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.

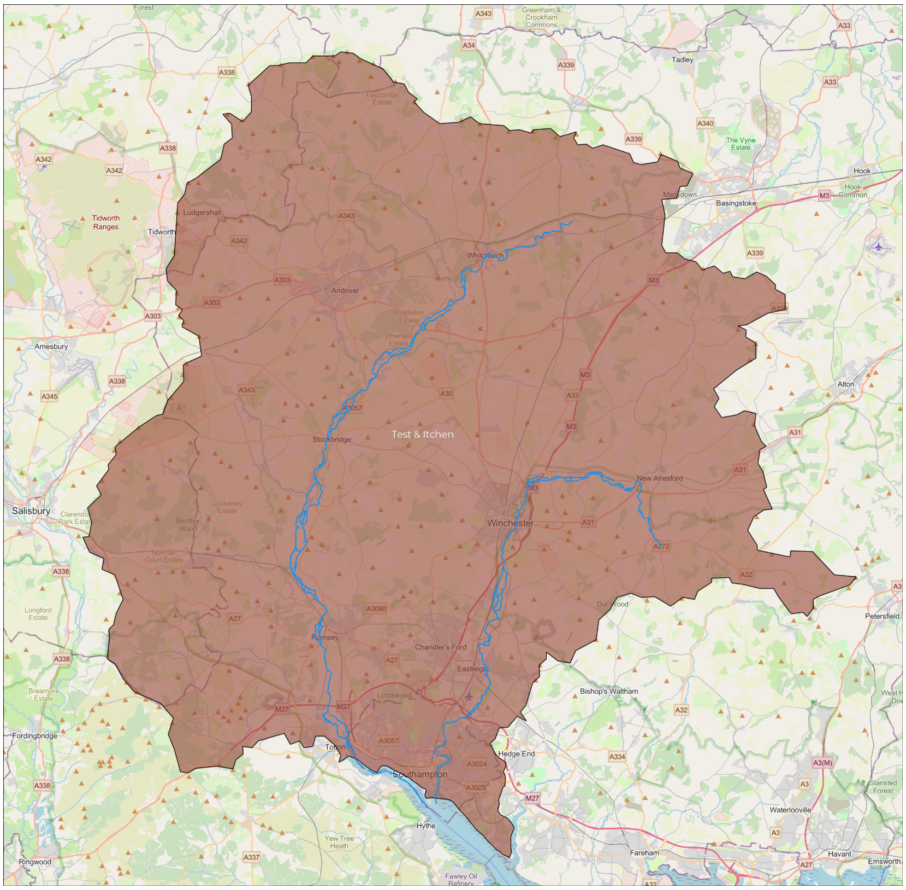


Figure 1: Map of the Test and Itchen Management Catchment[8].

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 Andover and Eastleigh.

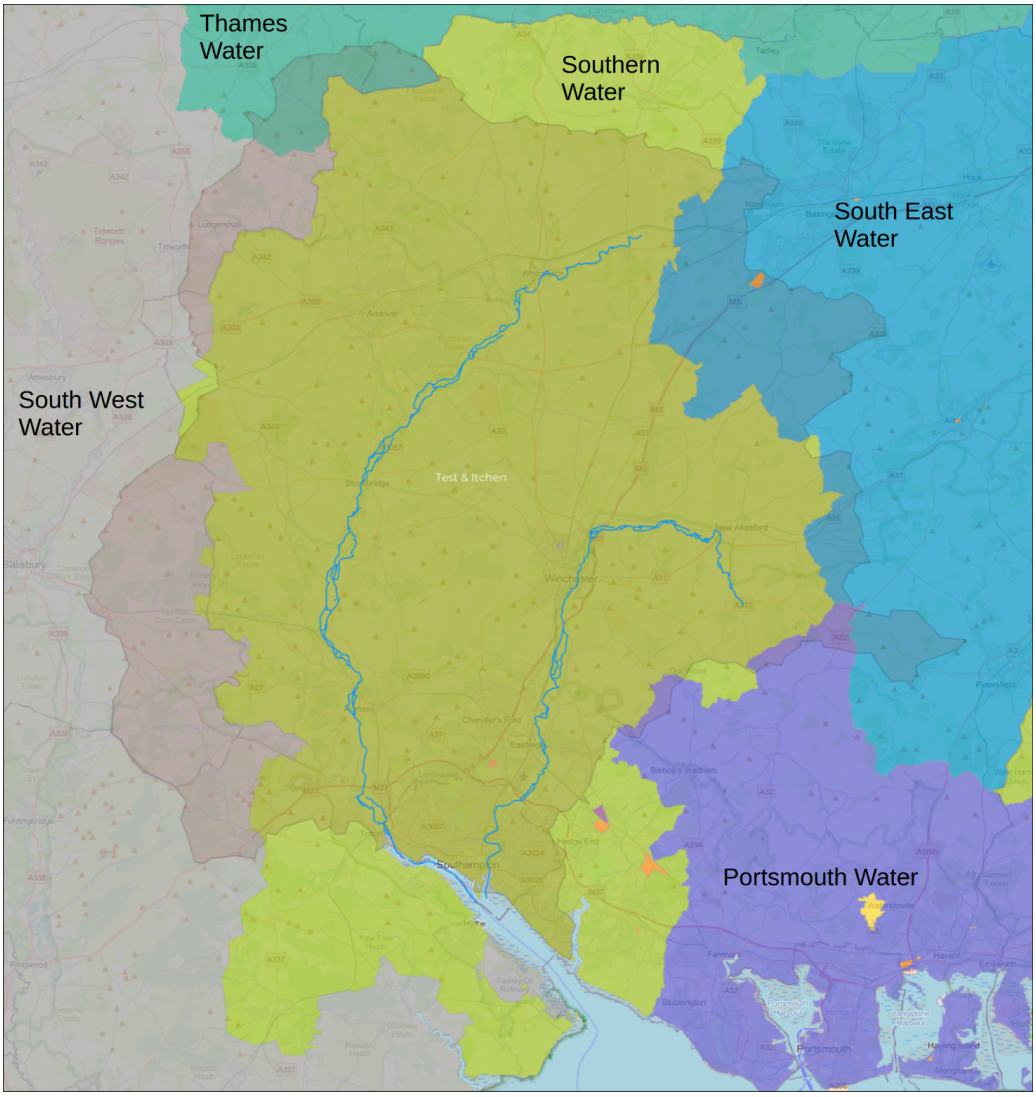
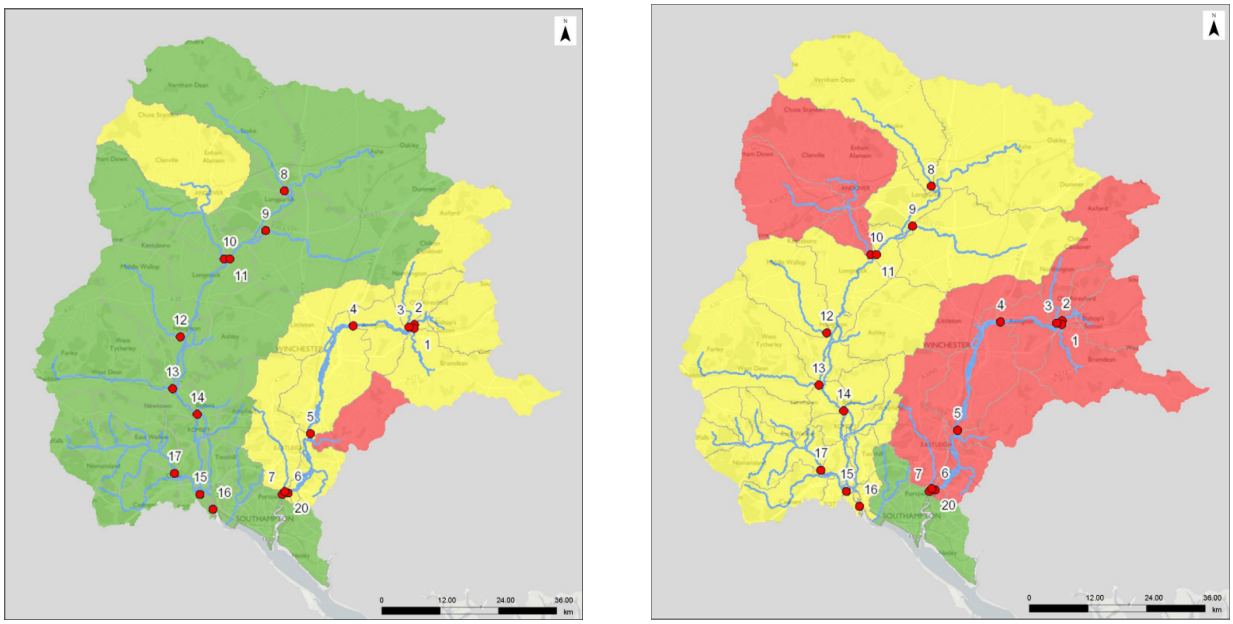


Figure 2: Map of the Test and Itchen Management Catchment, with Water Company shown [8].

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 available (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 quantity" was made. Additionally, conditions on minimum flow through Environment Agency gauging stations have been introduced, with the minimum flow increasing for 10 months of the year from 2027[10]

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[11], and Marchwood is also home to the British Army's 17 Port and Maritime Regiment[12]. Also, a number of cruise ships and container



(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]

ships use Southampton Docks as a berth, requiring a certain level of flow from the Itchen and Test to support large-draft vessels.

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 independent water companies that operate in the management catchment area, or otherwise abstract water from the Rivers Test and Itchen, are negligible compared to that of Southern 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 withhold funding from them, and are not operating these companies illegally
5. The debt held by public water companies is modelled monolithically
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.
8. Only publicly available data can be used in this analysis.
9. It is assumed that external water companies will not donate water from their abstraction to Southern Water.
10. It is assumed that external water companies will not sell allowance from their abstraction licenses to Southern Water.
11. It is assumed that population growth is a static rate and is constant.
12. It is assumed that there are no legal obstacles to the recommendations.
13. It is assumed that recommendations will be presented to one government (i.e. no cabinet reshuffle/elections occur at the same time).
14. It is assumed that the regional authorities fall under HM Government elected in 2024, as some recommendations align with its policy.
15. The effects of climate change not mentioned in this paper (rising sea levels etc.) are ignored.

Report part 3a: Crtieria for Method Selection

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

To decide on the systems thinking methods that will answer the questions set out in part 4, ten 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.

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. A method that can be performed with public information but would offer better insight with less accessible information 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 question(s)? 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.

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 necessarily 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 gathered 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. 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. 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

Method	Criteria										
	1	2	3	4	5	6	7	8	9	10	Total
Rich Picture	5	5	5	3	2	4	3	5	5	2	39
Pig Diagram	5	5	5	5	2	5	3	3	5	5	43
CATWOE	4	4	5	5	3	3	3	4	5	3	39
Systemigram	4	5	5	5	2	5	5	5	5	5	46
CLD	4	4	5	5	5	5	5	5	5	4	47
System Dynamics	2	3	5	4	5	2	5	5	5	4	40
Iceberg Model	5	5	4	3	2	3	3	3	4	2	34
N2	4	3	4	4	4	4	2	3	2	3	33
Cynefin Framework	4	4	3	3	2	3	4	4	2	5	34
Risk Management Framework	4	4	2	2	2	3	4	4	3	3	31
HTA	3	2	2	2	2	5	4	3	3	3	29
EAST-BL	2	3	2	2	2	3	2	3	2	5	26
SPTA	2	4	2	2	2	2	4	3	2	5	28
Viable System Model	3	2	2	2	2	2	3	3	2	3	24
Ishikawa Diagram	4	5	5	5	3	5	5	4	5	4	45
Context Diagram	4	5	5	4	2	3	3	5	5	5	41

Figure 4: Method Selection Table. HTA, EAST-BL, STPA from[13]. RMF from[14]. VSM from[15]. Rich Picutre, Pig Diagram, CATWOE, Systemigram, CLD, System Dynamics, Iceberg, N2, Context Diagram from[16]. Cynefin Framework from[17]

Report part 4: Application of methods and recommendations

This paper considers six research questions.

1. What key stakeholders are in the Test and Itchen Management Catchment, and what are their worldviews?
2. What subsystems are present in the system, and how do they interact with each other?
3. What elements of the system are most sensitive to intervention?
4. How effective are current initiatives at improving water security, and what can be learnt from them?
5. What negative consequences are likely from interventions in sensitive areas?
6. What are the greenhouse gas emitters in the system and in current initiatives?

Initially, a Pig Model[18] was created (see figure 5). 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).

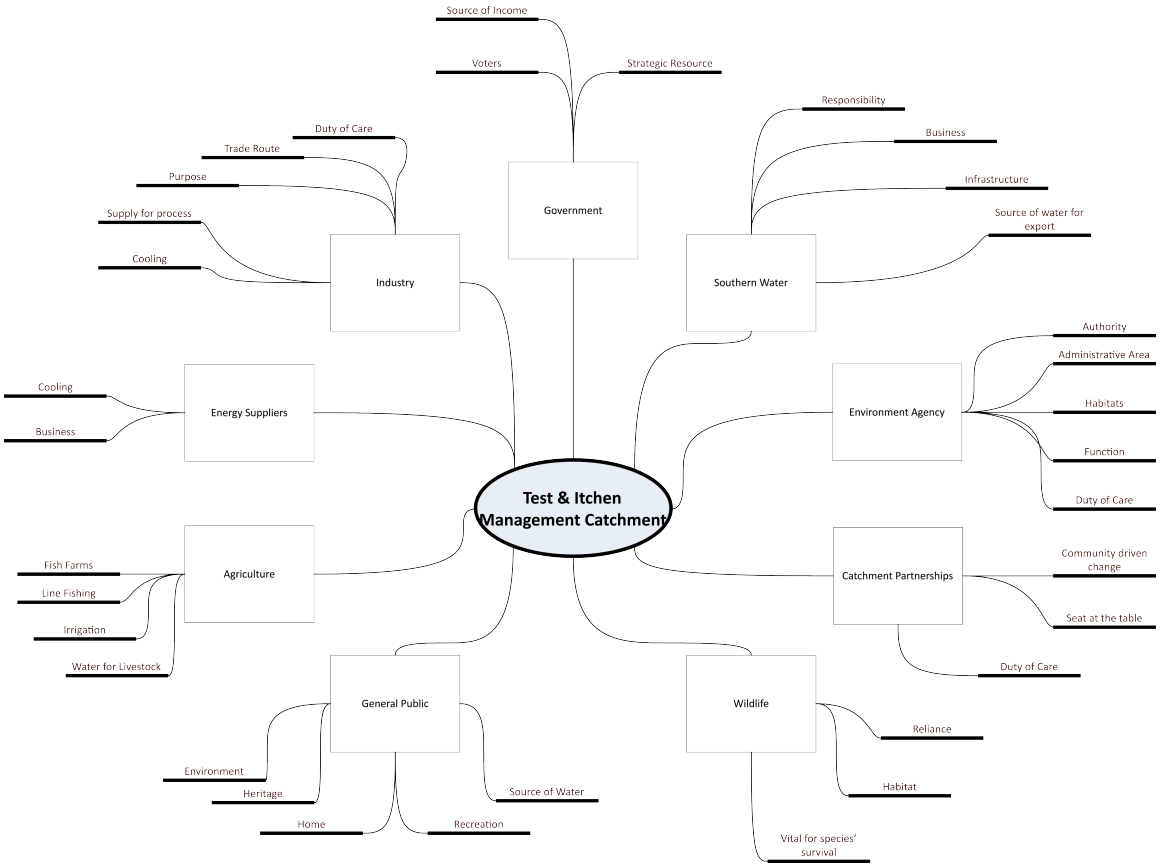


Figure 5: Pig Model[18] instance for Water Resilience.

A large amount of the value of the Pig Model is in its creation; beyond background knowledge, stakeholders and views were identified during drafting. 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"[19] It also provided insight into the overlap of views between different stakeholders. Some, like Southern Water, are directly reliant that they exist to supply water from this management catchment to customers. Others, like the Energy Suppliers, are less directly reliant in that they use the water from the management catchment to cool Marchwood Power Station[20].

Following this, a systemigram (figure 6) was drawn to explore the systems at play in the management catchment. Radoman's work[21] was used as a guide, along with a workshop presented by Brian Sauser[22].

The systemigram was constructed by defining root definitions "What to do (P), How to do it (Q) and Why do it (R)?"[23]. Sauser[22] talks about the systemigram as a storyboarding tool, with different scenes representing different interests and viewpoints.

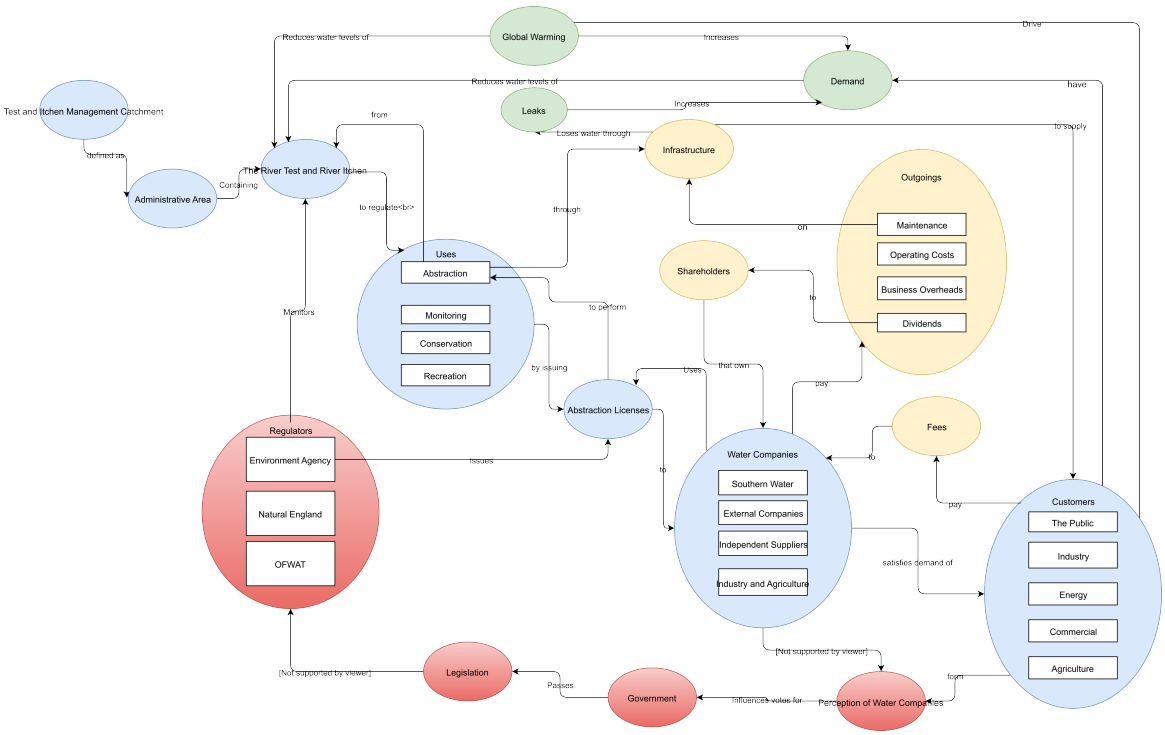


Figure 6: Systemigram of the Test and Itchen Management Catchment. Blue is the mainstay, red regulatory and legislative, yellow economic, and green environmental interests.

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.

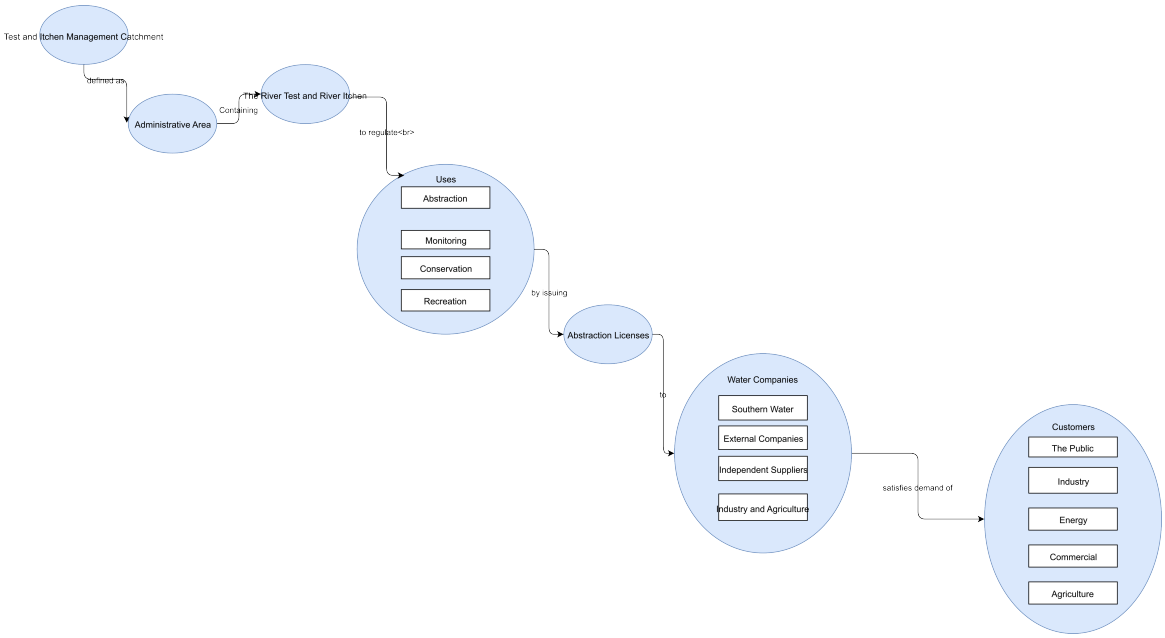


Figure 7: Mainstay of the Systemigram

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 companies use abstraction licenses to perform abstraction from the river Test and river Itchen through infrastructure to supply customers.

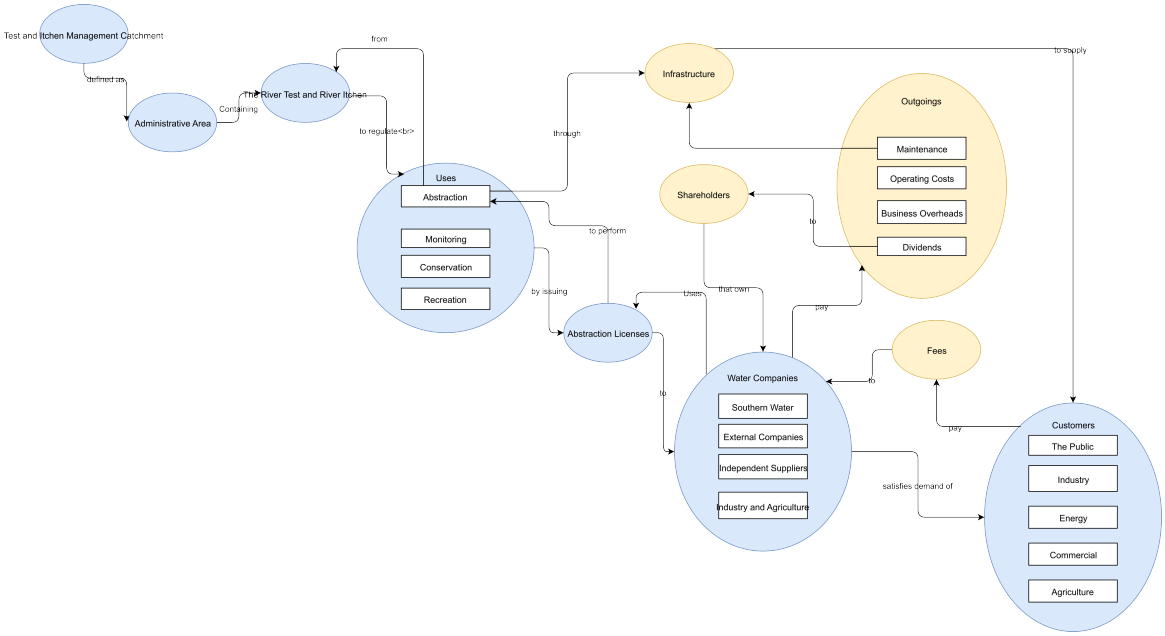


Figure 8: Scene 1 - Business

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.

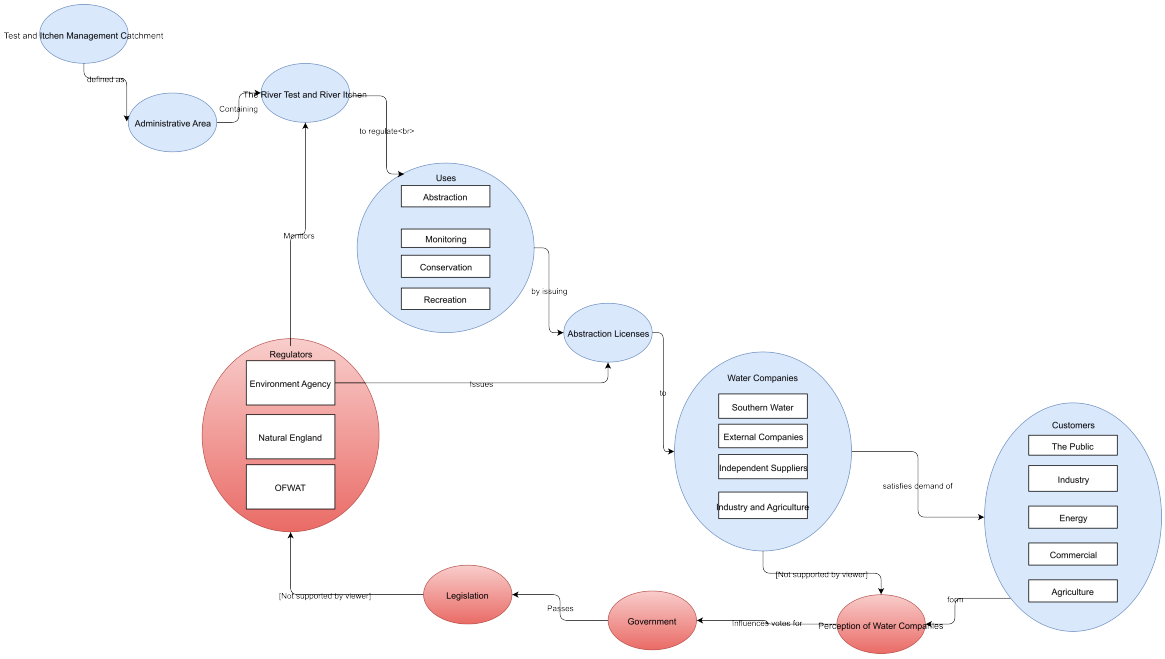


Figure 9: Scene 2 - Regulation

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 levels of the rivers, and also increase demand.

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.

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. The systemigram also shows that leaks contribute ultimately to demand for water, which lowers the available water in the river.

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.

With an understanding of the major systems at play, and their interactions, this information was used to generated an Ishikawa Diagram[24] (figure 10)

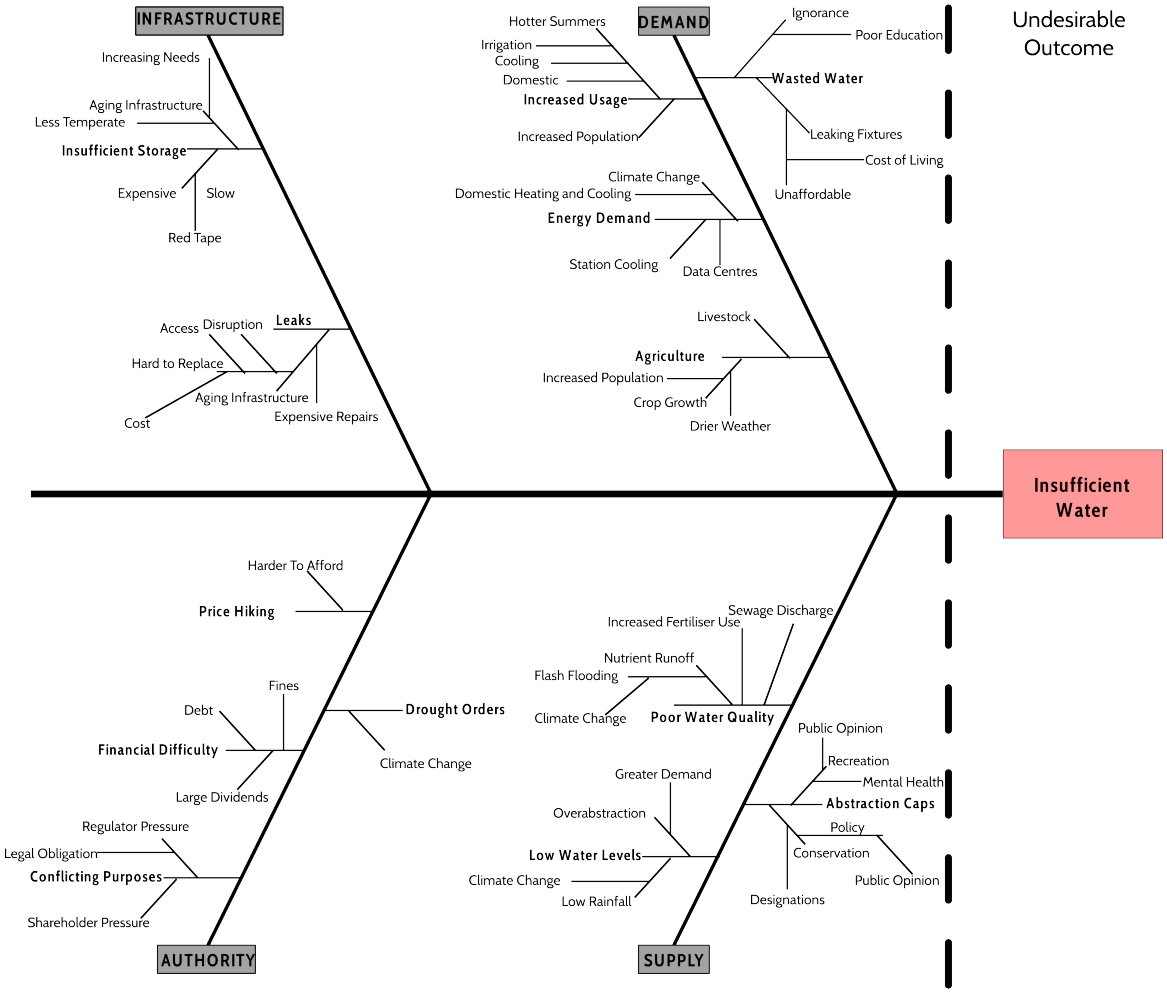


Figure 10: Ishikawa Diagram showing causes of insufficient water supply.

The diagram has been adapted to consider the undesirable outcome of "Insufficient Water" in a holistic way. 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.

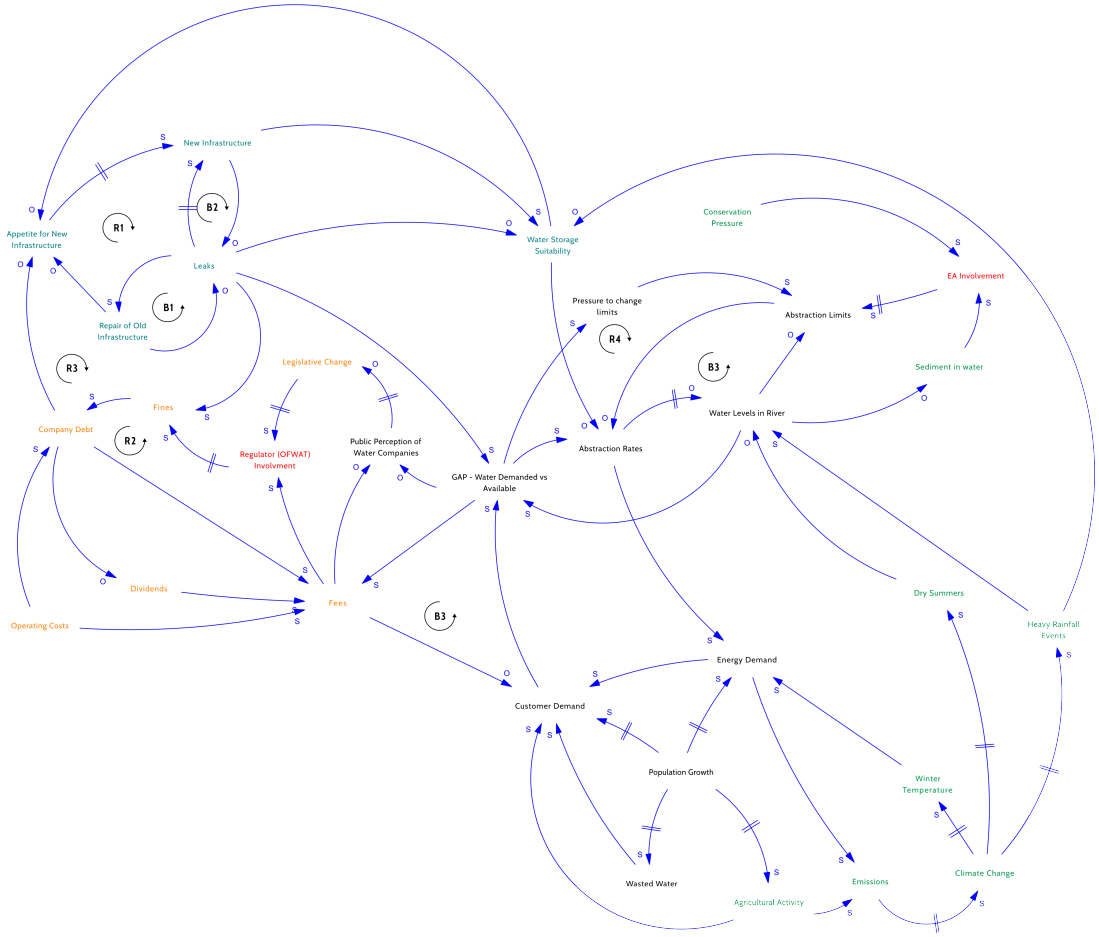


Figure 11: Causal Loop Diagram showing the interactions different elements of the system have on each other.

The CLD (figure 11) shows the interactions between different elements, 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[25]. The first is "shifting the burden": Loops B1 and B2 are both solutions to leaks in infrastructure. There is a delay in creating new infrastructure, and this is driven by the appetite that the water companies have for new infrastructure investment. B1 instead offers a quicker and cheaper "fix" in repairing the aging infrastructure that is being used. R1 shows the consequence of this: a reduction in desire for new infrastructure, which then makes repairs more attractive. This solution does not scale with increased needs being driven by population growth and climate change. As a result, there is a short term reduction in leaks, but the burden has shifted to infrastructure that cannot be fit for purpose without expansions or entirely new infrastructure.

Another archetype is the "drifting goals" archetype. 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 (B3). This leads to a gap between the amount of water demanded and the amount available. This can be remedied, but it is easier to simply pressure these limits to be lowered so that more water can be abstracted (R4). This has been shown in Southern Water's request to abstract more than they are allowed to from the river Test[26]. The CLD also shows that the main method of regulating usage of the river is through abstraction licenses. This corroborates what was seen in the systemigram (figure 6). 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. 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[27]. This results 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 12.

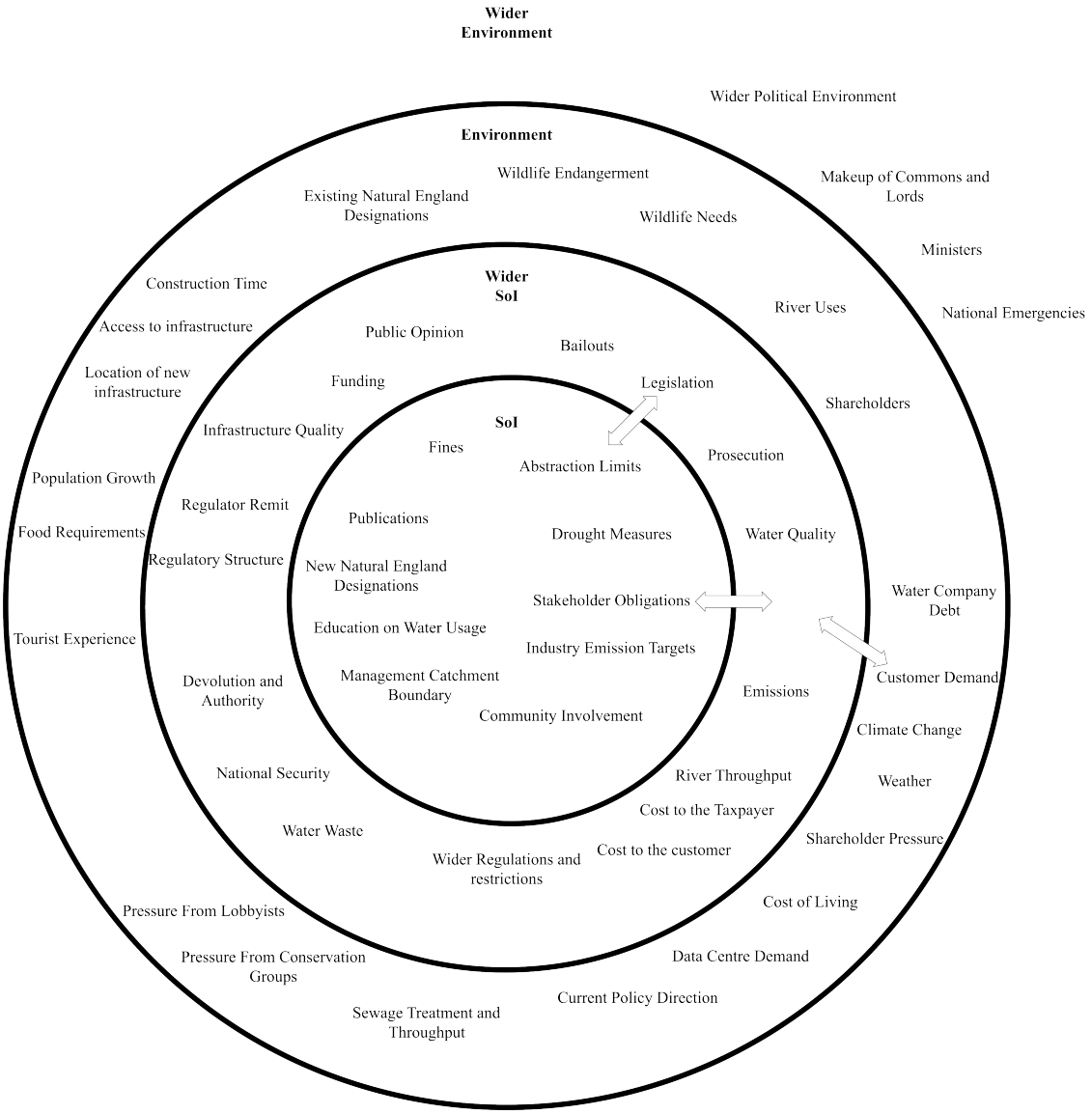


Figure 12: A context diagram showing what is controllable (SoI), what can be influenced (wider SoI), and what is uncontrollable (Environment and Wider Environment)

Of note in this diagram is how many important elements of the system are not within the SoI. This includes legislation, emissions, and public opinion. This is due to a few factors: A large number of important elements in the wider SoI are governed 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. 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 infrastructure 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.

5. Impacting fines is likely to result in reduced investment, and higher fees.

6. Greenhouse gasses are produced from abstraction itself, but also from energy demand, growing population, and agriculture.

This investigation has lead to the following five recommendations:

1. HM Government should subsidise the construction of new infrastructure, and remove some of the bureaucratic barriers to its construction. It is clear that the current system incentivises quick and cheap repairs over investment in the future, so making new infrastructure cheaper and less time-consuming will make it more appealing to water companies and will future-proof the infrastructure network. This will take time to see the impact for water security in the order of years, but in the short term increased construction effort will employ people and drive the economy, helping the government hit growth targets.

2. HM Government should grant the Environment Agency more instruments to hold water companies accountable, and to give customers agency. There is a current plan to integrate parts of the Environment Agency and Ofwat, however the whole water regulation apparatus could be integrated into DEFRA to give it influence on policy and legislation. This body would also be able to remove reliance on fines, and they could introduce limits (not targets, routinely broken by Southern Water[26]) on supply continuity and on emissions. This recommendation could be completed within the length of one Parliament (4 years) and benefits could be seen soon after this.

3. The Environment Agency should continue the Catchment-Based Approach and further integrate it into the regulation apparatus. Catchment Partnerships are a vector by which communities can be involved with River Basin Management Plans[2]. The benefits of this are already being seen, so further integration of it into the regulatory and management apparatus will have immediate positive effect.

4. HM Government should consider taking Southern Water under public ownership, or operate it as a QUANGO. A similar initiative has been undertaken with train operating companies being nationalised upon the end of their contracts[28]. Doing this for water companies would remove the drive for profits and dividends from the system, removing the conflicting purposes and again giving residents more agency in their water supply (through elections etc.).

5. The Environment Agency should be proactive in the education of the general public on the impact that their demand for water, food, and energy has on water resilience. As shown in figure 11, climate change are driven by population - through food demand, energy demand, and water demand. Promote low-emission food choices such as plant-based diets, water saving techniques, and energy saving techniques to combat the effect that climate change is having on the management catchment.

Report part 5: Ethics

The recommendations put forward are generally low-risk ethically, as they are generally restructuring or educational. There is a concern with infrastructure subsidy and de-regulation, however. Locations and the impact of any infrastructure must be carefully considered, to not damage any habitats and to not disrupt residents unduly. Any construction must go through some public consultation, to ensure that residents have agency on where this infrastructure is built. Additionally, there is a concern for emissions when constructing the infrastructure. Construction can be heavily polluting, so care must be taken to choose low-carbon or carbon neutral construction methods.

There is also risk in nationalisation of the water suppliers. Water suppliers, not least Southern Water, are complex organisations with large amounts of asset and debt. Managing this with taxpayer money may prove challenging, considering the many differing organisations that vie for their proportion of the budget. It is important to not let large debt and operational overheads hamper the efficacy of any organisation, water supplier or not.

Report part 6: Statement of Quality

No AI tool has been used in the creation of this assignment. This includes AI tools provided by Office suites and search engines, which were turned off for preference throughout.

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