Report part 1: Background Information

This essay sets out to provide five recommendations to *regional governance* on improving water security in the Test and Itchen Management Catchment. It investigates the management catchment for key stakeholders that must be considered in making recommendations, the system and subsystems at play in the region and their interactions, what lessons can be learnt from the current initiatives to improve water security, any knock on effects from interventions, and views the recommendations through a net-zero lens to assess their environmental impact.

The United Kingdom's Department for Environment, Food & Rural Affairs (DEFRA) has divided England into ten River Basin districts, generally relating to their geographical location. One of these is the South East district, which itself has 12 Management Catchments defined within it[1]. This way of dividing England's water supply is the result of the Catchment Based Approach[2], enabling on "locally focussed decision making and action," supporting existing river basin management planning. This approach defines a catchment as "A geographic area defined naturally by surface water hydrology.[W]e have adopted the definition of Management Catchments that the Environment Agency uses..."

One of these management catchments is the Test and Itchen Management Catchment, defined by the Environment Agency for water abstraction licensing[3] as the catchments of both the River Test and the River Itchen in Hampshire (see figure 1). The management catchment is predominantly rural, comprising around $1760km^2$ of Hampshire. The Test and Itchen are chalk streams, drawing flow from the groundwater along the northern section of the management catchment.[4] Both of the rivers have been declared Sites of Special Scientific Interest (SSSI) for their biodiversity[5][6], and the Itchen has been declared a Special Area of Conservation (SAC) for the presence of rare fauna [7]. The River Test runs from its source in Ashe to Southampton Water where it meets the Solent, flowing to the west of Southampton. The River Itchen runs from its source south of New Alresford to Southampton Water, flowing to the east of Southampton.

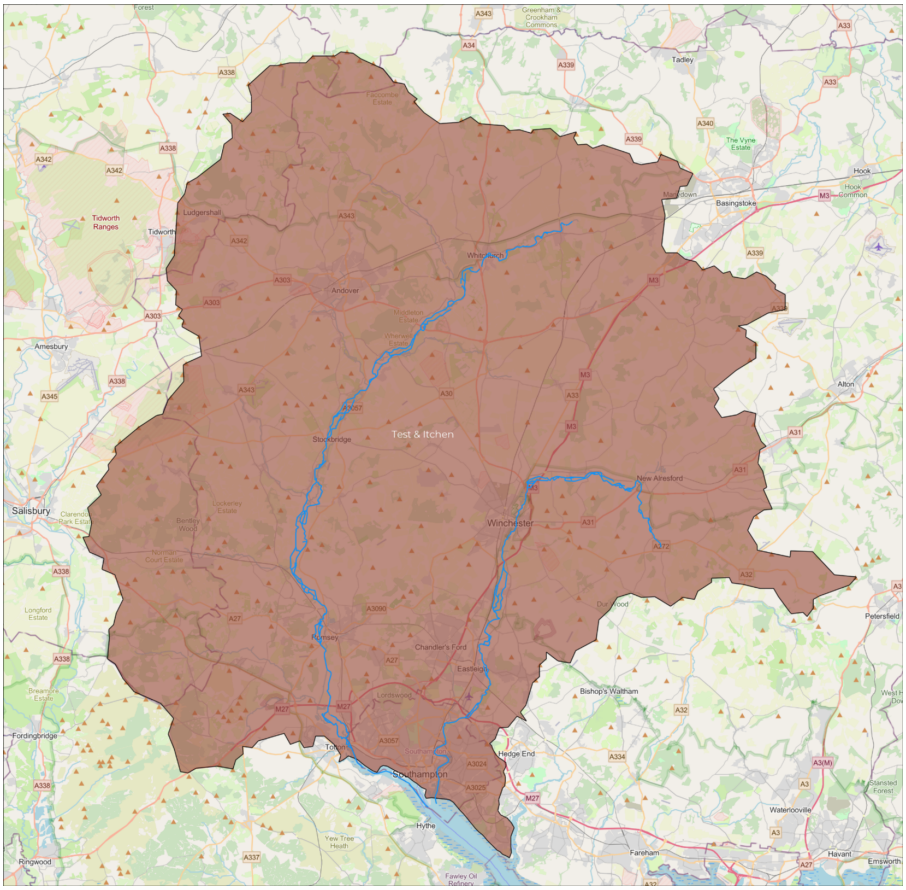


Figure 1: Map of the Test and Itchen Managemenet Catchment[8].

The rivers serve as a major source of public water for Hampshire, with water being distributed throughout

the management catchment as well as to other parts of Hampshire and to the Isle of Wight[4]. The majority of public water in the area is supplied by Southern Water with small sections of the management catchment being served by South West Water, Wessex Water, Thames Water, and South East Water[9] (see figure 2). Additionally, the management catchment encompasses four large settlements: The cities of Southampton and Winchester, and the Towns of Andoever and Eastleigh.

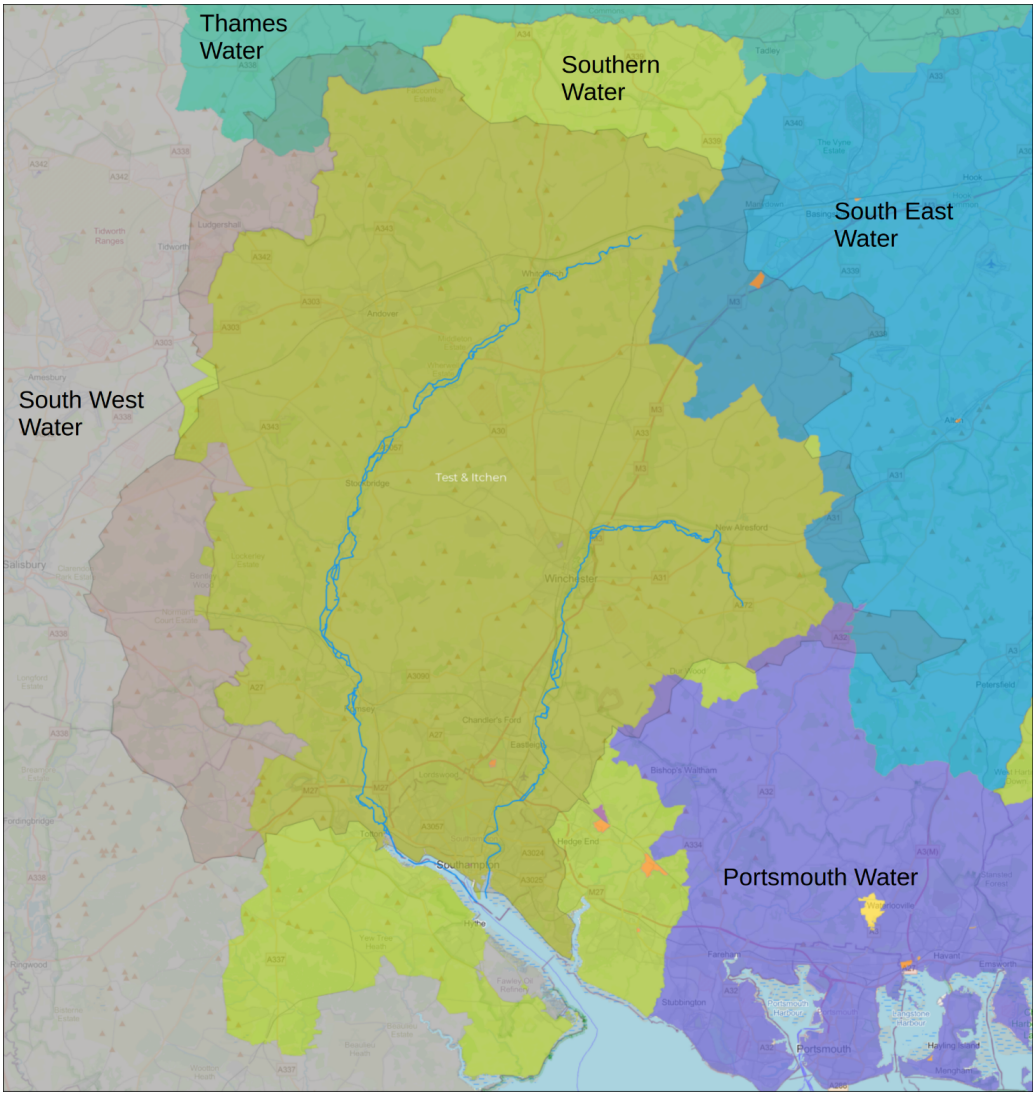
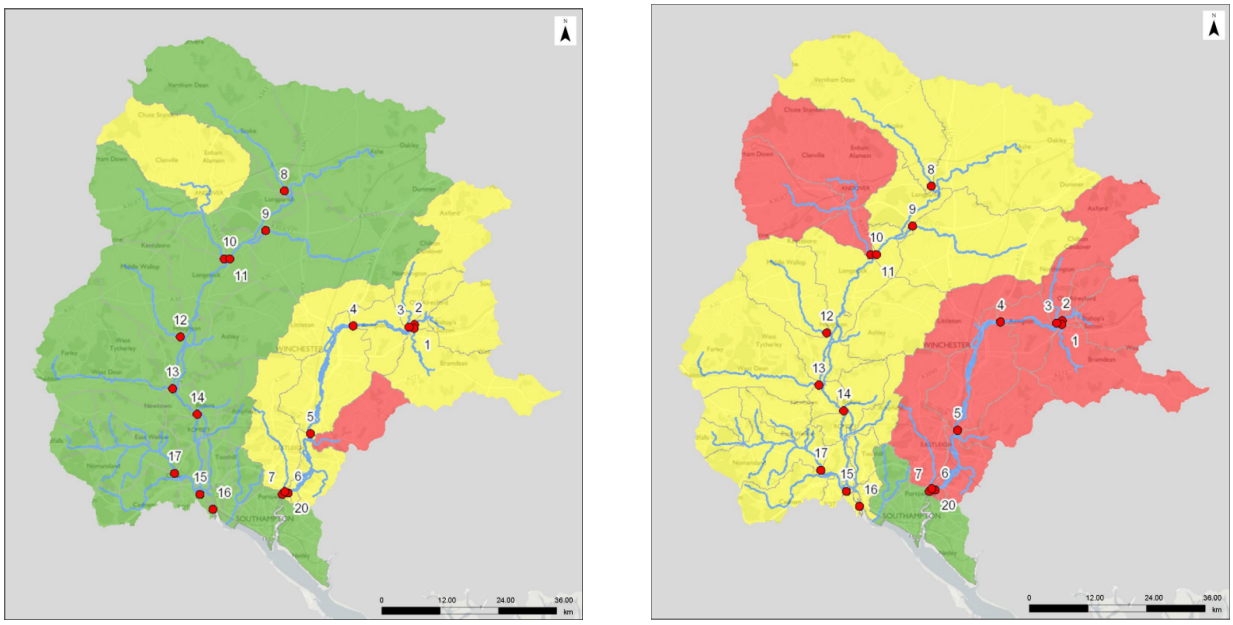


Figure 2: Map of the Test and Itchen Managemenet Catchment, with Water Company shown [8].

Water availability and reliability in the Management Catchment are reported in the Environment Agency's Abstraction Licensing Strategy (ALS)[3], which dictates where individuals and organisations are granted licenses to abstract water from the rivers or groundwater. It shows that from 18 test points along the Test and Itchen that 50% (Q50) of the time, water is available in the majority of the catchment along the Test, but that along most of the Itchen and in Andover only restricted water is avaible (see figure 3a). Across the whole catchment worsens to no water available along the Itchen and in Andover, and restricted water available along the rest of the Test when the flow is at levels exceeded 95% of the time (Q95)(see figure 3b). This has resulted in water being unavailable for licensing along the Itchen in its entirety, and restricted water available for licensing along the Test. Additionally, the abstraction licenses held by Portsmouth Water and Southern Water were reviewed in 2011 and 2019 respectively to improve availability along the Itchen. In Southern Water's case, a "Reduction in annual and daily quanity" was made. Additionally, conditions on minimum flow through Environment Agency guaging stations have been introduced, with the minimum flow increasing for 10 months of the year from 2027[10]

Since



(a) Q50

(b) Q95

Figure 3: Water resource availability colours at Q50 and Q95 for Test and Itchen ALS. Green: Water Available; Yellow: Restricted Water Available; Red: No Water Available.[3]

Report part 2: Assumptions

The following assumptions are made in the analysis to bound the problem space:

1. It is assumed that the needs and impacts of the various independant water companies that operate in the management catchment area, or otherwise abstract water from the Rivers Test and Itchen, are negligable compared to that of Southern Water and Portsmouth Water
2. It is assumed that the needs of areas outside of the management catchment (e.g. the Isle of Wight) remain static and can be modelled as constants.
3. It is assumed that stakeholders respect local authorities, regulators, and other organisations
4. It is assumed that shareholders in public water companies would not unreasonably withold funding from them, and are not operating these companies illegally
5. The debt held by public water companies is ignored
6. The sewage and wastewater systems in the Management Catchment are not considered. This paper focuses on the systems concerning water supply in the region
7. For water supply elements where sewage or wastewater is concern, the flow and processing of this is assumed to be static and monolithically modelled.

Report part 3a: Crtieria for Method Selection

1. Worldview - Positivist or Constructivist?
2. Data availability
3. Accessibility - of method
4. Output Relevance - Not just question but general insight
5. Question Relevance - Does this answer the question?
6. Development - Does it develop output of another method?
7. Facilitaiton - Does it enable another method?
8. Supporting Literature - Is it backed up?
9. Maturity - Is it established?
10. Flexibility - Can I make it fit?
11. Redundance - Is it already covered?

To decide on the systems thinking methods that will answer the questions set out in part 4, eleven criteria have been derived that various methods will be tested against in part 3b. Methods will be given numerical scores for each of these criteria, and those with the highest scores will be selected.

Firstly, what is the worldview that the method leans towards? This paper aims to take a mixed-method approach, meaning a spread of positivist and constructivist worldviews (and thus quantitative and qualitative methods) is desired.

What is the availability of the data that the method requires? Some methods require difficult-to-obtain information to give useful insight or to use the method entirely. Any method to be selected must be usable with publicly-available information, or with information available in academic databases. No method should require commercially sensitive information, or insight from an insider in any of the stakeholder organisations. A method that can be performed with public information but would offer better insight with less accessible infomormation are still viable, though will be penalised against those that are insightful with accessible data.

What is the accessibility of the method? A large number of methods can be performed with a pencil and paper or with a tool in a free digital office suite. Some may require tools only present in commercial office suites, and some require dedicated tools to perform. Methods will be graded on if the tools they require are expensive, difficult to learn, the availability of alternatives (e.g. free and open source software), and whether the tool locks certain options behind a paid license. The time taken to complete the method will also be considered; some methods will take a matter of minutes to produce useful insight, whereas some may take hours or days to be useful. A shorter method will generally be considered more viable.

What is the relevance of the output to the research as a whole? Methods will output data or insight that will be of varying use to this investigation. Some data will be directly applicable to the research questions in part 4, whereas some will be best used as starting points or supporting information to other methods. Methods will thus be selected against their overall pertinance.

What is the relevance of the output to the research question(s)? Whilst methods will be considered in their overall relevance, some methods will produce insight that directly helps to answer one or more of the research questions. These methods will be favoured over those that are not directly applicable but may offer insight that supports these direct methods.

Does the method support the output of another method? Some methods will be able to reinforce or even challenge the findings of other methods. Whilst not necccessarily being the most useful method to answer a question, its outputs build the credibility of other findings and thus the recommendations that come out of them.

Does the method's outputs improve or entirely enable another method? Some methods may require the findings from another method as inputs. Others may find they can be used in isolation, but are more useful when using information gatherd from another methods. Enabling or improving another method will result in a higher score.

Is the method based on good supporting literature? Systems thinking methods are normally introduced in academic journal articles, or by individuals that use them in their work (e.g. consultancy). Methods will be judged on the quality of their foundational material.

How mature is the method? Having a large body of evidence where the method has been used gives credence to the method and its usefulness. It also can improve the quality of its finding, as the evidence can be used as example implementations of the method and may highlight best practice in application. Additionally, methods will sometimes undergo revision in response to feedback from practicioners and participants, which improve their viability. Methods that are mature, have been used often, and have been revised will be preferred.

How flexible is the method to this area of research? Many different disciplines use systems thinking techniques, from healthcare to aviation. Moreover, techniques are often tailored towards different tasks, such as risk management or accident investigation. Methods will be judged on how easily they can be adapted to fit this paper's specific requirements: exploring a problem space, targeting specific areas of that space, or ideation of solutions to these problems. Methods that fit well without adaptation will be given the maximum score.

Is the method covered in its entirety by one or more methods, or does it do the work of multiple methods? Some methods will provide similar insights to other methods, and some will cover the same ground as multiple other methods. Redundant methods will be penalised, and methods that make multiple others redundant will be preferred to reduce complexity.

Report part 3b: Method Selection

- Rich Picture
- Pig Diagram
- CATWOE
- Systemigram
- CLD
- System Dynamics
- Iceberg Model
- N^2
- Cynefin
- RMF
- HTA
- Accimap
- EAST-BL
- SPTA
- VSM
- Ishikawa(Fishbone)

Report part 4: Application of methods and recommendations

To produce the five recommendations, this paper considers six research questions whose answers will inform the recommendations.

1. What key stakeholders are in the Test and Itchen Management Catchment, and what are their worldviews?
    - This is vital for understanding who will be affected by the recommendations, and in understanding any pushback that may arise as a result.
2. What subsystems are present in the system, and how do they interact with each other?
    - This is to see what the major areas of interest are, and where the recommendations should target.
3. What elements of the system are most sensitive to intervention?
    - Like above, this is to ascertain which elements or subsystems should be targeted for intervention.
4. How effective are current initiatives at improving water security, and what can be learnt from them?
    - Much work has been done to manage Britain's water resilience, so understanding what work has already been done will provide solid ground for new recommendations.
5. What negative consequences are likely from interventions in sensitive areas?
    - What are the key issues that may arise from interventions? This way they may be mitigated or the recommendation may be restructured to avoid consequences.
6. What are the greenhouse gas emittors in the system and in current initiatives, and how can they be mitigated?
    - Considering the problem space through a net-zero lens requires an understanding of the current impacts on climate change and thus how they may be targeted to reduce emissions.

To answer these questions, the methods selected in Section 3b have been performed below.

Initially, a Pig Model[11] was created (see figure 4) to satisfy question 1 - who are the key stakeholders and what are their worldviews? The Pig Model was developed as a quick method of identifying key stakeholders in a system, and in understanding how they view the system of interest (SoI). Designed to be performed individually or collaboratively, the Pig Model is used to understand "who to include in... collaborating community." The stakeholders were identified in a brainstorming session following research (see section 1) and using background knowledge, before updating and revising. In this instance, there are nine key stakeholders who will need to be considered in this report:

- Government (National and regional)
- Southern Water
- Environment Agency
- Catchment Partnerships
- Wildlife
- General Public
- Agriculture
- Energy Suppliers
- Industry

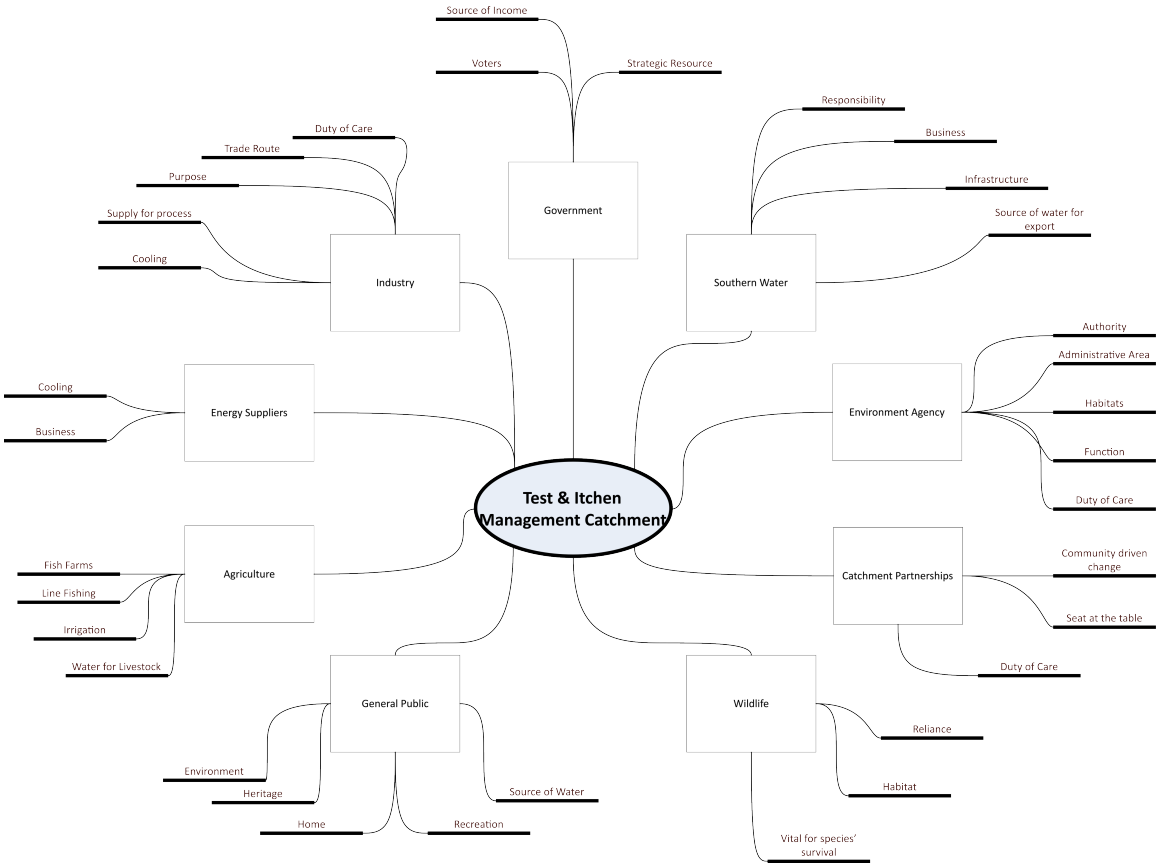


Figure 4: Pig Model[11] instance for Water Resilience.

A large amount of the value of the Pig Model is in its creation; beyond background knowledge, stakeholders and views were identified during drafting. Some of these, for instance Government interest, were previously not captured. Originally this was discounted as most interaction with the management catchment is performed through governmental departments and Quasi Non-Governmental Organisations (QUANGOs) such as the Environment Agency. However, in considering the purposes of the management catchment to the EA, it became clear that some important aspects are without its remit and are instead matters for national government. An example of this is strategic resource. Downstream of the River Test is Southampton Water, on the banks of which is Marchwood Military Port. Marchwood is the home base of the Tide class tankers for the Royal Fleet Auxiliary[12], and Marchwood is also home to the British Army's 17 Port and Maritime Regiment[13].

Additionally, some shareholders were known but viewpoints emerged from the analysis. For example, the General Public were initially identified as stakeholders but seeing the management catchment (and the rivers within it) as "heritage" was previously not captured. An example of this is the Itchen Navigation, a "straightened, controlled and diverted part of the River Itchen". It has a history of over 150 years, and forms the basis of a walking trail promoted by Winchester City Council's Visit Winchester website[14]. It also provided insight into the overlap of views between different stakeholders. Southern Water, Agriculture, Energy Suppliers, and Industry all see the management catchment as a facilitator of their businesses. Some, like Southern Water, are direct in that they exist to supply water from this management catchment to customers. Others, like the Energy Suppliers, are less direct in that they use the water from the management catchment to cool Marchwood Power Station[15].

Following this, a systemigram was drawn to explore the systems at play in the management catchment. Dr. Raquel Radoman's PhD Thesis[16] was used as a guide, along with a workshop at the 2019 SERC Research Review presented by Brian Sauser[17]. The systemigram was constructed by defining root definitions in the form "What to do (P), How to do it (Q) and Why do it (R)?"[18]. Sauser[17] talks about the systemigram as a storyboarding tool, with different scenes representing different interests and viewpoints. Each scene was thus given a root definition and the systemigram is divided into these scenes. The systemigram can be seen in figure 5.

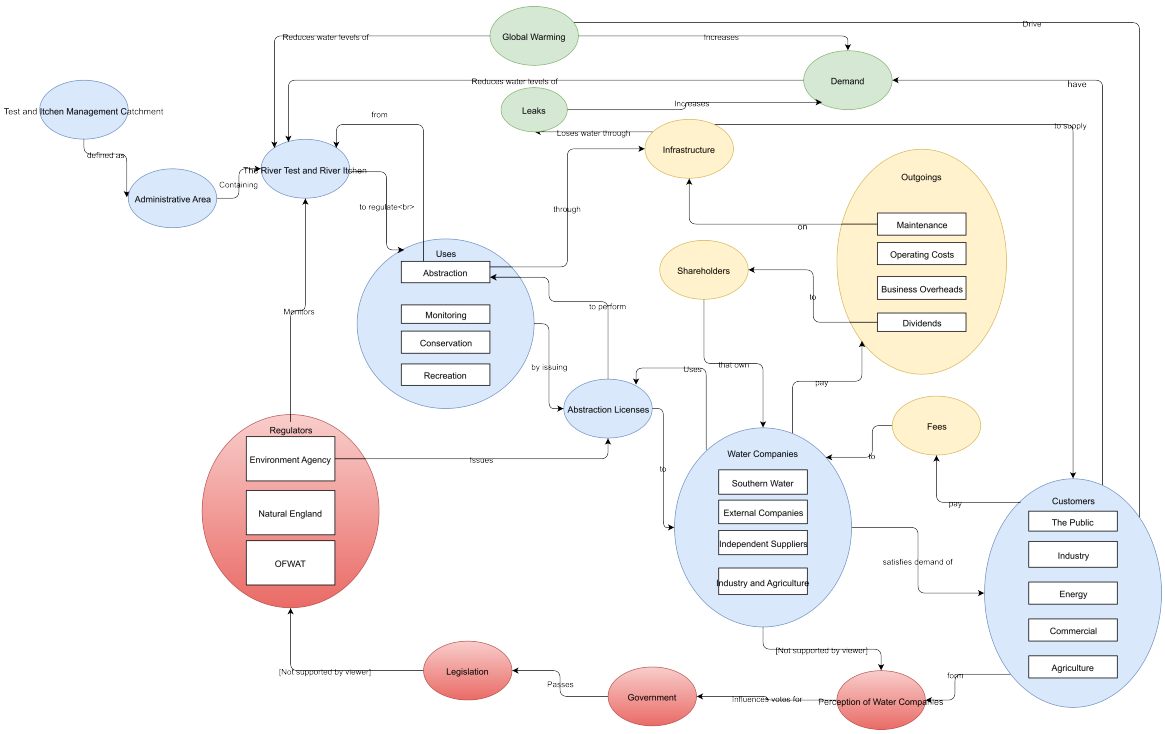


Figure 5: Systemigram of the Test and Itchen Management Catchment. Blue is the mainstay, red regulatory and legislative, yellow economic, and green environmental interests.

The blue bubbles represent the mainstay of the Systemigram, or the main root definition driving the system (figure 6):
The Test and Itchen Management Catchment Area is defined as an administrative area, (P) containing the river Test and river Itchen, to regulate uses such as abstraction, monitoring, conservation, and recreation, (Q) by issuing abstraction licenses to water companies such as Southern Water, external companies, independent suppliers, and industry and agriculture, (R) which satisfies the demand of customers such as the public, industry, energy, commercial, and agriculture.

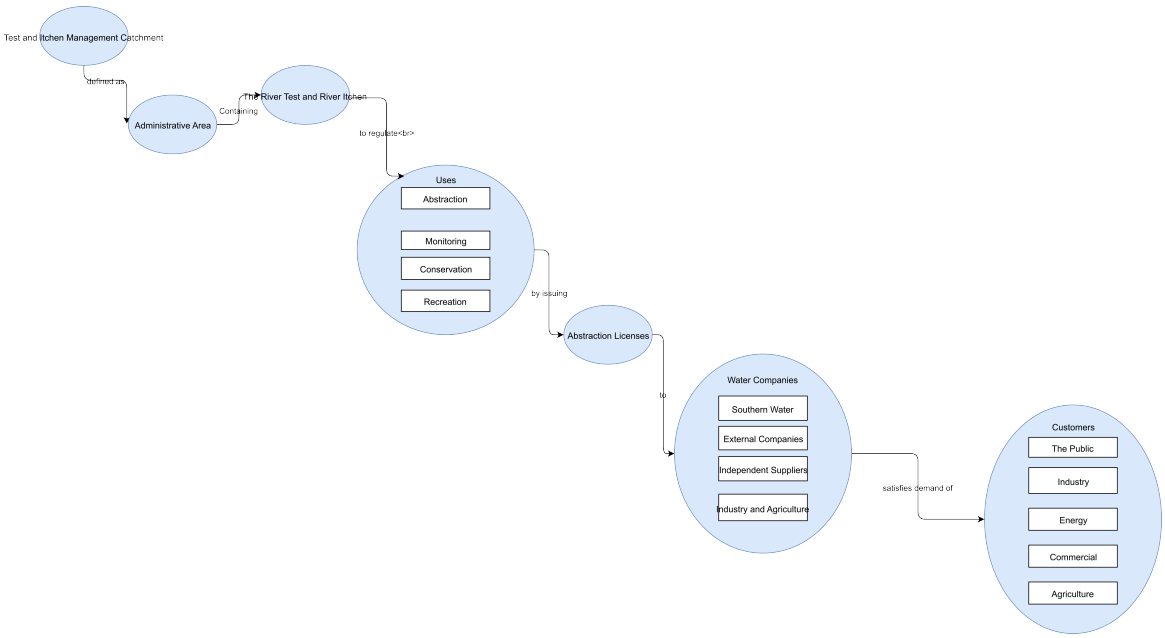


Figure 6: Mainstay of the Systemigram

The yellow bubbles represent the business and economic scene (figure 7):
The Customers pay fees to Water Companies who pay outgoings such as maintenance, operating costs, business

overheads, and dividends to shareholders who own the water companies, and they invest in Infrastructure to supply customers. The water comapies use abstraction licenses to perform abstraction from the river Test and river Itchen through infrastrcture to supply customers.

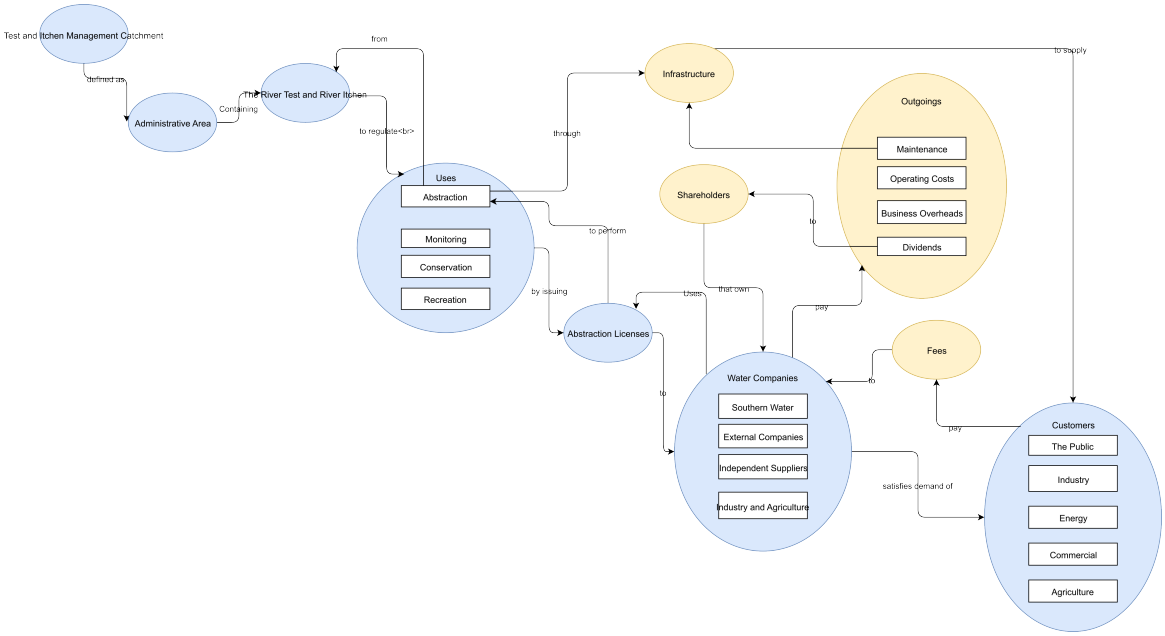


Figure 7: Scene 1 - Business

The red bubbles represent the regulatory and legislative scene(figure 8):
The customers form a perception of water companies driven by the performance and practices of the water companies, which influences votes for government, who passes legislation to control and give remit to regulators such as the Environment Agency, Natural England, and OFWAT, who monitor the river Test and river Itchen. The Environment Agency then issues Abstraction licenses.

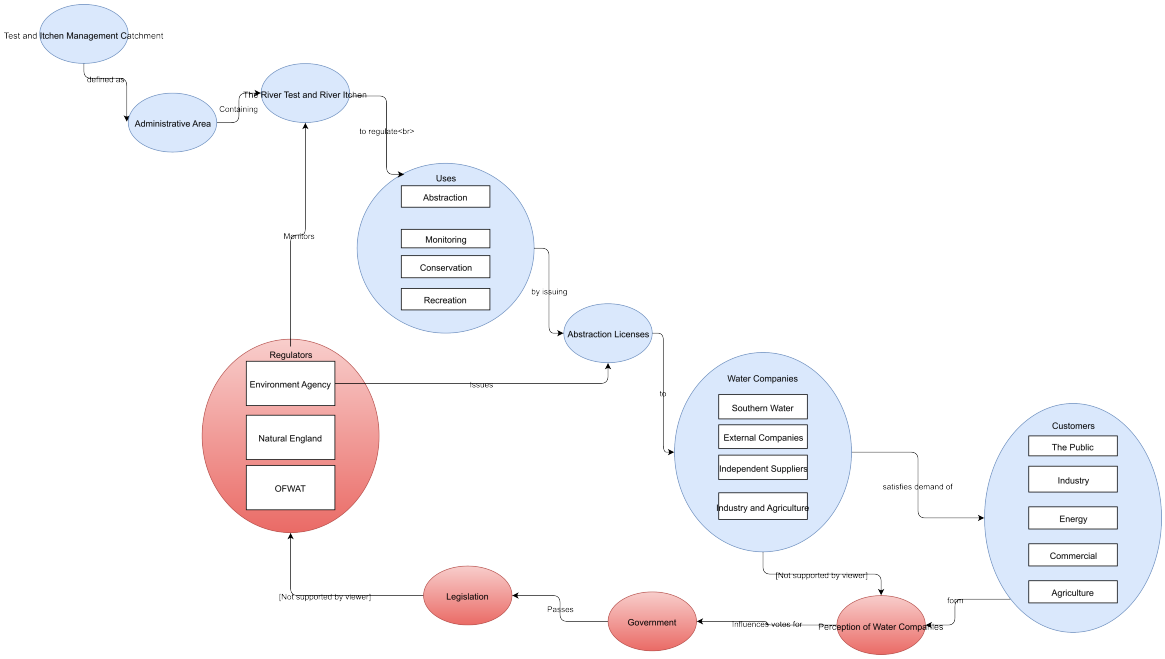


Figure 8: Scene 2 - Regulation

The green bubbles represent the environmental scene, which does not have its own figure as it is reliant on the business scene:
Customers have demand for water, which is increased by infrastructure that loses water through leaks, which

reduces the level of the river Test and the river Itchen. Customers also drive global warming, which reduces the water leels of the rivers, and also increase demand.

Generating the systemigram was a useful activity, as the separate scenes provide clear delimination between different interests and also show where these different interests form part of the core "story" that the diagram tells. Beyond that, it distilling the root definitions down to a diagramatic form has proved helpful as a reference. Moreover, the systemigram shows interconnections between different elements and scenes. The systemigram itself is a system, with elements and subsystems within it, and this model provides insight on the full system. From the diagram emerges a focus on abstraction licenses, as they are a key way that water companies and other abstractors are regulated. It also captures the central role that the Environment Agency plays, as a result of the importance of these licenses. There is however a long chain of elements from the customer's perception of water companies to the abstraction licenses, however, which may show a lack of customer agency.

Considering the economic scene, we also see that water companies are strongly incentivised to abstract and supply as much water as possible. Water Companies have a number of outgoings, which include investment in infrastructure along with other overheads. As a private company, Southern Water's purpose is to generate value for its shareholders, who are paid in dividends taken from profits. As such, the systemigram shows that they are incentivised to invest as little as possible into their infrastructure to maximise their profits and thus dividend payouts. They are also incentivised to charge as high a fee as possible for their services, something exacerbated by a lack of choice for the customer; water companies are geographically assigned, as opposed to the chosen supplier model used by other utilities. These fees are however regulated by Ofwat, which is not captured here but is captured in other methods (see figure 10).

Some expenditure on infrastructure is necessary, as infrastructure is required for water to be supplied. A focus on minimum expenditure however results in minimally viable infrastructure, which leaks. The systemigram shows that these leaks contribute ultimately to demand for water, which lowers the available water in the river. This is monitored by regulators, which prompts lowering of abstraction limits and increses of minimum flow limits to water companies. With less income from a reduction in water supply, companies may be then less incentivised to invest in their infrastructure, resulting in more leaks in a reinforcing loop.

The systemigram also captures the role that global warming plays in the system, acting as a driver of demand and also reducing the available water in the two rivers. As global warming is itself driven by customer activity, it serves to continuously reduce supply and increase demand regardless of actions on abstraction. As seen in figure 4, this also has implications for the river's other uses, namely as a habitat for endangered species and as recreation and environment for local residents.

With an understanding of the major systems at play, and their interactions, this information was used to generated an Ishikawa Diagram[19] (also known as a fishbone diagram, see figure 9)

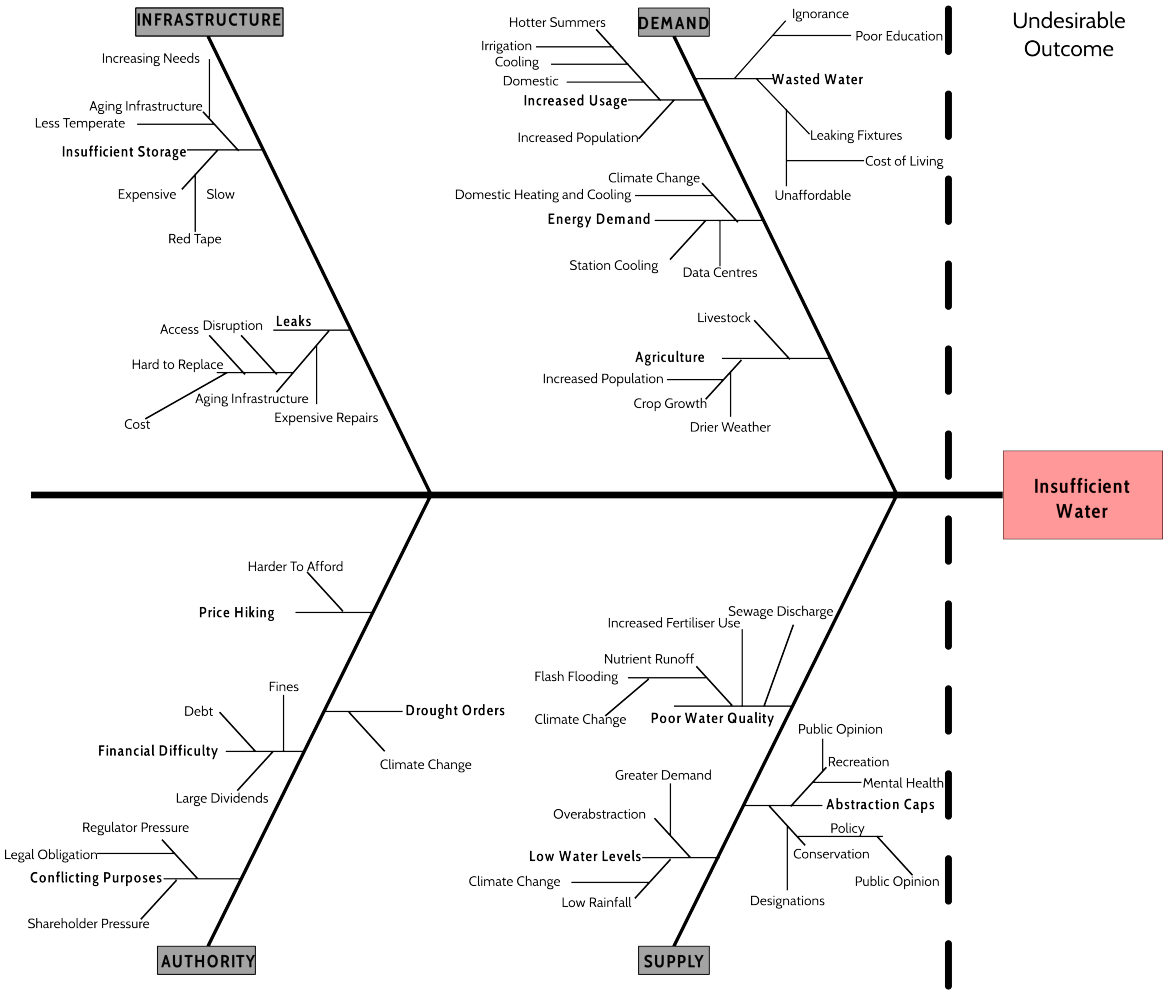


Figure 9: Ishikawa Diagram showing causes of insufficient water supply.

The Ishikawa diagram was originally designed to see the root causes of an undesirable outcome in a manufacturing environment. It has been adapted in this paper to consider the undesirable outcome of "Insufficient Water" in a more holistic way. Four root causes are defined (Demand, Supply, Infrastructure, and Authority) and shown as branches, and then their causes are listed as branches from those. This continues until a set of root causes are determined. Further fidelity could be acheived, but for the purposes of insight a high-level investigation is sufficient.

As with the pig model, the creation of the diagram was educative; some of the lower level causes were revealed, such as the cost of living affecting the public's ability to repair leaking water fixtures, wasting water overall. It also helped categorise different causes, which went on to inform the grouping of concerns in the Causal Loop Diagram (see figure 10) A key takeaway from the diagram is the focus on climate change's effect in the "Demand" branch, affecting all of "Increased Usage", "Energy Demand", and "Agriculture". Additionally, the diagram captures the conflicting purposes that the water suppliers face: They are legally obligated to supply water and have a duty of care over their environment, but also have pressure from their shareholders to grow and generate value for them.

All of the above diagrams have been used to generate a causal loop diagram, following the

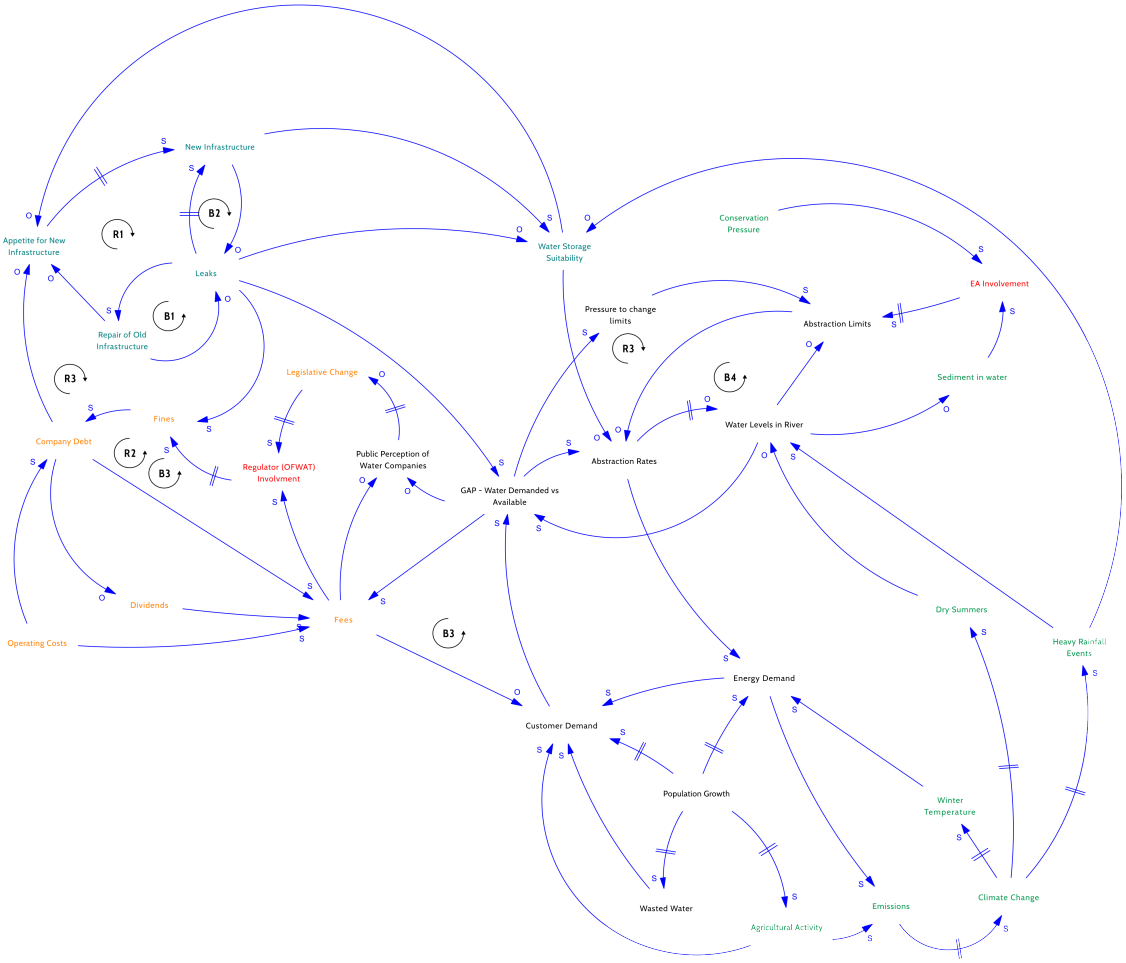


Figure 10: Causal Loop Diagram showing the interactions different elements of the system have on each other.

The CLD shows the interactions between different elements, the elements that are key in the system and those that are on the periphery, and can also be used to predict the behaviour that emerges from the system over time. A key way of doing this is by looking at system archetypes, as detailed by Kim and Anderson[20]. When looking at figure 10, two archetypes are apparent. The first is a sort of "shifting the burden", concerning leaks, new infrastucture and repairing old infrastructure. There is a time delay in creating new infrastructure, and this is also driven by the appetite that the water companies have for new infrastructure investment. It is required, however, to reduce the leaking and thus reduce overall amount of water needed to supply the demand, as shown by loop B2. Loop B1 instead offers a quicker and cheaper "fix" in repairing the aging infrastructure that is being used. This seems attractive and on the surface has the same effect as new infrastructure. Loop R1 shows the consequence of this however, as in the long term there is a reduction in a desire for new infrastructure, which then only serves to make repairs more attractive. Old infrastructure can only be repaired, not improved easily, so this solution does not scale with the increased needs being driven by population growth and climate change. As a result, there is an overall reduction in leaks, but the burden has shifted to an infrastructure network that cannot be fit for purpose without even more costly repairs and expansions, or entirely new infrastructure.

Another archetype that is obvious is the "drifting goals" archetype, where it is easier to reduce expectations and bend limits than actually achieve the goals that are set. This can be seen with the abstraction limits: They are dependent on the water that flows through the rivers, and they serve to moderate the abstraction (B4). However, this leads to a gap between the amount of water demanded and the amount available. This can be remedied with better infrastructure, efforts to reduce demand, or even a reduction in emissions and climate change in the long term, but it is easier to simply pressure these limits to be lowered so that more water can be abstracted. This has been shown in Southern Water's request to abstract more than they are allowed to from the river Test[21]. The CLD also shows that the main method of regulating usage of the river is through abstraction licenses. They serve to limit the amount that can be abstracted, and as such are the main controllable element from the Environment Agency's viewpoint. This corroborates what was seen in the systemigram (figure 5). Fines are the instrument

by which these licenses (and targets from Ofwat) are enforced, but then the diagram shows that there are many effects of fines that have negative consequences. An example of this is loop R2, where poor performance sours public perception of the company, which drives legislative change and regulator involvement. This results in fines, which increase the company's debt - something that is already an issue, considering the company's reduction in credit rating from BBB (negative outlook) to BBB- (negative outlook) by Fitch[22]. Such fines then result in an increase in fees, which serve to further degrade public opinion.

Finally, a context diagram was drafted to understand what areas are within the System of Interest (SOI), and can thus be controlled, which can be influenced (wider SoI), and which are uncontrollable but are important to take note of (Environment). Written from the point of view of the Environment Agency, this diagram can be seen in figure 11.

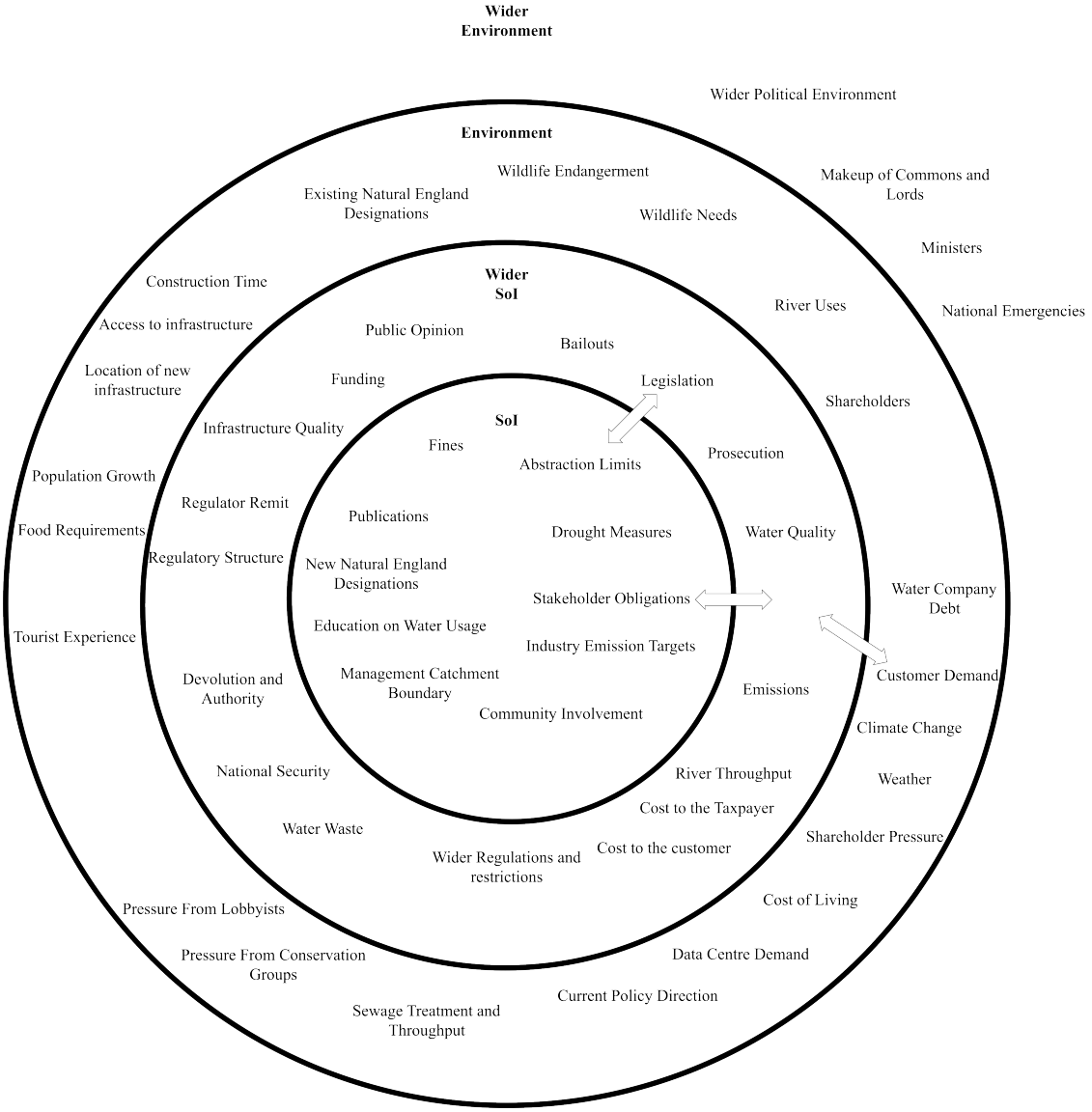


Figure 11: A context diagram showing what is controllable (SoI), what can be influenced (wider SoI), and what is uncontrollable (Environment and Wider Environment)

Of note in this diagram is how mamy important elements of the system are not within the SoI. This includes legislation, emissions, and public opinion. This is due to a few factors: The Enviornment Agency can only use powers granted to it by legislation (such as abstraction licenses) to manage the management catchment. A large number of important elements in the wider SoI are goverened by such legislation, which must pass through the Houses of Parliament. As these are voted on by members, there is no way to directly control whether it gets passed. Instead, the Environment Agency (and by extension DEFRA) can influence this by controlling content and by managing members and their constituents. Even abstraction limits are outside of control to an extent, as

the drought order requests are directed to DEFRA and not to the Environment Agency. Directly within control however are also elements such as publications and education, which can help to reduce wasted water and reduce the demand for water overall.

With the insight gained from the above methods, the research questions can be answered:

1. The key stakeholders in the management catchment are Southern Water, the Environment Agency, Customers of Southern Water, and wildlife

2. Key subsystems are the demand for water and subsequent abstraction moderated by abstraction licenses, the infrastrcutrure used to abstract and deliver this water, the business model that Southern Water operates, and the effect that climate change has.

3. Elements most sensitive are those best connected, such as fees, fines, abstraction rates, and demand.

4. Current initiatives such as the Catchment Based Approach[2], which aims to grant agency to the public who otherwise are removed from water companies' decisions, show promise and target an issue highlighted in this paper. Other initiatives, such as the new reservoires being constructed, may prove very useful but the time they take may stop them from avoiding outcomes such as supply discontinuity in the short term.

5. Impacting fines is likely to result in reduced investment, and higher fees, and with the taxpayer eventually funding these companies as Operators of Last Resort, may only serve to saddle a new publicly owned supplier with debt.

6. Greenhouse gasses are produced from abstraction itself, but also from energy demand, growing population, and agriculture. Mitigations that can be enacted are education on water demand's influence or subsidy of clean energy and low-carbon methods of construction.

Report part 5: Ethics

Report part 6: Statement of Quality

References

[1] E. Agency, *England | catchment data explorer*, https://environment.data.gov.uk/catchment-planning/, [Online; Accessed 2025/11/28], 2025.

[2] DEFRA, "Catchment based approach: Improving the quality of our water environment a policy framework to encourage the wider adoption of an integrated catchment based approach to improving the quality of our water environment," Department for Food & Rural Affairs, Tech. Rep., May 2013. [Online]. Available: https://www.gov.uk/business/environmental-management-water-water-quality.

[3] E. Agency, "Test and itchen abstraction licensing strategy a strategy to manage water resources sustainably," Tech. Rep., Mar. 2019. [Online]. Available: http://www.gov.uk/government/publications.

[4] E. Agency, *Test and itchen management catchment | catchment data explorer*, [Online; Accessed 2025/11/28], Mar. 2025. [Online]. Available: https://environment.data.gov.uk/catchment-planning/ManagementCatchment/3097.

[5] N. England, *Ssi detail*, [Online; Accessed 2025/11/28], 2023. [Online]. Available: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S2000170&SiteName=&countyCode=19&responsiblePerson=&SeaArea=&IFCAArea=.

[6] N. England, *Ssi detail*, [Online; Accessed 2025/11/28], 2023. [Online]. Available: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S2000227&SiteName=River%20Itchen&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=.

[7] N. England, *Designated sites view*, [Online; Accessed 2025/11/28], 2023. [Online]. Available: https://designatedsites.naturalengland.org.uk/SiteGeneralDetail.aspx?SiteCode=UK0012599&SiteName=River%20Itchen&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=.

[8] T. R. Trust, OpenStreetMap, and E. UK, *Arcgis.com*, [Made with Esri ArcGIS Map Viewer, layers: CaBA Catchment Partnerships, OS Open Rivers], 2025. [Online]. Available: https://www.arcgis.com/apps/mapviewer/index.html?layers=19e680430d7f4e679002eecef04c31a8.

[9] T. R. Trust, OpenStreetMap, E. UK, and Stream, *Arcgis.com*, [Made with Esri ArcGIS Map Viewer, layers: Water Company Boundaries (data provided by Stream) CaBA Catchment Partnerships, OS Open Rivers], 2025. [Online]. Available: https://www.arcgis.com/apps/mapviewer/index.html?layers=19e680430d7f4e679002eecef04c31a8.

[10] E. Agency, "Water resources licence to water," Tech. Rep., Mar. 2019. [Online]. Available: https://www.southernwater.co.uk/media/5o2p1vzz/114-appx-4-testwood-abstraction-licence-11-42-1816-546.pdf.

[11] G. O. for Science, "Systems thinking: An introductory toolkit for civil servants," Tech. Rep., 2022. [Online]. Available: https://www.gov.uk/government/publications/systems-thinking-for-civil-servants.

[12] N. C. F. Section, "Release of information," Tech. Rep., Apr. 2021. [Online]. Available: https://www.whatdotheyknow.com/request/ships_home_ports.

[13] B. Army, *17 port and maritime regiment rlc | the british army*, [Online; Accessed 2025/11/28], 2024. [Online]. Available: https://www.army.mod.uk/learn-and-explore/about-the-army/corps-regiments-and-units/royal-logistic-corps/regular-units/17-port-and-maritime-regiment-rlc/.

[14] W. C. Council, *Visit winchester | the itchen navigation heritage trail*, [Online; Accessed 2025/11/19], 2024. [Online]. Available: https://www.visitwinchester.co.uk/business-directory/the-itchen-navigation-heritage-trail.

[15] M. P. Limited, *Faqs*, [Online; Accessed 2025/12/05], 2011. [Online]. Available: https://www.marchwoodpower.com/faqs/.

[16] R. L. V. Radoman, "Enabling the open architecture approach in military systems: A systems thinking analysis," Sep. 2025. DOI: 10.26174/thesis.lboro.29922026.v1. [Online]. Available: https://repository.lboro.ac.uk/articles/thesis/Enabling_the_Open_Architecture_approach_in_military_systems_a_systems_thinking_analysis/29922026.

[17] B. Sauser. "2019 serc research review: Systems thinking workshop: The 5 w's of systemigrams." [Online Video; Accessed 2025/12/29]. [Online]. Available: https://www.youtube.com/watch?v=s5A9dUh1_Mk.

[18] P. Checkland, "Soft systems methodology: A thirty year retrospective," *Systems Research and Behavioral Science Syst. Res*, vol. 17, S11–S58, 2000. DOI: 10.1002/1099-1743(200011)17:1. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1002/1099-1743.

[19] K. Ishikawa, *Guide to Quality Control*, 2nd ed. Asian Productivity Organization, 1976, [Originally published by GEMBA NO QC SHUHO (in Japanese), 1968].

[20] D. H. Kim and V. Anderson, "Systems archetype basics: From story to structure," Pegasus Communications, Inc., Tech. Rep., 1998. [Online]. Available: www.pegasuscom.com.

[21] S. W. S. Limited, *Statutory notice for drought order application southern water services limited the southern water services limited (river test) drought order 2025 sections 73 and 74(2)(f) and schedule 8 of the water resources act 1991*, Jul. 2025. [Online]. Available: https://www.southernwater.co.uk/drought-restrictions.

[22] S. W. Limited and D. LLP, "Annual report and financial statements for the year ended 31 march 2025," Companies Hosuse, Tech. Rep., Jul. 2025. [Online]. Available: https://find-and-update.company-information.service.gov.uk/company/02366620/filing-history/MzQ4MDIyMjg1M2FkaXF6a2N4/document?format=pdf&download=0.