail' rather than totally 'fail safe' (as is expected under current levels of service). This is also known technically as 'middle state' focused and middle states refer to the failure modes of the system, which can be further explained as degrees of stress to a system that result in performance strains (leading to impacts and consequences). A stress could be the number of pipes that break and the corresponding strain could be the number of customers supplied who may be affected. This can be displayed graphically as a stress-strain curve, as exemplified in Figure 3, where the red, blue and green lines represent the stress-strain responses of different systems, with the green line representing the most resilient system. Service providers and other partners across the sector could use graph theory (Yazdani et al., 2011), synthetic water distribution and urban drainage networks (Mugume et al., 2015a) and/or physically based modelling approaches to examine resilience by testing different interventions and analysing results. The latter enables more realistic representation of system-specific interactions between structure (failed components) and function (performance). These types of analysis are being explored by the S&S research team for different systems (Mugume et al., 2015b; Diao et al., submitted).

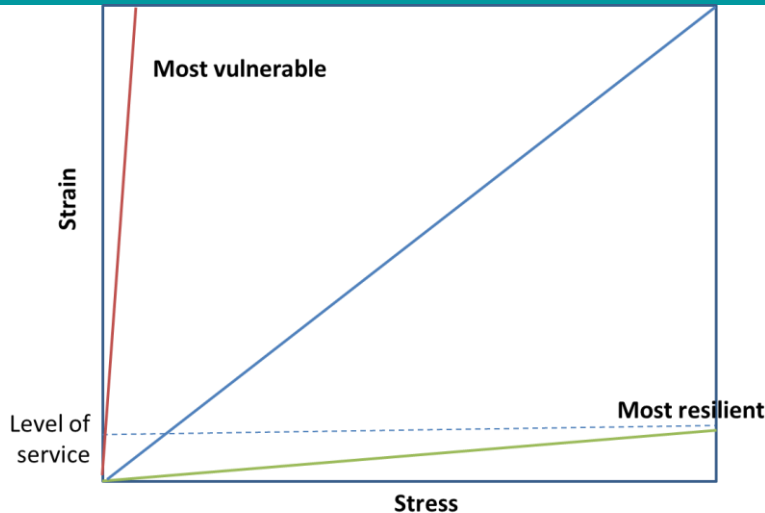


Figure 3 Middle state stress-strain curves (Butler et al., submitted)

For example, a service provider may use the indicator of investment diversification for financial resilience, as they have examined the effect of a particular adaptation intervention on failure modes and identified that it will minimise the level of service failure magnitude and duration and the resulting impacts and consequences. In summary, outcomes resulting from any proposed interventions must be articulated as an increase in the ability to cope with and recover from failures and related impacts and consequences for each type of resilience. This will enable Ofwat to show how it has guided the companies to demonstrate their action on overall resilience.

References

- Butler D, Farmani R, Fu G, Ward S, Diao K, Astaraie-Imani M. (2014) [A new approach to urban water management: Safe and sure](#), *Procedia Engineering*, volume 89, no. C, pages 347-354, DOI:10.1016/j.proeng.2014.11.198.
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Resilience Task and Finish Group Questionnaire Responses

Q1

This is our working definition of resilience for the water and wastewater services provision: ***'Resilience is the ability to cope with, and recover from, disruption, trends and variability in order to maintain services for people and protect the natural environment now and in the future'***. Do you agree with this definition?

Yes

No

If you answered 'no', please explain your answer (approx 100 words):

The proposed definition is a mix of resilience (ability to cope with disruption) and sustainability (for people and natural environment now and in the future). A resilience definition should be just that and focus purely on resilience; a separate definition should be referred to for sustainability. Whilst the proposed definition is akin to that given in the Water Act's Resilience Duty, we believe such definitions erroneously conflate the two concepts, which could create problems when water service providers try to operationalise them. Instead, we would advocate clearer definitions and terminology, such as those used within the Safe & SuRe project (Butler et al, submitted). This would provide clarity in relation to reliability, resilience and sustainability and how each builds on the other. The definitions we use are:

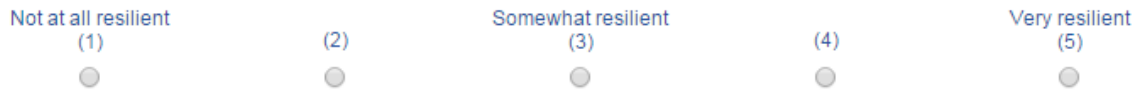
- Reliability - minimising level of service failure frequency under normal conditions (i.e. maximising compliance)
- Resilience - minimising level of service failure magnitude and duration under extreme conditions.
- Sustainability - the degree to which the system maintains levels of service in the long-term whilst maximising social, economic and environmental goals.
- People and the environment are implicit throughout all of these definitions, as 'levels of service' could relate to maintaining services for people (e.g. pressure of supply, DG2) or protecting the environment (e.g. preventing discharges in breach of BOD/ammonia consents).

Having three clear, operational definitions is better than having one definition that is confusing and not workable.

Butler, D., Ward, S., Astaraie-Imani, M., Diao, K., Sweetapple, C., Fu, G. and Farmani, R. (submitted) Reliable, resilient and sustainable water management: the Safe and SuRe approach. *ASCE Journal of Water Resources Planning and Management*.

Q2

Based on this definition, to what extent do you think the UK water and wastewater services sector is resilient?



To what challenges / risks do you think the sector is (or is not) resilient? (approx 100 words)

Somewhat resilient.**Why do think the sector is (or is not) resilient? (approx 100 words)**

In order to determine whether the sector as a whole is resilient, the resilience of different parts ('systems') of the sector need to be assessed (e.g. service resilience, system resilience, asset resilience, customer resilience and so on) in relation to a range of known and unknown threats (i.e. answering the question 'resilience of what to what?'). For example, some regulators or water service providers may be more resilient than others and within each organisation there will be areas that are more resilient (i.e. better able to minimise level of service failure frequency, magnitude and duration) by being well equipped to respond to known and unknown threats. Dealing with uncertainty is part of a resilience-based approach, which is in contrast to a risk-based approach (which focuses on probability and severity). For the sector to more fully embrace resilience-thinking, ways of responding to unknown threats are required. To do this tools that go beyond current risk-based approaches will need to be developed. Some regulators and water service providers have demonstrated their ability to learn from the impacts and consequences of past threats, which indicates to a degree the capacity to build internal resilience. For the sector as a whole to be resilient, however, requires wider resilience within the external socio-economic systems with which it interconnects.

Q3

Does your organisation have plans and/or planning processes in place to address water and sewerage resilience within your organisation?

Yes

No

- If you answered 'yes' please provide a few details (approx 250 words) including:
- How often are these plans updated and what are they based on?
- Is your whole organisation aware of these plans?
- Do you share these plans with other organisations?
- How much do other organisations contribute to your plans?

If you answered 'no' please briefly explain why not (approx 100 words):

The University of Exeter has in place a sustainability strategy, which is reviewed annually and includes services relating to water, sanitation and drainage. This strategy is based on

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current best practice and consultation with a range of internal and external stakeholders. The strategy is available on the institutional website and therefore available to internal and external people and organisations (e.g. <http://www.exeter.ac.uk/sustainability/energyandwater/>). Implicit within this strategy is the building of resilience of systems that provide these services i.e. their ability to minimise level of service failure frequency, magnitude and duration. By taking action to implement interventions such as mitigation (greenhouse gas emission reductions), adaptation (alternative water systems such as rainwater harvesting), coping (temporary measures such as additional services) and learning (improving best practice inline with experience), the University is increasing its resilience and at the same time strengthening its sustainability.

Q4

How do you evaluate, or test for, resilience within your organisation? And which segments of your organisation are evaluated or tested? (approx 100 words)

N/A. We are a research centre within a University, not a water service provider; therefore we are unable to comment directly in relation to what is required by this question. However, what we can say is that there is an urgent need for ways and means to measure, assess and compare resilience, whether in the form of metrics, indices or multi-criteria analyses. Ofwat is trying to create a framework that encourages, incentivises and enables the sector to deliver resilience. However, guidance (whether from Ofwat or others) is required on indicators and assessment based on the responses to this questionnaire and Ofwat's consultation on resilience. The current 'resilience principles' given in Ofwat's consultation document are not strong enough to guide service providers to assess, deliver and report on resilience.

Q5

Do you think that the same strategies can be used to ensure resilience to long term trends and short term shocks?

Yes

No

Please explain your answer, and provide examples of relevant long term trends and short term shocks (approx 100 words):

Responding to the impacts and consequences of chronic (long-term e.g. population growth or climate change averages) or acute (short-term e.g. climate change extremes or natural hazards) threats will likely require different interventions, though there may be some commonality across both. Differences in appropriate interventions are more likely to arise from the need to reduce the magnitude and duration of the impacts and consequences resulting from the threats on a particular system. We provide a useful categorisation of internal/external and chronic/acute threats in the previously referenced paper (as well as a categorisation of impacts and consequences).

Q6

What are the top three key things that would promote resilience in the water and wastewater services sector? (approx 500 words)

1. A clear definition of resilience and the terms contained within such a definition to enable a full understanding of what resilience actually is across all sector organisations (internal and external to the sector);
2. Recognition that resilience builds on reliability and towards sustainability, but that resilience is not in itself sustainability;
3. Development of a quantitative and/or qualitative 'toolkit' to assess (and/or measure) resilience (in its many forms) across the sector. Water service providers need guidance from regulators in this in order to give them confidence that what they are actually doing is building resilience and not just 'business as usual' or 'sustainability' but by another name. For example, interventions (whether green or grey) will need to be modelled and their effects on a system assessed (based on a number of performance outcomes) before they can be deemed as 'increasing resilience'.

Q7

Whose responsibility should it be to ensure resilience in the water and wastewater services sector?

Please enter 1, 2 and 3 next to your top 3 choices (with 1 as your most preferred)

- National government departments
- Other (please specify)
- Water companies
- Cabinet Office
- General public
- Water regulators
- Local governments
- NGOs
- European institutions

- 1 Water Companies
2 Water Regulators
3 General Public

Lloyd's Register Foundation Resilience Engineering Priorities consultation response

Dear Professor Bruno,

Thank you for providing the opportunity to respond to your report on resilience engineering.

The Respondent

This response has been compiled by the Safe and SuRe (sustainable, resilient) project research team from the Centre for Water Systems, University of Exeter (UK) led by Professor David Butler. The project is funded from 2013 to 2018 by the UK's Engineering and Physical Sciences Research Council. The Safe and SuRe (S&S) project has reliability, resilience and sustainability as core concepts in its conceptual and analytical frameworks and therefore the confidence with which we are commenting is high.

Whilst the S&S project focuses on water management, the framework it has developed could be applied across various sectors where resilience engineering approaches are being utilised. In our response we have therefore provided direct research-informed comment. For further information please refer to the project website (safeandsure.info) and/or contact Professor Butler (d.butler@exeter.ac.uk). Further details on the S & S project are given in the paper referenced below, which can be directly accessed at the link provided.

- Butler D, Farmani R, Fu G, Ward S, Diao K, Astaraie-Imani M. (2014) [A new approach to urban water management: Safe and SuRe](#), *Procedia Engineering*, volume 89, no. C, pages 347-354, DOI:10.1016/j.proeng.2014.11.198.

Please ensure to reference this paper where any information from this response is used within any documentation produced as a result of the consultation. A further forthcoming paper may be of interest and we would be happy to provide a copy once it is published:

- Butler, D., Ward, S., Astaraie-Imani, M., Diao, K., Sweetapple, C., Fu, G. and Farmani, R. (submitted) Reliable, resilient and sustainable water management: the Safe & SuRe approach. *ASCE Journal of Water Resources Planning and Management*.

To date the S&S conceptual framework has been formulated and applied in different analytical contexts. A summary of information is provided in Appendix 1 for interest and reference.

Our Response

- We agree that the term resilience has been used across disciplines and in relation to multiple systems. Point 8 notes resilience as an 'emergent property' and we believe discussion of or research into the relationship between properties and performance [of systems] could be useful – S&S is currently taking this approach. This would also facilitate cross-consideration of the relationship between resilience and structural integrity & systems performance (the latter of which is also the subject of a Foundation consultation being undertaken by Professor Michael Fitzpatrick);

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- We also agree with the statement in Point 13 that "What matters is preserving critical functionality, not the pre-existing system". This is an important focus for ongoing research, particularly for the water sector where there are a number of interventions (such as alternative water supply systems) that are outside the existing system/regime but could potentially enhance functionality;
- S&S has defined resilience in relation to levels of service under exceptional conditions (refer to Appendix 1 for further detail). Whatever the definition, there is always the question to ask: 'resilience of what, to what', which the examples provided in Point 10 demonstrate;
- Point 11 – we agree with this point, in that there has been a lot of qualitative research on resilience, but limited quantitative research across the different engineering disciplines. Discussion is often focused on many definitions as opposed to a practical application of the concept in standards or calculations. We would suggest this would be a good place to focus further research. The S&S framework helps set out a common language and it could be usefully applied to numerous disciplines. S&S is also developing and applying quantitative methods and recent publications to refer to include: Casal-Campos et al. (2015), Diao et al. (submitted), Mugume et al. (2015a), Mugume et al. (2015b), Behzadian et al. (2014) and Diao et al. (2010). Additionally Ofwat and Mott MacDonald (2012) produced a document regarding resilience planning;
- Boxed Consultation Points – for examples of the application of resilience engineering to modelled engineered systems please refer to above references (full references in list at the end of this response). Additionally, in parallel with the Foundation's consultation, there is a consultation open in the UK at present (until 28th August 2015) on the water sector's financial regulator's Resilience Duty, which was imposed when the Water Act 2014 was enacted. Ofwat's proposed document is very weak, as many terms are conflated (reliability and resilience for example) and it is unclear about how water service providers should assess and improve the many types of resilience (water sector resilience, service resilience, system resilience, asset resilience, ecosystem resilience and customer resilience to name but a few). S&S has formulated a response to help strengthen Ofwat's view on resilience. The outcome of the Ofwat consultation is due towards the end of 2015 and would be a valuable resource for the Foundation to follow in relation to resilience engineering in the UK's water sector. A final report on resilience from the UK to mention is the Cabinet Office's (2011) report, which discusses 'resistance, reliability, response/ recovery and redundancy' as features of resilience, though the S&S project is now taking approaches beyond this as it examines resilience across implementation stages;
- Other case studies gathered by the Foundation could include where a range of interventions (adaptation, mitigation, coping and learning in the case of the S&S project) have been implemented in real world systems and the actual response of the system (via impacts and consequences) to an unexpected threat monitored, measured and its performance against a specific level of service profiled. In relation to this, it would be useful if the case studies gathered by this consultation discussed where

resilience has been specified at the beginning of an intervention and consequently how the characteristics of a system lead to that system responding in a resilient way. This is in contrast to just illustrating where improved resilience may have been beneficial in retrospect and might have resulted in reduced or no system failure (as is currently the case in some of the examples described);

- We suggest that the document needs clarity on the way in which resilience is mentioned in relation to threats. For example, on pg14 it is stated that “floods [...] constitute a challenge to the resilience of several critical functionalities”. We would disagree with this phrasing – providing resilience to floods is a challenge, floods do not challenge resilience. Further to this, we would see resilience approaches incorporating uncertainty, rather than uncertainty being a challenge to the achievement of resilience. With regard to this, S&S has explored top-down, middle-based (or ‘middle/failure state’), bottom-up and circular directions. The middle-based approach considers the failure state of the system to be the point of interest, not the threat (as would be in a top-down approach) and therefore the uncertain nature of the threat can be by-passed. Instead, the many ways in which the system could fail in response to any threat, no matter the origin, becomes the focus and uncertainty is included in the assessment of resilience, rather than being a challenge. If there was no uncertainty, risk and reliability would be enough to quantify probability and severity and resilience would be superfluous;
- Many of the ‘challenges’ highlighted in Table 1 of the consultation document might be better termed ‘Threats to performance’ than challenges, as each in turn relates to a social or technical or socio-technical system. In enhancing resilience we are interested in improving the performance of the system. S&S has developed a 4 quadrant threat categorisation model, which covers external and internal (highlighted in the box at the top of pg 16) and chronic and acute threats (refer to Figure 1 in Appendix 1). We would support the recommendation that future research should examine the implications of resilience approaches of known and unknown threats to performance. Awareness should also be raised that potential solutions (‘interventions’), such as those listed in Table 1, do not necessarily guarantee resilience and there may be trade-offs between level of resilience and social, economic or environmental consequences such as cost or level of service;
- In response to Point 29, we would argue that the suggested approach, to build capability in identifying all threats (termed ‘all hazards’ by some scholars) is inappropriate and would be far too resource intensive in respect to both time and money. Instead, where appropriate, the aforementioned middle-based approach should be utilised where the system failure state becomes the focus. Identifying the ways in which a system can fail independently of the threat is a more achievable option and negates the requirement for probability estimations/distributions, thus moves beyond purely risk-based approaches to resilient approaches. Reducing the foreseeable probability of failure will reduce risk but not necessarily improve resilience – resilience is about minimising disruption not the likelihood of that disruption happening. For unknown threats, what is needed are approaches to assessing the impacts and

consequences of failure, so that interventions can be developed and implemented accordingly to minimise disruption. In summary, we would recommend that future research should develop resilience engineering approaches for sectors based on all of the directional approaches: top-down (known), middle-based (unknown), bottom-up and circular (known/unknown), as highlighted in the S&S framework. Consideration of the acceptability of 'safe to fail' rather than 'fail safe' systems should also be researched, as current levels of service may be unsustainable and therefore in order to be resilient some systems may have to be safe to fail rather than fail safe (as is the norm in current engineering – the 'acceptable outcomes' approach);

- Based on this, new metrics, indicators and methods of performance assessment for both tangible and intangible costs and benefits may be required and we agree that research in this area is critical and should engage with big data and community-based approaches. Current UK Research Council projects are assessing how data that already exists can be used to improve the resilience of systems and this type of research should be further supported;
- Resilience approaches are inevitably cross/trans/inter disciplinary, as the consultation document emphasises. Future research that examines cross-organisational communication and the understanding and operationalisation of resilience planning would be vital to further resilience agendas;
- Point 38 (and generally this section) – there is ongoing work in the UK to establish the UK Collaboratorium on Infrastructure and Cities (UKCRIC1), which will lead world-class research. The Foundation could perhaps explore co-funding routes into the development of facilities and tools to support resilience research and the furthering of knowledge and socio-technical development;
- Point 40 - we would welcome the establishment and funding of a global network for researchers, practitioners and policy/decision makers, working in the field of or trying to apply resilience engineering, perhaps with national 'hubs' feeding into a global centre. Such a network would need to be tasked with making the latest resilience engineering research highly visible, which would require political presence and strategic action;
- Points 44, 49 and 55 – we would also support the assertion that funding is required for research that examines (a) the interplay of resilience engineering and societal resilience through public/community engagement and capacity building approaches and (b) the global complexity of resilience in layers of complex systems (such as some of those mentioned in subsequent points);
- Points 64-66 – The S&S project team would be very interested in collaborating with the Foundation to develop the field of resilience engineering, particularly in relation to guidance, publications, training and development (at all levels), public engagement, measures, tools, methods, interventions and knowledge exchange. We will certainly be

¹ <http://ukcric.co.uk/>

assisting in the achievement of the aims outlined in points 65 and 66 and would therefore be happy for the Foundation to contact us to discuss opportunities.

Appendix 1 – The Safe and SuRe project



Figure 1 The relationship between reliability, resilience and sustainability, the Safe & SuRe pyramid (Butler et al., 2014)

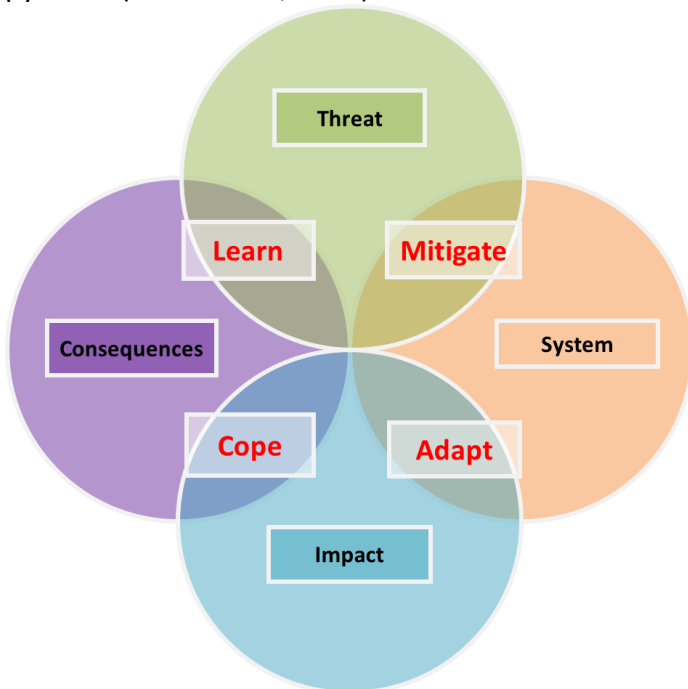


Figure 2 Building reliability, resilience and sustainability - the Safe & SuRe conceptual framework (Butler et al, submitted)

S&S terminology and definitions (Butler et al., 2014; submitted) are provided below; the relationship between these concepts is illustrated in Figure 2. Please note that the term ‘system’ could apply to any type of system (e.g. infrastructural, financial, organisational):

- Sustainable – the degree to which the system maintains levels of service in the long-term whilst maximising social, economic and environmental goals;
- Resilience – the degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional conditions [extremes];
- Reliability – the degree to which the system minimises level of service failure frequency over its design life when subject to standard loading [normal conditions];
- Threat ('disruption, trend, variability') – any actual and/or likely event with the potential to reduce the degree to which the system delivers a defined level of service. Can be internal or external to a system and includes knowns and unknowns;
- Impact – the degree of non-compliance with the defined level of service [results from a threat];
- Consequence – any outcomes and effects of the impacts (i.e. non-compliance with a level of service) on each pillar of sustainability;
- Cope – any preparation or action taken to reduce the frequency, magnitude or duration of an impact on a recipient (society, economy, environment);
- Mitigate - reduce the threat;
- Adapt – efforts to increase system reliability and resilience;
- Learn – embed experiences and new knowledge in best practice;
- Recover – regain the ability to deliver and comply with a defined level of service.

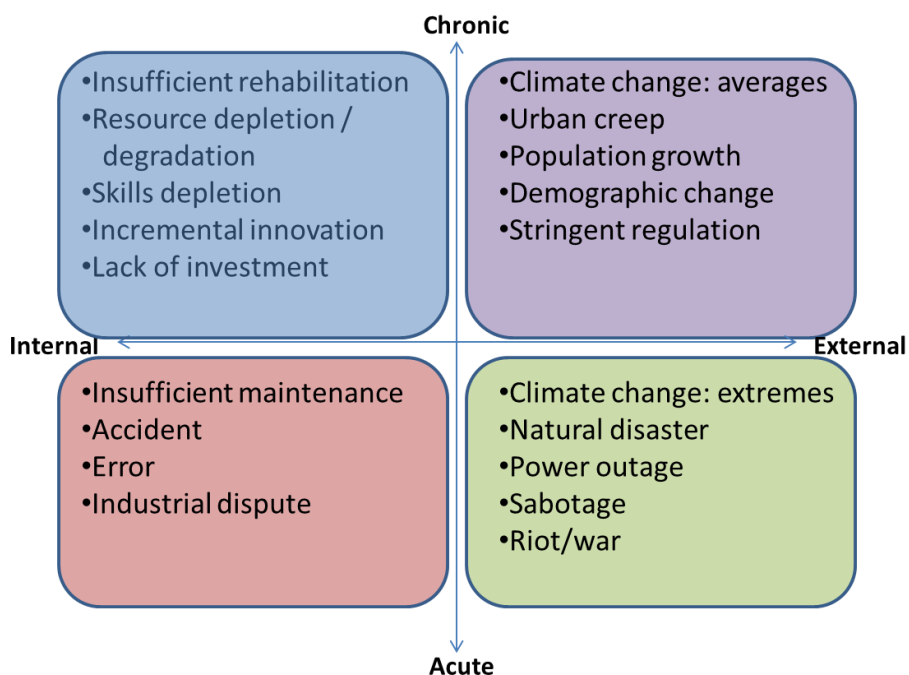


Figure 3 The four quadrant threat categorisation used within the Safe & SuRe project (Butler et al., submitted)

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EA Water Company Drought Plan Guidelines Consultation Response

This response has been compiled by the Safe and SuRe (sustainable, resilient) project research team from the Centre for Water Systems, University of Exeter led by Professor David Butler in conjunction with Geography from the College of Life and Environmental Sciences. The Safe and SuRe (S & S) project has developed a Threat-System-Impact-Consequence approach to reliability, resilience and sustainability of the water sector and we have provided direct research-informed comments in this response.

We are formulating our reply in this format, as we are responding to one question only, which is Q9:

“Please tell us if you have any other views or comments on these proposed changes that have not been covered by previous questions.”

After a section on General Comments we focus on some of the specific areas in the guidelines, which are covered in sections with sub-headings in bold. Our recommendations are formatted in bold italics for clarity.

General Comments

Resilience – this is a concept and approach that is receiving wide attention throughout the water sector. Currently resilience is only mentioned on page 21 in relation to the Habitats Regulations Assessment in the context of reducing a feature’s resilience against man-made or natural changes. As a document guiding water companies to plan for drought, ***greater mention of or reference back/signposting to ways or documents in which they should be planning for resilience would be pertinent, a kin to the numerous mentions of what should be included in emergency plans. This is particularly relevant as it is one of the key recommendations of the National Drought Group.*** Drought plans should propose or facilitate actions that aim to achieve, or improve, resilience of water supply systems and their management to either low rainfall or prolonged dry periods;

How to write a drought plan – this section says that the water companies should consider droughts outside of historical range. There is likely to be much variation in how companies perceive a drought outside of the historical range. ***It would be useful if the EA guidelines could provide further guidance on this, particularly in relation to modelling future (rather than historic) droughts under climate change scenarios. Drought simulation can be subjective and at present there is no reference to ascertaining climate change-derived droughts through the use of UKCP09 data or similar. Again if this should be covered in other documents such as Water Resource Management Plans or Emergency Plans, then they should be signposted.***

Triggers

S & S defines a Threat to be: *“any actual and/or likely event with the potential to reduce the degree to which the system delivers a defined level of service”*.

This is of relevance for drought plans as they would need to include any potential threat that may affect the ability to meet water supply requirements. At present the guidelines

appear to miss that UK droughts tend to be magnified by the actions of non-hydrologic systems, which become triggers. That is, the actions of people in response to changes in systems such as the financial markets can lead to unusually high demands. For example, research into historic droughts shows that almost always droughts become much worse because of a factor unconnected to rainfall. For example, the weak pound in 1976 made the UK a more affordable place to holiday and the number of visitors coming from the rest of Europe increased. The hot sunny weather made beautiful landscapes and coastlines the places to visit and the unusually large visitor numbers led to unusually high water demand in sparsely populated areas that were met by businesses that were not being rationed, which drained the limited resources available to these normally small populations. The outcome may have been different if the weather had not been quite so hot and the exchange rate not quite so favourable. We see visitor pressure as a trigger for other droughts - 1984 for example. Consequently, demand patterns that are initially unexplainable should be included in the list of triggers.

Consideration of non-hydrologic triggers of drought could be better-embedded in the guidelines in the following places:

- ***Preliminary discussions*** section – could be extended to include experts in world markets or the tourism sector;
- ***Page 3: How to write a drought plan and How to identify drought triggers*** sections - Emphasize the need to include non-hydrologic triggers of drought such as anticipating unusual demands linked to world events (see above example). This will require monitoring of current affairs beyond the water sector;
- ***Restrict water use temporarily*** section - water companies should be encouraged to consider in detail how they might restrict water use in potentially vulnerable zones associated with the context of unusually high demands;
- ***Apply for drought permits and orders*** section – a final bullet could be included, such as: an assessment of external non-hydrological events potentially resulting in difficult to predict unusually high demands that could lead to a drought permit/order being required.

To increase the resilience (minimising of service failure magnitude and duration) of the water sector to drought, this is an essential inclusion to make, as it would permit some expansion of the drought order requirements where unexpected increases in demand could be considered alongside consecutive dry winters or short summer droughts.

Maintain supply - Prioritising actions

Currently the guidance recommends prioritising the planning of actions that:

- Are easier to carry out;
- Have limited negative effects on the environment;
- Are of an appropriate scale.

Consideration should be given to those actions which may take slightly longer to carry out, but that may yield greater benefits over those that are purely easy to carry out. Water companies should be encouraged to appropriately assess the trade-offs of all planned actions in order to maximise resilience.

Strategic Environmental Assessment (SEA)

In assessing the effects of actions on the environment water companies may be required to carry out a Strategic Environmental Assessment (SEA). The EA guidelines could give more detail (perhaps via a footnote or supplementary section) on the conditions that would lead to the need for such a large scale policy level study for a drought plan e.g. if there is significant abstraction from several sources over a short period of time requiring the transportation of large volumes of water from one major habitat to another major habitat. On page 22 the guidelines briefly discuss the SEA and refer the water company to check if they need one, but provide no detail on how to do this. Water companies would not want to undertake such a major, costly study unless required and therefore providing examples of when the SEA might be required may be of use. Further on this point, the guidelines require so many detailed environmental studies, but with no clear guidelines as to when these are applicable or at what level one or the other is required.

Consideration should be given to the inclusion of supplementary guidance or sign-posting regarding when all of the assessments listed might be required.

Drought Communications Plan

There is a great deal of focus on increasing public awareness during a drought and encouraging water efficiency as the drought develops. However, in order to promote resilience and improve preparedness, water companies should be encouraged to develop awareness campaigns promoting water efficiency at all times.

This section should highlight the need to develop a communications plan before, during and after a drought. Increasing awareness of the need to be water efficient particularly in locations vulnerable to drought would promote greater resilience through customer preparedness. Again, any relevant documents should be signposted.