South Staffs Water

Decision Making Framework for South Staffs Water

PR19 Investment Programme

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List of Abbreviations

Abbreviation	Definition
AIC	Average Incremental Cost
AMP	Asset Management Plan or Programme
CAM	Cambridge Water
CBA	Cost Benefit Analysis
CCG	Customer Challenge Group
DCF	Discounted Cash Flow
DM	Demand Management
DMA	Distribution Management Area
DMF	Decision Making Framework
DWI	Drinking Water Inspectorate
DWSP	Drinking Water Safety Plan
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
EA	Environment Agency
EBSD	Economic Balance of Supply and Demand
IO	Investment Optimiser
JNCC	Joint Nature Conservation Committee
MCA	Multi Criteria Analysis
MCM	Mitigation Cost Method
Mld	Mega litres per day (million litres per day)
NPV	Net Present Value
NYAA	Normal Year Annual Average
ODI	Outcome Delivery Incentive
OPM	Output Performance Measures
PR14	Periodic Review 2014
PR19	Periodic Review 2019
RCV	Regulatory Capital Value
RSA	Restoring Sustainable Abstractions
SSC	South Staffs Group of Companies (including Cambridge Water)
SST	South Staffs Water
SO	Single-Objective
THR	Target Headroom
UKWIR	UK Water Industry Research
WAFU	Water Available for Use
WFD	Water Framework Directive
WRMP	Water Resource Management Plan
WRZ	Water Resource Zone
WtP	Willingness to Pay
WTW	Water Treatment Works

Glossary of Key Terminology

Key term	Definition
Problem Measures	Measures used to define a problem. E.g. Water quality.
Assessment Measures	Measures used to differentiate potential solutions. E.g. Cost
Indicators	Interchangeable with measures.
Problem	An issue that the Decision Making Framework will identify optimum solutions for.
Options	Identified projects and schemes which can contribute to resolving the predefined problem.
Metrics	Scales that can be used to quantify measures. E.g. CAPEX £000
Aggregation level	The grouping together of measures, metrics and solutions. Aggregation can occur across space and time. E.g. Water Resource Zones, Annual Time step.
Solution	An option considered to solve a defined problem either in part or entirely
Portfolio	A group of options that in combination can solve the defined problem
Constraints	Conditions that define what constitutes a solution
The 'Must' objectives	Specific factors that must be satisfied for the portfolio to be considered a solution
The 'Want' objectives	Factors that will distinguish how good is a particular solution relative to others
Mathematical Optimisation	Mathematical Optimisation is a technique be used to solve problems formulated with defined goals and constraints.
Optimum solutions	Solutions that resolve problems in the most effective way defined by the goals
Outcome uncertainty	A type of uncertainty that arises when a range of outcomes that do not consider all probabilities are utilised in decision making.
Forecasts	Attempting to predict future conditions. Forecasts can be used to test the performance of solutions under different conditions.
Scenarios	Description of different alternative futures.
Scenario analysis	The process of testing model outcomes under a range of different scenarios to reduce uncertainty in the decision making process.
Sensitivity analysis	Testing the performance of different solutions under different conditions and identifying any potential performance thresholds based on specific parameters.
Parameters	Numeric or measurable values that form and define the condition of a model.
Utilisation	How intensively a source is used relative to its maximum capacity
Mutually exclusive	Options that cannot be chosen simultaneously
Mutually inclusive	Options which must be selected together
One way dependency	A link between two options where one forms a pre-requisite to the other.

1 Introduction

1.1 South Staffs and Cambridge Water

South Staffs and Cambridge Water (SSC) includes two regional water supply only companies: South Staffs Water (SST) in the Midlands and Cambridge Water (CAM) in East Anglia.

SST supplies 1.275 million people and over 550,000 properties primarily across parts of the West Midlands, Black Country and Staffordshire. The two principle sources of water are a reservoir in the River Trent catchment (supplying the Central Water Treatment Works) and the water treatment works on the River Severn.. These surface water sources provide approximately 50% of the water to meet the Company's average daily demand of 300 Ml/d, the remainder of supply being derived from groundwater. SST also bills and collects sewerage charges on behalf of Severn Trent Water.

CAM supplies 319,000 people and 133,000 properties in and around the city of Cambridge extending to Ramsey in the north, Gamlingay in the west, Balsham in the east and Melbourn in the south. It meets average daily demand of 75Ml/d entirely from groundwater sources. Cambridge Water operates in one of the driest and fastest-growing areas of the UK. Cambridge Water bills and collects sewerage charges on behalf of Anglian Water

1.2 Background

SSC is entering into the planning phase for the regulatory 2019 Periodic Review (PR19) and has identified the likely need for significant investment at its major surface water treatment works over the next several Assessment Management Plans (AMPs). This need creates an opportunity to take a holistic review of the long-term supply capabilities of the SSC network with a view to identifying whether alternative approaches might deliver greater benefits for customers particularly in light of future uncertainties.

SSC has developed a supply capability road map, a business plan to meet regulatory requirements in 2019, which has been shared with the regulators, within which several option streams are being progressed. Currently in Stage 3 (of four) of the business plan preparation, it is considered likely that the optimum investment strategy will feature elements of a number of, if not all, of these option streams, culminating in a more resilient supply capability for its customers in the future (Figure 1).

SSC has employed Arup to develop a Decision Making Framework (DMF) to guide the long term investment strategy and the selection of capital projects for the PR19 submission.

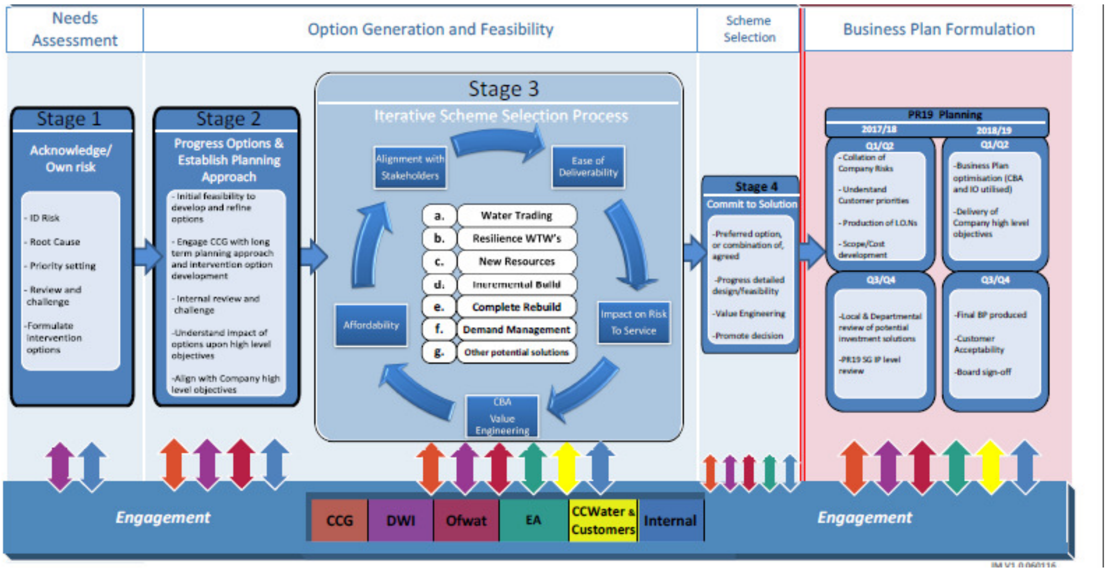

Figure 1: SST PR19 Strategy Development Process

1.3 Objectives of the DMF Project

SSC are faced with a series of investment decisions for PR19 that could result in a level of capital investment that has not been seen in previous SSC price reviews. This is driven by:

- Water quality failures in the SST regions at the two existing water treatment works and within the network
- Reductions in deployable output due to decreasing groundwater availability and quality
- An obligation to assess and address the resilience of their systems.

The objective of the DMF project is to create a framework that enables the range of capital investment options available to SSC to be compared against each other and an optimised portfolio be selected and justified. The framework is driven by both the need to ensure that trade-offs between multiple resource options are robustly evaluated (as required for the Water Resource Management Plan (WRMP)) and that the most effective investment portfolios are chosen with respect to long term asset management and the ability of SSC to respond to future uncertainty.

The identification of investment options is being undertaken through a series of option development workstreams as illustrated in Figure 1 (Stage 3). These workstreams are summarised below.

1.3.1 Option Generation Work Streams

Resilience

The resilience workstream aims to define *business* resilience and thus explore and consider opportunities for improving the resilience of SSC's supply capability, including any viable outputs identified from the other option streams.

This workstream aims to achieve:

- Identification of the business outcomes that are key for SSC
- The identification of the desired states that characterise resilience at SSC
- The assessment of South Staffs Water (SST) maturity with respect to the desired states

This workstream, whilst related to the main Decision Making Framework project, has a wider remit than the DMF method itself and therefore is not explored further in this particular report. There are number of elements within the new DMF method however that may influence the maturity level of South Staffs' resilience.

Resilience in the context of this report relates to ***Operational*** resilience i.e. flexibility, reliability and future proofing. Other topics including environmental sustainability, deliverability and social sustainability are considered part of the business resilience but are evaluated separately for comparative purposes for decision making.

Demand Management

The aim of the demand management workstream is to identify appropriate options for inclusion in the long term plan. The following aspects of demand management are being considered:

- Leakage reduction – to include active leakage control, repair run times, pressure management, Distribution Management Area (DMA) improvement, supply pipe leakage policy and mains rehabilitation
- Treatment works losses
- Metering policy including technology to enable tariff development and water efficiency targeting, location, replacement policy, change of occupier, compulsory metering to achieve full meter penetration
- Water efficiency education and behaviour change
- Working with Housing Developers
- Rainwater harvesting and greywater recycling

The objectives of the workstream are:

- To develop fully justified (cost / benefit) demand management strategies for each region.
- To identify the optimal demand management strategy for each region.
- To identify possible groups of options to reduce demand at varying scales.

Water Treatment Works (WTW) Rebuild

The aim of the WTW workstream is to identify the engineering options required to maintain compliant deployable output. Both incremental and new build options are being appraised.

The objectives of the workstream are:

- Identify options and preferred solution for incremental rebuild of the WTW's
- Identify options and preferred solution for the new build of the WTW's
- All options must meet quality and quantity long term capability expectations and regulatory expectations and legal obligations (DWI, Defra and EA)
- Maintain compliant quality and sufficient quantity during any transition works
- Optimally mitigate risks and meet resilience expectations

Resources and Trading

The aims of the resources and trading workstream are:

- To identify opportunities for new resource development in each region.
- To identify opportunities for water trading in each region.

1.4 Approach to the DMF Project

This report describes the DMF that the Arup led team has developed in collaboration with SSC. It is structured as follows:

- Description of the regulatory context in relation to SSC's needs
- Review of decision making methods
- The proposed approach to decision making for SSC.
- Proposed criteria to be introduced in the new DMF
- Implementation approaches of the new DMF and potential tool development and testing (needed for stage 4 of the business plan)

2 SSC Approach to PR14

In the previous WRMP period SSC was able to demonstrate that no deficit was forecast over the planning period, and therefore there was no need to develop or selectoptions designed to meet that deficit. This limited the need for a formal decision making framework like Economic Balance of Supply and Demand (EBSD). Water resource investments that were required for reasons of compliance were mandated into the Business Plan.

Investment requirements for PR14 were relatively modest and the investment decision making was guided by a tool called Investment Optimiser (IO). This was used to assess the cost benefit of proposed options and to select the investment portfolio to maximise the net financial benefit against maximum expenditure constraints.

There are a number of challenges facing SSC that indicate an alternative approach to PR19 would be appropriate. A series of stakeholder engagement activities were held with SSC staff to understand perceptions on the lessons learnt from PR14 and the challenges that they anticipate for PR19, these have been used to develop this DMF.

3 Decision Making Methods

3.1 Approaches to Investment Decision Making

There is much theory and opinion on how the best decision for an organisation is achieved. Figure 2 depicts a generic definition of the SSC decision process.

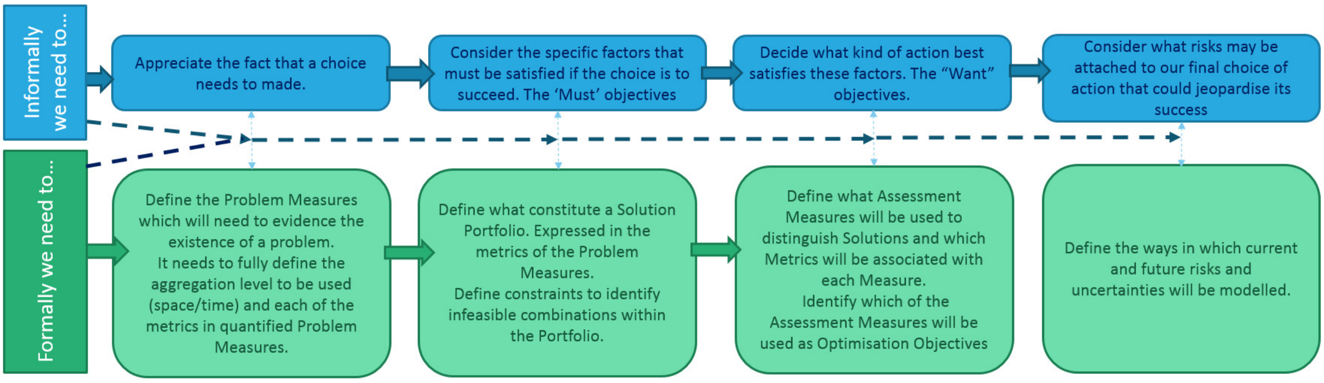

Figure 2: Decision Making Process

Decision making for any large asset base or system will always be complex and be driven by a number stakeholder needs and requirements. A number of different methods are available to use and will support a decision. All these methods will invariably need to consider the benefits and costs arising from that decision, though the inputs and outputs from that decision process may vary. Some of the typical methods used in management of infrastructure are:

1. **Cost-Benefit analysis (CBA)** – organisation (only taking into account benefits to the organisation itself).
2. **CBA – Community** (taking into account costs and benefits for the organisation and the broader community).
3. **Multi-Criteria Analysis (MCA)** (wide range of criterion which are both qualitative and quantitative in nature, and reflect cultural, social, economic and environmental indicators).

3.1.1 Cost Benefit Analysis (CBA)

CBA analysis quantifies benefits and costs over a period of time. These benefits and costs are usually discounted to Net Present Value (NPV) and compared using a set of decision criteria. CBA requires quantification in financial terms and is a traditional method for optimising a decision.

There are however some limitations with CBA due to the difficulties in quantifying intangible impacts in financial terms, and the 'single' result output can shield the decision from debate on potential complex impacts from the decision. It is now recognised that these intangible elements are an important part of the overall discussion before making a decision. Different approaches can be used to define a financial value on these items including mitigation cost method (MCM) and Willingness to Pay (WtP). MCM compares the cost to mitigate the impact to the acceptable compensation level for those affected. An examples of this would be creating wetlands to offset land drainage. WtP is already used by SSC in decision making.

3.1.2 Multi Criteria Analysis (MCA)

CBA describes costs and benefits to the decision makers in monetary terms, and a description of the other intangible, non-quantifiable factors which can potentially hide important debates before the final decision is made. This is often the biggest risk for larger, more complex decisions and when organisations often choose to use MCA for a more informed evaluation of the decision.

MCA is often used as best practice to support decision making (D. Savic, 2002, Cohon, 1978, D. A. Van Veldhuizen and G. B. Lamont, 2000). MCA is used to represent the different outcomes or aspects of each option being considered. The criteria are often weighted to reflect the importance of the element to the business in the decision. Through the weighting of different criteria, a final overall answer is then provided for each option being considered. This approach can allow an organisation to tailor the decision approach to its own objectives and needs. The downside side to that ability is that some believe that decisions can be manipulated by those who define the weighting and criteria. To mitigate this, governance and transparency is key for a decision to be upheld.

Applications of MCA range over different sectors, including transportation (Maity and Roy, 2014, Maity and Kumar Roy, 2016, Acharya and Biswal, 2016) and management of water resource systems (Dauer and Krueger, 1980, Matrosov et al., 2013, Fritz et al., 1977, Xiao-qiang and Zhi-e, 2015, D. C. Major, 2013). Within the English water utility sector UKWIR has recently released guidance for a revised decision making framework that moves away from least-cost EBSD (UKWIR, 2002a, UKWIR, 2002b) into a wider array of more advanced techniques that also include multi-objective analysis (UKWIR, 2016). The benefits of Multi-criteria Analysis (MCA) over CBA and least-cost planning has been demonstrated in a research study applied to the Thames water resource system (Matrosov et al., 2015). Thames Water is also planning to apply MCA within their WRMP19 to allow for a more transparent assessment methodology where planning solutions are screened against a wide variety measures in addition to NPV cost (i.e. deliverability, resilience, sustainability) (Thames Water, 2015).

3.2 Water Resource Decision Making Methods

3.2.1 Background

Every 5 years, water companies are required to develop a long term WRMP.   This requires:

- Making 25 year forecasts of supply and demand (Supply Demand forecasts). If a deficit is forecast within 25 years, then;
- Developing Options which will contribute to meeting that deficit, and;
- Selecting the best Option or Set of Options.

For companies with a forecast deficit, a typical problem visualisation is shown in Figure 3.

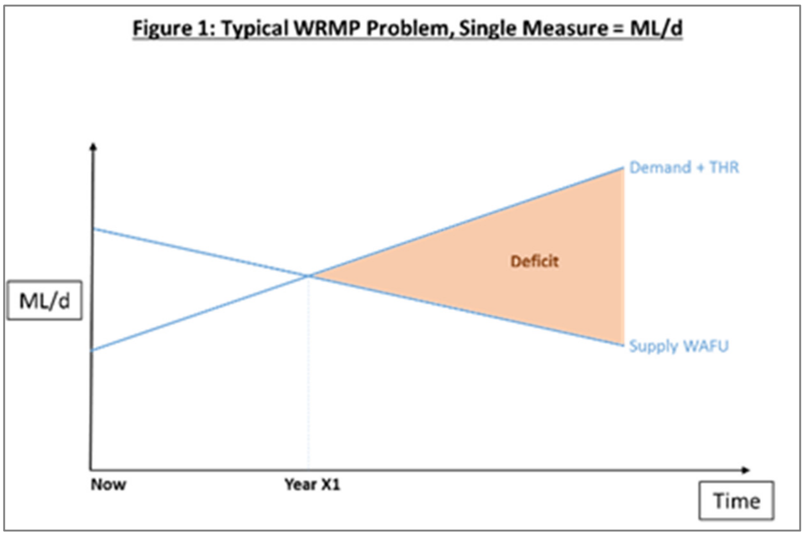

Figure 3: WRMP Problem Visualisation

In Figure 3, the problem is forecast to exist in Year X1 onwards when Water Available for Use (WAFU) will fall below Demand + Target Headroom (THR). The problem is then fully defined by the red area in the chart.

The water industry has developed a range of methodologies and guidance (Decision Making Frameworks) which support water companies in the task of developing solutions to this problem and in communicating the outputs to others.

Many water companies in the UK are predicting deficits in one or more Water Resource Zones (WRZ). They have sought to apply versions of the decision making frameworks developed over the last decade by UKWIR and regulators, and until recently, most of those centred on variants of EBSD.

3.2.2 Economic Balance of Supply and Demand

EBSD is a decision framework that is well established within the water industry, with supporting WRMP Guidelines developed by regulators to support its practical use and application by water companies.

The EBSD Framework is designed to address a particular type of Problem / Solution structure. The problem is that Demand and Supply are forecast to be unbalanced in the future. The solution is a Portfolio (or a Schedule) of investments to increase Supply-side Capacity or reduce Demand to ensure a future balance. EBSD guides in the steps for making the decision of which is the best portfolio or schedule of investments.

The types of things that are included in the framework are:

- Level of spatial aggregation: Supply/Demand/Option Benefits are at Water Resources Zone level
- Target Headroom calculated at WRZ level and added to Demand
- Level of time aggregation: Inputs and output are on annual time step

- Within year Variability: captured via Planning Scenarios, Dry Year Annual Average, Dry Year Critical Period
- Planning Period: Minimum of 25 years
- Cost Assessment Period: linked to new asset life
- Costs: Discounting, Calculation of Opex, inclusion of Social and Environmental costs

EBSD provides for varying levels of sophistication in the modelling. For example, in PR14, some companies with less complex problems used a selection procedure within their Options Appraisal which is a simple ranking of discounted unit costs (AIC/AISC's).

3.2.3 Developments in WRMP Decision Making

As the complexity of water resource planning decision making has increased the industry has developed enhanced water resource planning modelling technique. There are several ways of extending EBSD, these include:

- MCA : Multi Criteria Analysis
- MGA : Modelling to Generate Alternatives
- Real Options Analysis

3.2.3.1 Multi-Criteria Analysis (MCA)

This approach is discussed in section 3.1.2. It goes beyond least Cost and can consider other criteria such as increased resilience. This approach aligns with the desire to ensure that investments are appraised on a range of relevant criteria and addresses one of the main critiques of EBSD which requires all factors to be monetised.

3.2.3.2 Modelling to Generate Alternatives (MGA)

MGA is a modelling approach which seeks "Near Optimal" portfolio solutions. There may be portfolios which have similarly good performance to the optimal, and MGA is a mathematically orientated technique to locate them. It can be implemented within an optimisation tool however we would not recommend it for the current SSC context as it does not add significantly to the output of the less complex MCA approach. If required, an MGA add on could be added to an MCA approach at a later date.

3.2.3.3 Real Options Analysis

Real Options is a technique which is well established in other industries but new within WRMP. It is a method of valuing flexibility and examining the trade-off of delayed investment; an example is given in Figure 4 to illustrate this technique. In practice, implementing this approach in a consistent way within an EBSD type of model is complex, and requires a large amount of analysis of potential decision routes under different circumstances which are likely to be scheme specific.

Some appreciation of relative flexibility is worthy of considering within the SSC DMF approach. At the current time, however, a full real options analysis is likely to be overly complex.

Real Options Example

Consider two Portfolios which both serve to meet a forecast deficit expected to reach 10 ML/d. Portfolio 1 builds one large scheme, portfolio 2 builds two smaller schemes in succession and is 5% more expensive in terms of whole life NPV.

	Portfolio 1	**Portfolio 2**
Schemes	Opt A	Opt B and Opt C
NPV of Whole Life Cost	£100m	£105m
Capacity Added	A = 10ML/d	B = 5 Mld C = 5 Mld
Start Year	2022	B : 2022 C : 2027

A Real Options approach would consider Portfolio 2 to be inherently more flexible; option B is built but leaves the option to build Option C to a later date. If in the meanwhile demand changes then the decision on Option C can be changed.

With Portfolio 1 a commitment has been made earlier to the 10 Mld scheme. Is it worth paying £5m more for the flexibility that Portfolio 2 brings? This will depend on how likely it is that there will be a large amount of "Regret" associated with Portfolio 1.

Figure 4 : Simplified Illustration of Real Options Analysis

3.3 SSC Water Resource Context

UKWIR recently published new guidance on WRMP Methods for 2019. Central to the guidance is a risk assessment, termed the "Problem Characterisation", of the current water resource zone (WRZ). This aims to identify how big the water resource supply-demand issue may be and then secondly, how difficult the problem is to solve.

In order to define the SSC position with respect to the UKWIR guidance a problem characterisation workshop was held with SSC subject matter experts. This workshop concluded that compared with the position in PR14, both the SSW WRZ and CAM WRZs face new risks to their overall supply-demand balance. The problem characterisation was developed collaboratively and is shown in Figure 5. This highlights that both WRZs are in the amber area of Medium strategic needs (scale of the problem) and complexity scores. Based on the information presented in South Staffs respective WRMP14 period, both WRZs would previously have been in the green areas of lower risk. Further details of the problem characterisation are provided in Appendix B. The implications of the WRMP problem characterisation on the decision making method to be adopted by SSC are:

- An enhanced decision making method should be used;
- an aggregated rather than simulated approach is appropriate ; and
- a scenario based method should be considered.

		Strategic Needs Score ("How big is the problem")			
		0-1 (None)	2-3 (Small)	4-5 (Medium)	6 (Large)
Complexity Factors Score ("How difficult is it to solve")	Low (<7)				
	Medium (7-11)			SS C	
	High (11+)				

The key drivers behind the changes to the level of risk are:

- A wider appreciation of drought resilience which means that both SSW and CAM may be vulnerable to droughts that are different to those experienced historically.
- Wider resilience issues affecting both WRZs; in South Staffs there is a potential decline in the volume, quality and reliability of available water resource without the renewal of long term treatment work assets, whereas in Cambridge there are long term growth concerns and regulatory pressures on abstractions licenses.
- High level concerns due to regulatory pressures on abstraction licenses which are leading to license claw back and sustainability reductions.
- In South Staffs added complexity is introduced due to the limited flexibility of the current water supply network which potentially requires parallel upgrades to the two strategic treatment works.
- In Cambridge, long term regional growth is being encouraged by government but with large uncertainty over the amount and timing.
- In Cambridge a limited amount of new supply side options are available which require consideration of intercompany bulk import supply side solutions with associated additional uncertainty in timing, costs and access.

Figure 5: WRMP Problem Characterisation

3.4 Proposed Decision Making Method

With ideas from within the latest UKWIR guidance, the EBSD methodology can be adapted to include multiple criteria for judging investments against non-financial criteria. This addresses one of the major flaws that some people have had with the EBSD methodology which originally set out that a single metric of cost was used to judge competing investments and that non-financial criteria (environmental, social) were monetised

It is proposed that a Multi Criteria Analysis (MCA) using an extended aggregated approach is the basis of the new framework. It is a sufficiently flexible approach to enable a range of sensitivity and scenario analysis to be developed to build confidence in the final decision. This is to help ensure that investments are appraised on a range of relevant criteria in line with the latest UKWIR WRMP guidance. Utilising the aggregated approach in PR19 is considered the most pragmatic approach and a first step to applying a more rigorous set of methods for the future.

4 Development of the Decision Making Framework

4.1 The SSC Context

In order to help develop the framework a series of workshops were held with SSC subject matter experts and the SSC Executive Committee. These were as follows:

- **Workshop 1**: The bespoke Arup Drivers of Change methodology was utilised to help identify the future impacts on the business and the core outcomes required of the business. The outputs of this exercise are summarised in Table 1 and help set the context for the investment decision making framework.
- **Workshop 2**: A water resources risk based problem characterisation for the South Staffs and Cambridge region was jointly developed with SSC subject matter experts. This followed the latest UKWIR guidance and was utilised to guide the choice of decision making methods.
- **Workshop 3**: The focus of the third workshop was on the identification and selection of indicators to guide the decision making process. This workshop was instrumental in the design of the DMF that is presented in subsequent chapters of this report. Figure 6 shows an extract from this workshop.
- **Resilience Workstream**: In parallel to the workshops a separate piece of work was undertaken to develop a definition and measurement of resilience relevant to SSC.

Further details of the above are provided in the Appendices.

Table 1: Drivers and Outcome Delivery Incentives (ODIs)

Working Group Drivers	Exec Drivers	SSC's ODIs
Raw availability	**Ability to meet demand**	Excellent water quality, now and in the future
Fit for purpose system (now)	**Ability to meet Quality Requirements**	Secure and reliable supplies, now and in the future
Resilience	**Ability to Influence Demand**	Excellent customer experience to customers and community
Population growth and location		Operations that are environmental sustainable
Large scale effective demand management	**Provide shareholder return**	Fair Customer bills and fair investor returns
Harnessing opportunities for technological development	**Ability to adapt in the future**	-

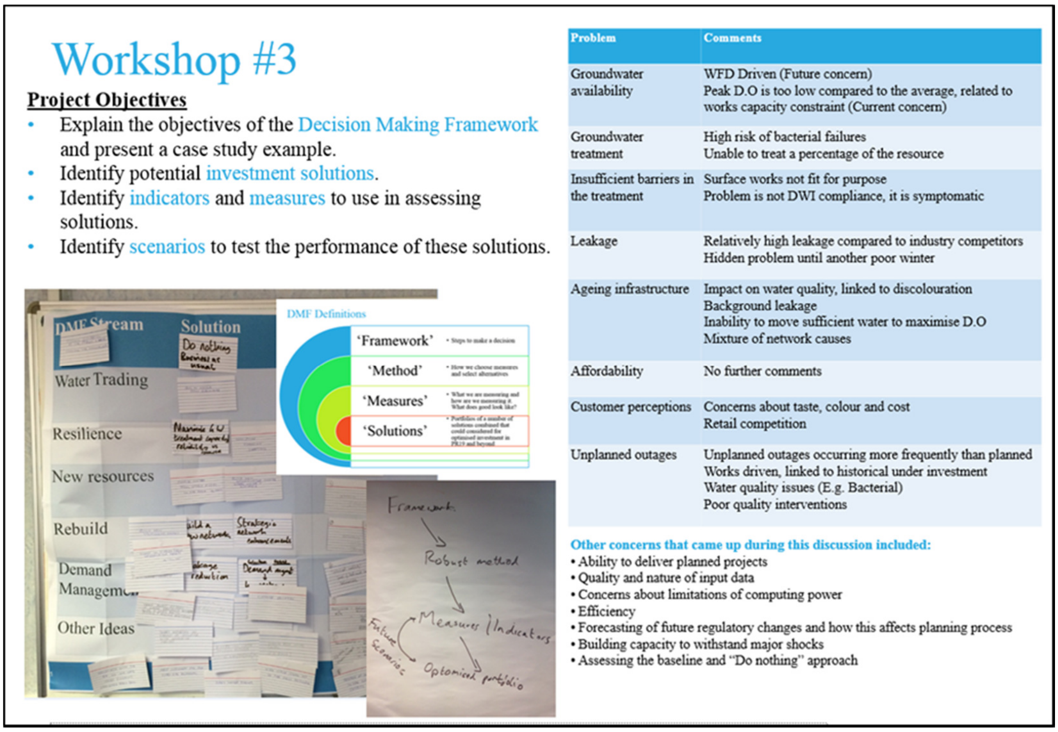

Figure 6 : Summary of Workshop #3

4.2 Features of the framework

The objective of the DMF project is to create a framework that enables the range of capital investment options available to SSC to be compared against each other and an optimised portfolio be selected and justified. The framework is driven by both the need to ensure that trade-offs between multiple resource options are robustly evaluated (as required for the Water Resource Management Plan (WRMP)) and that the most effective investment portfolios are chosen with respect to long term asset management and the ability of SSC to respond to future uncertainty.

In light of these challenges the DMF was developed to focus on two key questions that must be solve simultaneously, the first around quantity of water, the second about quality of water:

- **Quantity:** The DMF seeks investment portfolios that satisfy the time varying supply demand balance under a range of future scenarios; notably impacts of headroom, outage, climate change and population growth.
- **Quality:** The DMF seeks investment portfolios that satisfy a range of time varying and spatially varying water quality challenges.

Key features of the DMF structure are discussed below

4.2.1 Timing of Option Starts

The problem to be solved is a time based problem; varying demand over the planning period and varying water quality standards. The decision as to when an option starts and therefore how quickly benefit accrues within the planning period is a critical part of the modelling approach. The framework seeks to allow the model to optimise the start date of options with varying impact on performance criteria and maximising the ability to achieve a no-regrets decision. For example delaying a decision to the latest possible start date retains the most flexibility for future decisions.

The framework is based on an annual time step. The magnitude of the problem is set for each year of the planning period and varies through the planning period, the optimisation model is required to identify portfolios of solutions that satisfy the problem in each year of the planning period. For each year of the planning period the model accrues scores against performance indicators based on the options that have been utilised; therefore the earlier that a high scoring option is implemented the greater the performance score over the whole planning period.

4.2.1.1 Capacity versus utilisation

A consideration of utilisation is very valid in a WRMP context with seasonal variations in demand meaning that a balanced view of variable opex over the year should inform any cost based decision.

Different types of options tend to have very different relationships between fixed and variable costs. Since South Staffs are considering various option types then it makes sense to consider both Fixed and Variable Opex in the decision and to provide for an output in terms of different utilisation levels.

Certain options with relatively low Capex/high Variable Opex may be cost-effective if their anticipated use is only in Peak Periods. Modelling utilisation of schemes allows this to form part of the optimisation decision.

4.2.1.2 Interdependencies

Water resources options may typically be interdependent in some way. For example, in a limited yield situation, two surface water options with potential yields of 0.5 ML/d and 0.8 ML/d may not have combined benefit of 1.3 ML/d if both are chosen.

In construction options it is common to have a one way dependency, for example, an initial build A, could be followed by an extension build B. This implies that A can be selected without choosing B. However, B cannot be selected without A having been selected and constructed.

Within an aggregated modelling approach as is being proposed here for SSC, there are limitations to the representation of interactions of sources. For very complex situations of conjunctive use, a system simulation would be needed to fully represent those interactions. It is however entirely feasible to pre-define certain logical relationships and to ensure that a portfolio is only considered to be a candidate solution if it respects those relationships. Typical dependencies included within the framework are shown below:

Type of Relationship	Data Required	Example	Constraint on the Solution	Example Options
Mutually Exclusive Groups	Groupings of Options	ME Group 1 = {Opt1, Opt 2, Opt3}	Maximum of one Option from the group can be included	Variants of Metering Schemes Variants of a Build Scheme
Mutually Inclusive Groups	Groupings of Options	MI Group 1 = {Opt4, Opt5}	Neither Option Or Both Options must be included	Option 5 is an upgrade option with no direct benefit. Option 5 enables the benefits for Option 4 to be realised.
One Way Dependence	Pairing, direction.	Prerequisite =-Option6 Dependent = Option7	Can only choose Option 7 if Option 6 has been chosen at some time earlier in the schedule. Can choose Option 6 alone.	Option 6 = Phase 1 of a construction scheme Option 7 = a possible (but not essential) Phase 2 of the same scheme
Limited Yield	Groupings and Impact	LY group	Limit utilisation	Two surface water schemes on same river. Subject to a total yield limit.

4.2.1.3 Uncertainty and Risk

The type of uncertainty most relevant to the SSC is outcome uncertainty which arises when a range of outcomes that do not consider all possibilities are utilised in the planning process. There is no obvious solution or tool that can remove or completely resolve the issue of uncertainty from the decision making process. However, there are techniques that can be applied in the planning process to ensure that the decision making outcomes remain robust and flexible even in the face of uncertainty. These are:

- **Sensitivity analysis;** this allows the modeller to understand the circumstances under which the optimal solution changes. The optimal strategy is said to be robust if it is insensitive to changes in parameters. The DMF has been set up to allow sensitivity of key elements to be tested (for example variations in resource yield).
- **Scenario analysis** is a technique that allows the performing of multiple sensitivity analyses at the same time. It involves describing uncertainty using a means of a set of possible future outcomes called 'scenarios'. Scenario analysis gives the modeller an ability to reduce uncertainty in the decision making process by exploring the performance of the model under different future conditions and selecting portfolios that delay the decision point to the latest possible date. The DMF has been established in order that the impact of alternative future scenarios around both demand and water quality can be tested.

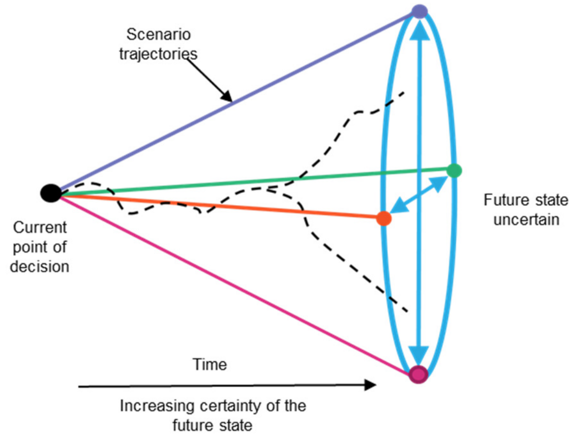

Figure 7 : Impact of different future scenarios

4.2.1.4 Flexibility

Within WRMP, there is interest in the concepts of flexibility and adaptability. Different investment portfolios may be more or less inherently flexible due to the nature of the options that they contain. The Real Options analysis approach seeks to mathematically assess this. Whilst this is not considered appropriate for the SSC context it is important the same "no regrets" principle is brought into the DMF review stage. It is anticipated that this will take place as part of a Flexibility Review process at the portfolio analysis stage; an example of this is shown in Figure 8 and further information is provided in the Appendices.

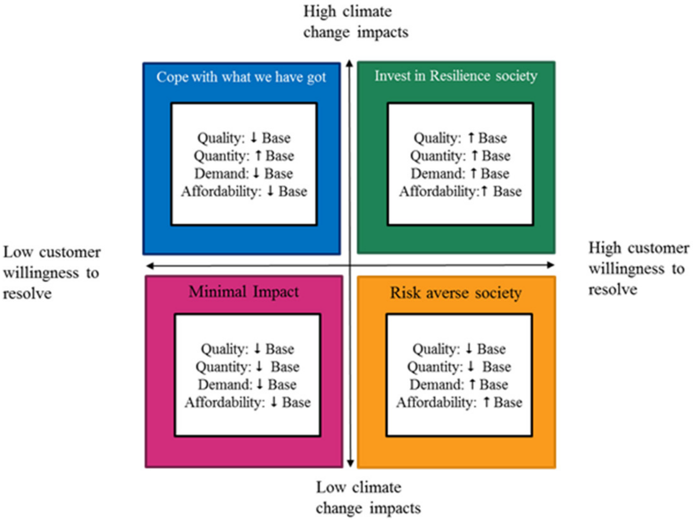

Figure 8 : Example of a flexibility review

4.2.1.5 Multiple Objective Optimisation

MCA can be used to analyse the scores, trade-offs and project combinations and establish an optimised portfolio of options. This portfolio will meet the constraints set but also optimise against the other performance objectives which the analyser deems most important. By running the tool using a range of future scenarios (eg. High population growth) different indicators can be varied to identify the optimum portfolio choice.

A typical approach to MCA is to use the method to identify portfolios that meet a predefined "best" position, for example the "Least Cost" or the "Most Resilient" portfolio. A better approach is to form an understanding of trade-offs. In this example, the optimisation question to be answered should be based on preferring Low Cost, High Resilience answers. Multiple Objective optimisation allows for more than one objective, each meeting several criteria, to be considered at the same time. The approach utilises trade-offs between competing criteria and finds for example, the set of least cost portfolios at different resilience levels The output from the optimisation if done with two objectives at the same time are "Pareto Optimal" portfolios which lie on the frontier.

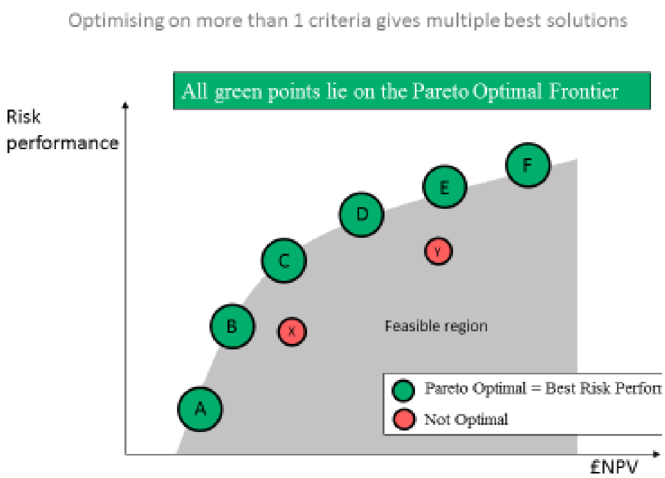

Figure 9 : Illustration of trade-offs and identification of the Pareto Optimal Frontier

The trade-offs approach is inherent to the framework outlined in this document. The aim is to guide the decision making process through visibility of trade-offs between timing, performance, impacts and cost. To this end, indicators do not have the same unit of measurement as would be the case in a monetised framework, instead they are designed to enable competing impacts to be balanced in a meaningful way. Figure 9 illustrates the trade-off approach, all portfolios in the grey area are feasible but those on the frontier are optimal.

5 Framework Structure

This chapter sets out the full structure of the Decision Making Framework and the required data inputs. It is split in two sections:

- **Problem Definition;** components of the framework that define the problem that the model must solve.
- **Option Assessment;** details of the metrics used to measure the performance of all investment options entered into the model.

5.1 Problem Definition

The framework has been developed to identify feasible portfolios of options that address two primary future scenarios and one secondary scenario criteria as follows:

- **Quantity;** the selected portfolio must, as a minimum, be able to meet the water resource zone supply demand balance for every year of the planning period.
- **Quality;** all options within the selected portfolio must meet the water quality target set for the location. Options are only eligible for selection in any given year if they meet the water quality target of that year.
- **Affordability;** a secondary criteria of maximum annual and AMP based expenditure is also included within the functionality of the framework.

5.1.1 Quantity

For each year of the planning period the DMF requires the demand requirements to be set for each water resource zone (wrz). This is the volume of water required for the zone including allowances for headroom, climate change and population growth. In line with water resource management planning guidelines, and in order to understand the normal operating scenario, the annual demand in the framework is set as a three tier problem:

- Dry year annual average (DYAA)
- Dry year critical period (DYCP)
- Normal year annual average (NYAA)

In any year of the planning period the combination of options selected must be able to deliver the volume required for each of these scenarios as a minimum. The model is free to provide a volume greater than that required and subsequently partially utilise some sources; utilisation in any given year is thus an indicator of the flexibility and an important item of analysis. All volumes are mega litres per day (Mld).

In order to understand the impact of different population growth and climate change projections it is envisaged that a series of different future demand projections are generated that reflect different futures. Different portfolios would be generated by the DMF to meet each of the scenarios and the output tested with respect to uncertainty and flexibility. This is discussed further in section 6.

5.1.2 Quality

The water quality component of the DMF is a result of the treatment challenges experienced by SSC and the subsequent generation of the Long Term plan in conjunction with the regulators. The company needs to ensure that investments related to a particular source will deliver the required water quality both now and in the future against a range of possible future challenges. The key questions faced by the company are, firstly the level of current and future water quality risk that should exist across its sources and secondly the speed at which improvements in the management of that risk against both current and possible future challenges should be deployed. There are choices to be made and trade-offs to consider in terms of the degree of sophistication, future proofing and flexibility for future adaption depending on the pace and scale of emerging challenges. There is likely to be more than one acceptable solution to the various quality issues, and thus a degree of potential for different optimised portfolios.

Water quality is impacted by both external and internal factors and investment decisions need to take account of known and likely changes to both. External factors such as raw water quality arriving at abstraction points, pollution, climate change impacts on water quality, peak summer temperatures and third party contamination can all be assessed in terms of risks, historic information and assumptions made on current and future challenges.

Assessments of water quality cover a wide range of parameters and it is not the intention of this framework to provide a detailed analysis water quality; its purpose is to allow comparison between different investment options. In conjunction with SSC's water quality experts, a series of high level water quality metrics have been identified against which the performance of investment options can be assessed, these are as follows:

- Micro biology; E Coli, Coliforms, Clostridia, Cryptosporidia
- Pesticides; Nitrates, Metaldehyde
- THM potential
- Aesthetic / Discolouration potential; Iron, Manganese and Aluminium

A risk based approach to performance against these metrics was developed with SSC, and is shown in Figure 10. At the left hand end of the scale is low performance and at the right hand end is high performance, in all cases compliance is achieved.

For each source of water a target performance is set in the DMF that varies with time. The target performance is based upon known current challenges, possible future challenges and the company approach to managing water quality risk. The time based nature of the framework allows the impact of future uncertainty to be tested through different water quality scenarios; Figure 11 shows how these scenarios are inputted.

Within the DMF the quality target acts as binary switch; investment options are either able to meet the required quality target at a given capacity in the given year, or they do not. If they do not meet the target in a given year then they cannot be selected although they could have been utilised in other years when there is reduced quality target. This enables options to be utilised in the early part of the planning period but then removed or downgraded in later years if the quality target has been increased or the raw quality has deteriorated.

	Water Quality Grade				
	Higher Water Quality Risk				Lower Water Quality Risk
	1	3	5	7	10
Micro biology E Coli, Coliforms, Clostridia, Cryptosporidia ***Nitrates*** ***Metaldehyde***	**Unacceptable likelihood of failing to meet regulatory compliance, performance significantly lower than industry norm.**	**Low likelihood of failure, low end performance**	**Minimal likelihood of non-compliance but low performance with respect to the industry**	**Minimal likelihood of non-compliance but average with respect to the overall water quality**	**Minimal likelihood of non-compliance with excellent water quality performance for customers**
Aesthetic / Discolouration potential Fe, Mn, Al criteria	Al 30 ug/l Fe 20 ug/l Mn 15 ug/l	Al 25 ug/l Fe 18 ug/l Mn 10 ug/l	Al 15 µg/l Fe 15 µg/l Mn 5 µg/l	Al 10 ug/l Fe 10 ug/l Mn 1 ug/l	Al 5 ug/l Fe 5 ug/l Mn 0.5 µg/l

Figure 10 : Water Quality Targets

Quality Problem Settings

Source Name: *Enter source name* **Standards to achieve (1,3,5,7,10)** **5 Yearly blocks**

		Next AMP					Following AMP					Future AMPs						
ex works compliant	**Score**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 6**	**Year 8**	**Year 9**	**Year 10**	**3rd AMP**	**4th AMP**	**5th AMP**	**6th AMP**	**7th AMP**	**8th AMP**	
Micriobiology	E Coli																	*Enter target scores (1,3,5,7) for the source for each year of the planning period, based on current and future raw water quality challenges.*
	Coliforms																	
	Clostridia																	
	Cryptosporidia																	
Pesticides	Pesticides																	
Nitrates	Nitrates																	
THM formation potential	THM formation potential																	
Metaldehyde	Metaldehyde																	
Aesthetic / Discolouration potential	Al																	
	Fe																	
	Mn																	

Figure 11 : Template for entering water quality target scores per source

5.1.3 Affordability

Additional functionality has been included in the DMF to allow the annual and AMP based Totex to be capped. This is intended as a proxy measure for affordability and enables portfolios to be generated within the constraint of set expenditure limits. It is anticipated that this functionality will be used towards the end of the business planning process to guide the final portfolio selection.

5.2 Option Assessment

Each investment option that is entered into the DMF must be assessed against the capability and performance criteria as shown in Figure 12.

	Option Capability		Option Performance				
	Quantity MLD	Quality	Totex £	Operational Resilience	Deliverability	Environmental	Customer Preference
Option 1							
Option 2							
Option 3							
Option 4…							

Figure 12 Framework structure

The option capability criteria are those measures that quantify the ability of an option to meet the quantity and quality problem definition as described previously; these are absolute measures of capability.

The performance criteria are those measures that enable the DMF to optimise the portfolio against competing factors that are not directly comparable, these are:

- Totex; whole life cost assessment of the options using a single discount factor set for the whole framework allowing least cost optimisation to the undertaken.
- Resilience; Operational resilience of an option in meeting constraints and the ability to adapt to change.
- Deliverability; Ease of implementing an option.
- Environmental Sustainability; Operational impact on the environment, including carbon, biodiversity and sustainable abstraction.
- Customer Preference; the extent to which the option is in line with customer preference.

Each of the criteria are further discussed below.

5.2.1 Option Capability

5.2.1.1 Quantity

The quantity indicator seeks to demonstrate how each option will contribute to the supply demand balance. All options will be required to show the quantity impact described in terms of annual Mega litres per day (Ml/d) including a range of uncertainty. These are against the following planning scenarios:

- Dry year annual average (DYAA)
- Normal year annual average (NYAA)
- Dry Year Critical Period (DYCP)

In order to reflect the uncertainty that commonly exists in the calculation of resource yield at the planning stage, the framework requires users to enter a worst case and best case as well as their normal estimate. This enables the sensitivity of resource projections to be tested in the outputs. It should be noted that the DMF yield figures below may be reduced under some water quality targets, this is discussed in the section below.

Savings from demand management (DM) measures are entered as an annual saving through each year of the option, data entered into year 40 is assumed to be a residual benefit and will be applied in every subsequent year of the planning period. Figure 13 shows how quantity data is entered into the framework.

Supply capacity

	Ml/d	Dry year annual average (DYAA)	Normal year annual average (NYAA)	Dry Year Critical Period (DYCP)
Quantity (Ml/d) provided by Option	Extreme scenario yield esimate			
	Lower Yield Estimate			
	Best Central Yield Estimate			

Demand reduction profile

Year

	Ml/d	1	2	3	4	5	....	40+
Annual water saving from demand management measures	Lower Estimate							
	Best Central Estimate							
	Upper Estimate							

Figure 13 : Quantity Inputs

5.2.1.2 Quality (Treatment Capability)

Provision of water at the right quality is an essential part of SSC's operation and licence to operate. The ability to meet this performance requirement is a core consideration in relation to new investment decisions.

Individual options presented to the framework must state the quality standard which can be achieved with respect to the quality performance standards. In some instances the treatment performance standard is proportional to the volumetric output (for example a progressive rebuild of the works); the quality input data is therefore linked to a maximum works output. If the option is selected, the maximum volumetric output that the DMF can utilise in the supply demand balance is the lower of the maximum works output at a required quality standard and the yield as described in section 5.2.1.1.

Quality - Deployable Output

Raw Water Source	*Enter source reference*	*Enter name of the source*

Water Quality Indicator	Performance Level [Column A]	Output (Ml/d) [Column B]	Performance Level [Column C]	Output (Ml/d) [Column D]	Performance Level [Column E]	Output (Ml/d) [Column F]
Micro Biology						
Pesticides						
Nitrates						
Metaldehyde						
THM Potential						
Asethetic Discolouration						

Notes:
1) When completing this worksheet it is essential to refer to the raw water quality target for the source. If the option does not meet the target, it will not be selected.
2) It is mandatory to complete columns A and B, columns C to F are optional and only required if a change in output would change the water quality performance level

Target Levels

Water Quality Indicator	Performance level				
	1	3	5	7	10
Micro biology E Coli, Coliforms, Clostridia, Cryptosporidia	Unacceptable likelihood of failing to meet regulatory compliance, performance significantly lower than industry norm.	Low likelihood of failure, low end performance	Minimal likelihood of non-compliance but low performance with respect to the industry	Minimal likelihood of non-compliance but average with respect to the overall water quality	Minimal likelihood of non-compliance with excellent water quality performance for customers
Nitrates					
Metaldehyde					
Aesthetic / Discolouration potential Fe, Mn, Al criteria	Al 30 ug/l Fe 20 ug/l Mn 15 ug/l	Al 25 ug/l Fe 18 ug/l Mn 10 ug/l	Al 15 µg/l Fe 15 µg/l Mn 5 µg/l	Al 10 ug/l Fe 10 ug/l Mn 1 ug/l	Al 5 ug/l Fe 5 ug/l Mn 0.5 µg/l

Figure 14: Water quality leaving treatment works (ex works)

5.2.2 Option Performance Measurement

5.2.2.1 Cost

It is recognised that while decisions made on cost alone do not support holistic business and service improvement, cost remains crucial together with the provision of shareholder returns and fair customer billing.

Business investment costs are typically measured in the water industry in terms of total expenditure 'totex' which references whole-life costs as opposed to traditional capital expenditure ('capex') and operational expenditure ('opex') cost models. Ofwat introduced 'totex' in PR14 in an attempt to move the industry away from capital intensive solutions that provided return on regulatory capital value (RCV) but which were not necessarily the most sustainable, socially acceptable or lowest whole life cost solutions. The original methods of appraising a decision on different cost bases was often influenced by different incentives (or penalties) potentially resulting in a biased comparison.

The framework utilises when assets are built. For each asset, the cost spend over the asset lives is considered, knowing for example after how many years replacement costs are expected to incur for each asset, and the construction period over which the initial capex spend is spread. The annual cost profiles of capex, opex and vopex costs are then accounted starting from the first year of activation of selected schemes.

For each option, inputs will be required in annual minimum, medium and maximum values for:

- Capital expenditure (£/yr)
- Capital Renewals (£/yr)
- Fixed operating costs (£/yr)
- Variable operating costs (£/ML)
- Network Costs and benefits (£/Ml)

Capital costs are split into “initial capex” and “replacement (or renewal) costs”. Initial capex figures are non-recurring costs associated with the acquisition of fixed assets (e.g. pipeline, land purchase), while replacement cost expenditure are asset replacement costs required during the planning period. Figure 15 illustrates the cost breakdown concept utilised in the framework.

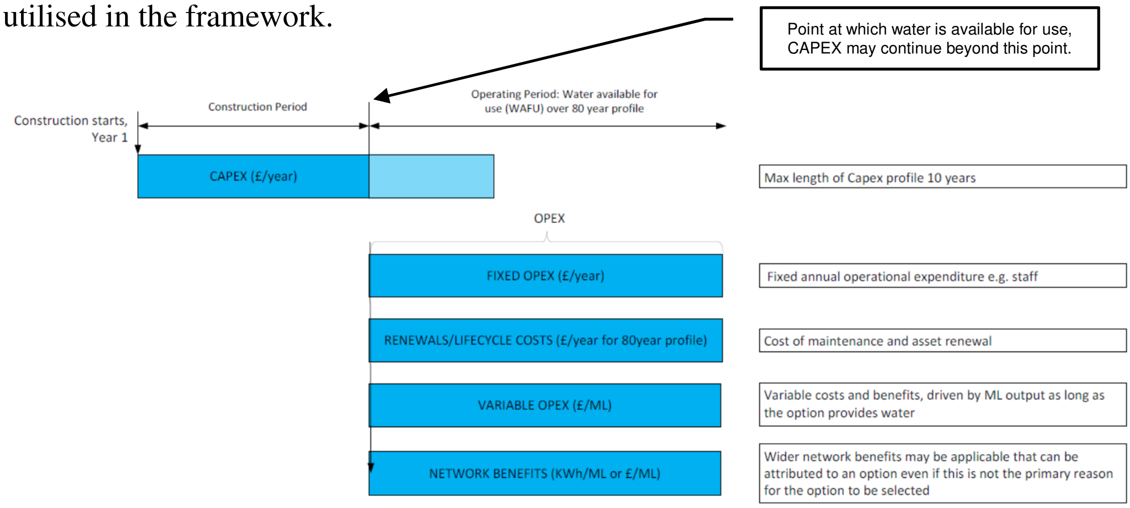

Figure 15 : Application of cost data in the framework

All comparison of costs is done on whole life cost using a discount factor set at a global level in the framework, this enables sensitivity analysis on the discount factor to be undertaken.

Each component of the cost data is discussed further below.

Capital Expenditure

Financial capex reflects non-recurring costs associated with the acquisition of fixed assets.

Initial capital expenditure (£'000): Physical structure or land purchase. Initial capital expenditure may apply not only to supply-side schemes (e.g. new reservoirs) but also to demand management measures that involve capital investment, such as new domestic meters and leakage reduction (Figure 16).

The total construction period is the time that it takes for the benefit to commence. In some instances, such as demand measures, benefit accrues immediately and so this period will be set to zero although expenditure continues beyond year zero.

Capital Investment

Total Constuction Period (Years)											
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Construction Phase Expenditure (£k/yr)	low estimate										
	mid estimate										
	max estimate										

Figure 16: Capex inputs

Capital Renewals

Replacement expenditure (£'000): Data is either entered into the framework as periodic costs against a defined set of asset classes (Figure 17) or as a cost profile through the whole planning period.

Capital Renewals (£k)

	Asset Class					
	Freq Renewal (Yrs)					
Lifecycle Expenditure (£k)	low estimate					
	mid estimate					
	max estimate					

Figure 17: Capital Renewals Input

Fixed Operational Expenditure (Fopex)

Fopex reflects costs incurred during the operation of an option that are fixed regardless of changing levels of output, for example operating staff. These are expressed in £'000/year and typically include staff costs (Figure 18).

Operating Costs

		£k / yr	description of assumptions	
Fixed Operating Costs Expenditure £k/yr	low estimate			*free text*
	mid estimate			
	max estimate			

Figure 18: Fixed Operating Costs Input

Variable Operational Expenditure (Vopex)

Vopex describes operational costs incurred during operational life of an option which vary with changing levels of output. These are usually expressed in £/Ml/d and typically reflect energy, chemical costs or network costs that vary depending upon the level of utilisation of the option. (Figure 19)

		Energy KwH/Ml	Chemicals £/Ml	Other £/Ml
Variable Operating Costs	low estimate			
	mid estimate			
	max estimate			
	Note: £/KwH set at a global level			

Figure 19: Variable Operating Costs Input

The energy unit cost and annual escalation is set at global level within the model which enables consistency sensitivity analysis across the portfolios.

5.2.2.2 Operational Resilience

A resilience definition and review has been completed within the separate resilience workstream to describe what "good resilience" for South Staffs would look like. A tool described as a "resilience lens" has been created with a number of key business objectives and a selection of desired states. Elements from this business resilience tool can be associated with outputs from the DMF and in several different criteria when used in the assessment of investment options (Figure 20). A single investment option on its own will have limited influence on the lens however, if the cumulative impact of multiple options is considered, then an overall resilience performance for a portfolio can be calculated and compared against other portfolios. The choice of investment options is not able to influence performance against the entire resilience lens but will impact elements of the resilience lens as indicated in Figure 20.

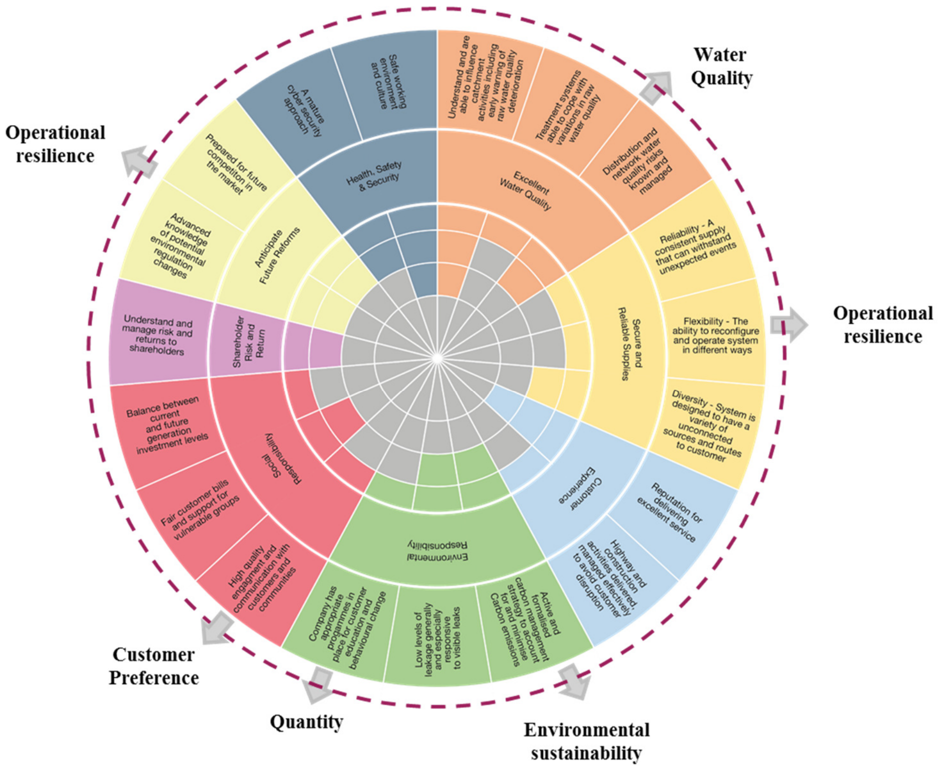

Figure 20 : Resilience Lens segments and their linkage to the DMF

A major area of SSC's resilience that the choice of the long term plan investment options can impact on it operational resilience. In conjunction with SSC, a number of elements of operational resilience were considered for inclusion in the DMF, the selected categories are listed below:

- The extent to which an option impacts the **reliability of supply** to customers at the right volume and quality across the WRZ.
- The extent to which an option impacts the **flexibility of supply** options across the WRZ.
- The extent to which an option impacts the **diversity of supply** options available in the WRZ.

The purpose of the DMF is to assist SSC in making decisions about how best to meet the supply demand balance in the long term through the replacement, upgrade or abandonment of existing assets and resources. The assessment of operational resilience in the DMF is therefore comparative rather than absolute; options are scored to show how they impact the operational resilience of the WRZ when compared to other investment options.

Each option is scored from zero to five, with the lowest score assigned to options that have a low impact on resilience and the highest score to those that have the largest impact on resilience. The factors considered in the scoring are shown in Figure 21.

	Reliability	Flexibility	Diversity of supply
Principle	**The degree of reliability of critical assets - levels of unplanned outage**	**The degree of flexibility to reconfigure system to respond to events**	**The degree of diversity of supplies available; level of dependency on sources.**
Factors	Levels of drought susceptibility; range of yield Level of competition for the resource	Physical location of the resource within the network, ability to help support areas of single source	Extent to which the WRZ deployable output is dependent on this option
	Treatment vulnerability; level of complexity, difficulty of treatment, extent of dual streaming, extent of bankside storage. Experience of outage on existing sites	Ability to help the network recover, particularly with respect to North South and South North transfers	Extent to which the local network or area of supply is dependent on this option.
	Impact on discolouration events	Ability to provide extra capacity from normal (peak demand)	
Score	*Enter Option Score (0 to 5)*	*Enter Option Score (0 to 5)*	*Enter Option Score (0 to 5)*

Figure 21 : Operational Resilience

In order to allow comparison of options within the DMF a significance factor has been applied to the resilience scores. This is the option's volumetric output (Mld) as a fraction of the total WRZ demand, thus a 10Mld option with a resilience score of 5 would have the same overall score as a 50Mld option with a score of 1.

5.2.2.3 Deliverability

Deliverability describes the complexity of an option in terms of execution. More complex solutions may provide a step change improvement but the benefits are less certain. A less complex solution may be a quick win and simple to implement but may not provide longevity of solution. For new technology there is also a risk that it will not work as well as expected, or that it costs more than anticipated. The principle behind this indicator is relevant to all five ODIs at South Staffs although water quality compliance and security of supply are the most relevant. It provides a pragmatic means to measure the ease of an option in terms of development, implementation and operation to deliver a required outcome.

Within the DMF deliverability is defined as follows:

Third Party Approvals - the degree of difficulty involved in obtaining permission to undertake the option and the likelihood that the options will be approved. This includes environmental impacts for example and effort associated with mitigating unacceptable impacts, the costs of this are included in the totex figure. For example a scheme which is located near or within an area of social or environmental significance will incur significantly more complex and intensive third party approvals and requirements.

Benefits Proven – the degree of confidence that the scheme will deliver anticipated benefits. This is demonstrated through the strength of the evidence base of solution benefits being demonstrated previously at scale in the water sector, and context relevant to the scheme proposed (i.e. track record in material benefits). For example, a well-established treatment technology may have a strong evidence base demonstrating benefits but if it has never been applied at similar scale to that proposed by SSC this option is less well proven than one which has a strong evidence base at the relevant scale.

Operations Proven – the degree of confidence that South Staffs will be able to operate, undertake or deliver the scheme without issue. This is based on both the technology maturity and how well acquainted SSC are with the site, for example introduction of an existing mothballed site would be more deliverable than the introduction of a new resource.

Contractual Supply Chain Risk – Level of risk associated with suppliers and their supply chain needs for scheme. This revolves around the number of players in the supply chain with whom SSC do not already have existing or trusted relationships. Each new relationship represents an additional element of risk within the scheme as issues are more likely to arise within new relationships where expectations are not as well established and understood as in long standing supply chain relationships.

The scoring matrix is shown in Figure 22.

Deliverability

	Third Party Approvals	Benefits Proven	Operations Proven	Contractual Supply Chain Risk
5	Scheme does not trigger any third party approval.	Anticipated results proven at scale in the UK. High degree of confidence.	Technology and resource already used by South Staffs. Proven track record in with South Staffs.	Existing supply chain with good relationships well established. Simple contractual arrangements. Low risk.
4	Scheme triggers simple third party approval. South Staffs are well versed in the process. Scheme will almost certainly be approved.	Anticipated results proven in theory or outside the UK. High degree of confidence.	Technology or resource known to South Staffs but not currently used or use being significantly increased..	Existing supply chain with some new players and some existing players. Contractual complexity relatively simple.
3	Scheme triggers moderately complex third party approval. South Staffs know the process. Some uncertainty around likelihood of approval.	Strong evidence demonstrates that the scheme will deliver anticipated results. Good degree of confidence.	Technology or resource new to South Staffs but well known to other water companies. .	Both new and existing players in supply chain for scheme. Moderate contractual complexity, moderate degree of risk.
2	Scheme triggers complex third party approval process. South Staffs unfamiliar with process. Some uncertainty around likelihood of approval.	Evidence demonstrates that the scheme will deliver anticipated results. Moderate degree of confidence.	Technology not currently implemented in the UK or new resource to South Staffs with some data availabilty , not currently used by others.	Most players in the supply chain are new to South Staffs but all have very strong track records. Contractual complexity greater than usual for South Staffs
1	Scheme requires complex third party approval, not previously undertaken by South Staffs. Much uncertainty around likelihood of approval success. It is as likely that the application will be rejected as approved.	Evidence suggests that the scheme will deliver anticipated results. May require additional investment to get these benefits. Moderate degree of confidence.	Technologies not implemented anywhere else in the world or totally new resources with no data availability. .	Most players in the scheme supply chain are new to South Staffs. High degree of contractual complexity and risk.

Magnitude Factor	
1	Less than 10 Ml/d
2	10 Ml/d - 40 Ml/d
3	40Ml/d - 100 Ml/d
4	More than 100 Ml/d

Total Deliverability Score = Sum of scores x Magnitude

Figure 22 : Deliverability Scoring

5.2.2.4 Environmental Sustainability

Environmental sustainability is an important part of SSC's existing decision making and operations, with a specific ODI allocated to "Operations which are environmentally sustainable". Within this outcome there are several different ODIs including leakage (financial incentive to meet set performance levels), water efficiency (PCC), biodiversity and operational Carbon (which are non-financial reputational measures).

Within the DMF Environmental sustainability has been measured through the following elements:

- Lifecycle carbon
- Biodiversity
- Sustainable abstraction

A description of how these factors are addressed in the framework is provided below.

Lifecycle Carbon

Carbon emissions are ordinarily measured as 'embodied' or 'operational'. Embodied carbon is the sum of emissions of greenhouse gases from the manufacture, transport and construction of materials, together with end of life emissions. Operational carbon is the emissions of greenhouse gases during the operational or in-use phase of a building or asset. It is often simpler to only measure operational carbon as more control and visibility of emissions sources are available. SSC currently report carbon emissions through energy consumption figures (kWh/year) compared to total output (ML/year). Whilst this approach will not represent 100% of emissions attributable to the SSC network and asset operations, it is deemed to be a significant proportion and therefore representative for comparison purposes in this new framework.

The carbon lifecycle scoring method is shown in Figure 23.

Carbon Emissions

Energy Consumption		kWh/year	
Output		ML/year	
KWh/ML	=Energy / Output	KWh/ML	
CO2e factor - energy	0.50036	kgCo2e/KWh	*(UKWIR workbook 15/16 value)*
Operations Carbon for Option	'= KWh/ML x kgCO2e/KWh	kgCO2e/ML	
Comparison Score			
Carbon Score	=comparison score x output		

Score	***Comparison of option carbon with corporate measure***
5	*<0.1% of total corporate emissions*
4	*>0.1% - <0.3% of total corporate emissions*
3	*>0.3% - <0.5% of total corporate emissions*
2	*>0.5 - <1% of total corporate emissions*
1	*>1% of total corporate emissions*
SST Region emissions 2015/16 = 42,796,197 Kg CO2 on 120,964Ml	

Figure 23: Carbon scoring

The average energy consumption per year in full operation is calculated. This is then divided by the expected output from the option to quantify KWh per ML. This is multiplied by the emissions factor provided in the current UKWIR workbook.

The emissions result is then compared with the corporate total figure (currently 0.48TonnesCO2e/ML) and a score assigned. The final carbon score is calculated by multiplying the assigned comparative score by the volumetric output of the option.

Biodiversity

Biodiversity represents the variety and population of animals and plants and the effectiveness of the natural systems that support them. Measuring changes in Biodiversity in a business' decision making demonstrates stewardship and social responsibility in this area.

In 2010, the UK was a signatory to Convention of Biological Targets, where a set of 20 global targets were defined dedicated to biodiversity goals (known as the 'Aichi Targets'). It has taken more than 5 years to define a biodiversity indicator to inform the decision making process for a business. As biodiversity is a devolved responsibility in the UK, it is difficult to pinpoint specific quantifiable measures that are comparable. There are also many different indicators to choose from rendering any tool cumbersome for the user. Since Aichi, The Joint Nature Conversation Committee (JNCC) has defined an indicator for biodiversity specifically for decision making as the "number of publicly accessible records [within the National Biodiversity Network Gateway] at 1km^2 resolution or better" (http://jncc.defra.gov.uk/page-6073). Therefore, on a global, national and regional scale, biodiversity can be used in decision making based on land area impacted (hectares) and a qualitative means to represent change over time for any indicator relevant to the decision. The indicator developed by the JNCC does not say if the solution reaches a specific target or if the solution is 'good or bad' for biodiversity. It does, however, define if a solution has a detrimental or improving effect on biodiversity, or no change. The JNCC also included time in this qualitative method, short term representing change over 5years or less and long term as changes over more than 10years (http://jncc.defra.gov.uk/page-4230). The European Environment Agency and Defra both subscribe to this method in their KPI expectations.

SSC's current ODI for this indicator quantifies the 'number of hectares under active environmental management'. Whilst this is an easily understandable and comparable measure, it does not define the extent of the success of the management being undertaken from a particular approach or method. The Decision Making Framework takes both South

Staffs current measure as a scaling factor and the JNCC indicative impact scale and provides a simple way for the tool's user to define biodiversity as appropriate to the solution in question. As with the JNCC approach, it will not specify targets to be met or if a solution is good or bad, but it does enable the decision to be informed regarding likely positive and negative impacts to an area of space affected by the implementation of a solution.

The biodiversity scoring method is shown in Figure 24.

Hectares affected is based on understanding of the biodiversity in the area and how the solution may impact it.

To replicate the JNCC definition described above, 'implementation' period equates to 5years or less from the start of build/implementation to point of hand over. 'Operation' represents the long term effect on the biodiversity after the solution is implemented and is operating as business as usual.

Biodiversity

Hectares Affected		hectares	
	Implementation Phase	Operational Phase	
Biodiversity			
Biodiversity Score	=[implementation + operation] x hectares		

1	Detrimental
2	No Change
3	Improvement

Figure 24: Biodiversity Scoring

This impact scores are defined as follows, compared to prior to implementation:

- **Detrimental:** For the biodiversity measures important to the area affected, a detrimental impact is anticipated
- **No change:** There will be no impact or change to the existing biodiversity of the area considered
- **Improvement**: A positive impact is anticipated from the solution in the area considered.

The scores are then scaled by area affected for option comparison.

Sustainable Abstraction

Regulators and the industry at large agree that water abstraction must be sustainable and does not damage the environment. Sustainable abstraction can incorporate leakage, water efficiency, metering and consumer behaviour. As these are covered in other indicators and workstreams, this sub indicator allows the user to score sustainable abstraction based on designation against the affected catchment area and the difference estimated from solution implementation. Solution development will be done with the appreciation of water cycle in geographical and volume terms to ensure that demand is met in the right location across the network. This is associated with the quantity measure but also that the quantity is in the right place. The current Restoring Sustainable Abstraction (RSA) Programme is likely to lead to licence changes and designation changes that are not currently known which can make this a difficult measure to pinpoint over a longer time horizon planning period. If a region is designated as over abstracted by the environment agency then abstraction licences are likely to be reduced or removed. Some licences are also time limited.

The Environment Agency provide Catchment Abstraction Management Strategies for specified catchment area. These are informed on a water availability status for the region. South Staff area is considered a medium water stress area, Cambridge a high water stress area (i.e. over abstracted). The framework needs to be account for the regional differences and any potential future changes that may be enforced.

Abstraction licences impacts need to be considered using the following information:

- Size of catchment area available and the volume affected within this area
- Environment Agency designation of abstraction from the catchment that is deemed sustainable
- The Abstraction Licence available to South Staffs, even if it not fully utilised

The decision framework assesses what the change in abstraction would be against the Licenced volume due to a solution's implementation.

The framework therefore uses volume abstracted (Ml/d) and a qualitative score based on Environment Agency's current water resource availability status designation as a scaling factor (in order of increasing benefit):

- 1 – Over abstracted
- 2 - No Water Available (no new licences)
- 3 - Water available, no deterioration or impact on WFD
- 4 - Reduction in abstraction e.g. Demand Management

The sustainable abstraction scoring method is shown in Figure 25. The water sensitivity score is based on the Environment Agency definitions for the area in question.

Impact scoring is arranged to show any reduction in abstraction to have a more favourable (higher) score, and a lower score for where abstraction is taking place in areas that are highly water stressed.

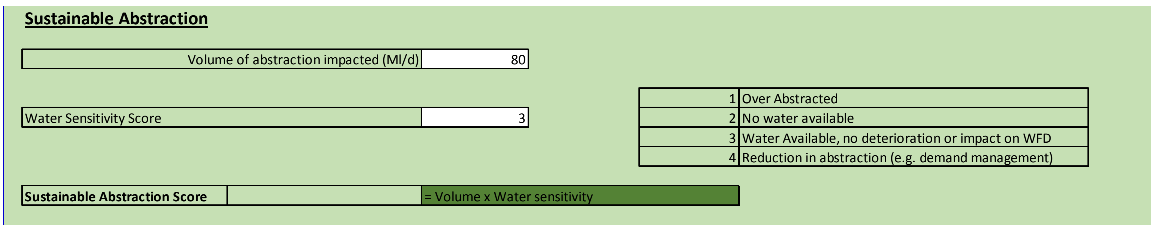

Figure 25: Sustainable Abstraction Scoring

The sustainability abstraction score is then derived by a simple multiplication of score and output (ML/d).

Combined Score

The final environmental performance score score is a sum of the three inputs described above. It is important to note that this indicator covers a number of different and complex elements in sustainability. The scoring is to be used for comparison purposes only. A low score does not necessarily imply a solution is detrimental to the environment, but that it has less positive benefit compared to other solutions considered.

5.2.2.5 Customer Preference

The embedding of customer's preference within the technical decision making process is a critical element of investment planning; in order to allow decisions to be guided by this a simple indicator has been utilised as shown in Figure 26. This applies a score to each option based on how well it is aligned with customer preferences. This is informed by customer engagement workshops.

Customer Preference

Score	Definition
3	Most aligned with customer preference
2	
1	
0	Neutral
-1	
-2	
-3	Least aligned with customer preference

Figure 26 : Scoring of customer preference

6 Using the Framework

The framework enables the collection of data on investment options in order that an optimisation exercise can be undertaken to generate a number of different outputs. These outputs will then need to be used in various ways to test both the sensitivity of the model, as well as exploring how the proposed solutions would work in different future scenarios. A key part of this is the generation of multiple objective trade of curves and how verse vary under the different future scenarios.

The diagram in Figure 27 illustrates these steps:

- Step 1: The base approach will be run to solve a specific problem (quality and quantity) using "business as usual scenario", generating a least cost optimisation as well as trade-off plots and alternative objective optimisations. Associated model sensitivities will be identified and quantified.
- Step 2: A series of alternative future scenarios will be developed, for example climate change or population growth projects, each generating slightly different specific problems to solve. Alternative least cost and alternative objective optimised portfolios will be generated and compared to the base model. Key changes to the base approach will need to be agreed with stakeholders.
- Step 3: A second iteration of the base run is performed, incorporating agreed changes.
- Step 4: Customer acceptability testing of proposed solutions is then carried out and feedback incorporated into previous settings. Further iterations to be run as required.

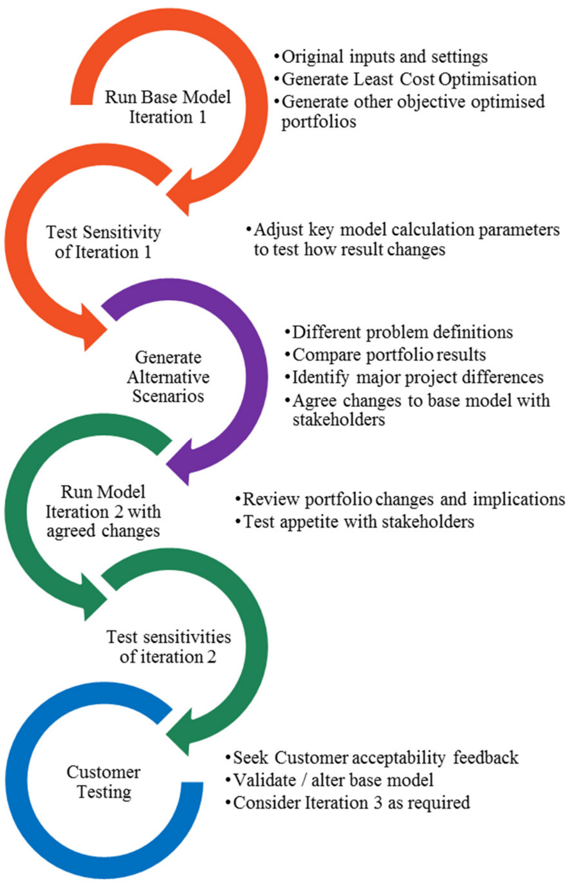

Figure 27: Using the decision making model outputs

7 Conclusion

The decision making framework developed for SSC sets out the proposed approach to decision making, the content of the indicators and the data capture requirements. In order to utilise the framework this must be operationalised using an optimisation engine that will process and optimise the data in accordance with the rules set out in the DMF, notably:

- Generation of all feasible portfolios (combination of options) that are able to simultaneously satisfy defined quantity, quality and affordability scenarios in the planning period.
- Optimisation of portfolios in order to demonstrate the pareto frontier between least cost and the other performance criteria of resilience, environment, deliverability and customer preference.

A number of options for the building of the optimisation engine were considered. SSC subsequently decided to modify and develop new algorithms for their existing Investment Optimiser software in preference to purchasing a new optimisation engine that had been developed by other suppliers from EBSD models.