C5 B

Cost and Efficiency

C5B Technical Annex 17
Resilience Investment Case: Technical Approach and Business Case

NTPBP-EXT-IC-0519

BRISTOL WATER

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1 Foreword

Resilience is the ability to cope with, and recover from, disruptive events in order to maintain services for people and protect the natural environment, now and in the future.

We currently have a number of assets, measures and plans in place to ensure that our systems are resilient from a variety of threats and risks. With our AMP6 focus on operational resilience, we have measures in place which protect all but 9,063 of our customers from failure of any one above ground asset (water treatment works or pumping stations) in population centres greater than 25,000.

The purpose of this document is to set out our customer led, outcome focused plan which will mitigate risks posed by and associated with resilience. Our target builds on our performance in AMP6 by providing resilience so that issues with any of our critical assets (e.g. one of our key pumping stations, service reservoirs or mains) do not affect more than 10,000 people. We aim to achieve this ambition by 2030, with 65% of the at-risk population being addressed in AMP7.

The Resilience investment case, one of 21, will summarise the facts, risks and investment requirements for resilience for the next review period for 2020 to 2025. This investment case will also summarise performance for resilience for the current review period from 2015 to 2020 and our methodology for determining and delivering the future resilience strategy.

This investment case document is a technical annex to section C5.B of our overall business plan submission, as illustrated by the diagram below:

This investment case is aligned to the Water Network Plus Wholesale Control aspect of our business plan. It is recommended that this investment case is read in conjunction with the PR19 Investment Case Summary Document [1] which outlines in detail our methodology for defining investment.

[1] Bristol Water PR19 Investment Cases Summary Document NTPBP-INV-PR1-0635

2 Executive Summary

In order to provide customers with resilient water supply and meet their priority of safe and reliable water supplies, we will focus on enhancing the resilience of our critical mains. In conjunction with this we will also focus on ensuring that existing connectivity is fit and well, should the need arise for its use in an extreme event. We will achieve this by investing £13.974m, installing 14.9km of mains (550m of which is sliplining), 74 valves (including 34 intelligent dynamic valves), and 23 turbidity meters to achieve improved resilience for 542,886 people and contributes 2.78% to our supply interruptions target. Innovative approaches have been applied to both understanding the risks to resilience and in developing interventions to mitigate this risk, building on our track record of leading the industry in resilient water supplies. When considering our efficient and innovative approach we plan to deliver our resilience capital programme for £12.856m.

At Bristol Water we have completed an extensive customer engagement programme which has identified that one of five key priorities for customers is that we keep the water flowing to their taps, and one of our four key outcomes is that we provide a Safe and Reliable Supply.

This investment case will address specific operational resilience risks by utilising a totex approach to determine necessary capital investment in our critical mains to provide protection to our customers water supplies.

We have a long term ambition to improve the resilience of our supplies. Our initial target is to improve resilience so that issues with one of our critical assets (e.g. one of our key pumping stations, service reservoirs or mains) do not affect more than 10,000 people by 2030, and in the long term, will not affect more than 3,000 people for more than 24 hours. Therefore, in order to meet our customers' priorities, we need to invest to improve the resilience of our supply systems.

Our resilience investment in AMP6 means that by 2020, we will have infrastructure in place to mitigate the risk of the loss of any individual water treatment works, pumping station or service reservoir affecting more than 25,000 people. However, 832,886 people will still be at risk of losing supply if one of the mains serving them fails and is unable to be fixed for a 24 hour period. This risk is low, and the population affected from an individual main failing is no more than 150,270. Through our engagement programme our customers have told us that they are willing to pay for a performance improvement of approximately 65% of the 832,886 people (542,886 people) in AMP7.

To deliver our customers' priorities we will measure progress via performance commitments for which we have set delivery targets both for the end of AMP6 and for AMP7. In AMP7, resilience is measured by the number of people in population centres greater that 10,000 at risk from asset failure (target 290,000) and supply interruptions (target 1.8 average minutes per property). These will also be the 2024/25 targets.

We are employing innovative approaches in the use of Dynamic Boundary Valves to enable us to react to severe disruption events automatically, mitigating risks in our systems to address the weak points in our critical mains infrastructure.

We have identified 81 critical mains which, should they fail, would affect population centres greater than 10,000. These serve 832,886 people, which is 68.6% of the total population served. Through this investment we will reduce this to 290,000 people (23.9% of the total population served) by 2025, with these remaining people being protected by 2030. This investment will secure resilience for a significant proportion of our customers within the next AMP period, whose supplies are at risk of being lost due to asset failure.

We will achieve this in a number of ways:

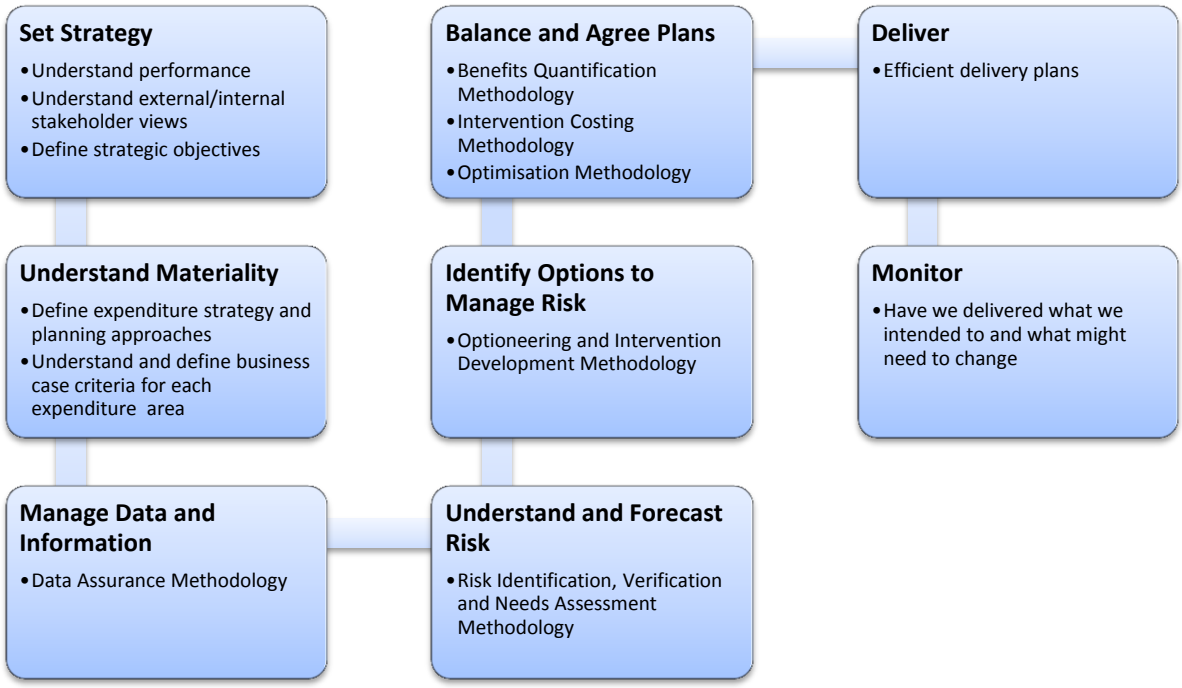
- By addressing known constraints in asset performance that are part of existing resilience plans;
- By undertaking a System Resilience Assessment to develop an improved understanding of the risk including root causes, likelihood and potential risks during planned operational activities; and
- By implementing a programme of measures to address shortcomings in the resilience of critical mains, including mains duplication, installation of manual and dynamic valves and turbidity meters.

Should we fail to invest in resilience or not achieve the associated performance commitments mentioned above, the key risk is that we will not be able to provide resilience to customers in population centres greater than 10,000 if a critical asset fails for an extended period of time. Consequently we will not provide our customers with the Safe and Reliable Supply that is a key outcome for them

In addition, given the function of some of our assets, we must ensure that these assets are fit and well in terms of providing resilience to our customers. Therefore there is a risk that we will not be able to provide resilience to customers in relation to two specific assets (near Millmarsh reservoir and in the Belluton Narrows area), if these assets were to be relied upon to provide resilience in the event of an extreme event, and subsequently fail.

In order to ensure that we meet customer's priorities and mitigate the risks associated with resilience we have adopted an asset management totex focused approach as set out in Figure 1.

Figure 1: Approach to meeting customer Priorities and Mitigating Risks



This approach enables us to demonstrate full "line of sight" from customer priorities, through risk review, options analysis and Optimisation, to Outcomes and benefits provided for our customers.

We plan to invest £13.974m from 2020 to 2025 in order to achieve the performance commitments associated with the outcome 'Safe and Reliable Supply', as set out in Table 1.

We have set ourselves a challenging target of reducing our costs by 8% during AMP7. This will be achieved by delivery of our business transformation programme and results in a post-efficiency investment of £12.856m.

Costs are allocated to the Treated Water Distribution Business Unit. Investment is all related to infrastructure assets and is 87% other capital expenditure and 13% maintenance.

Table 1: Associated performance commitment targets and percentage contribution

Performance commitment	Unit	2019/20 Baseline	2024/25 Target	Total Performance Improvement Required in AMP7	Resilience contribution to performance Improvement
Supply interruptions	Average mins per property	12.20	1.80	10.40	2.78%
Population at risk from asset failure	No. of people (population)	832,886	290,000	542,886	100%

Our AMP7 investment in resilience will help ensure our assets are being maintained appropriately to deliver resilient water services to current and future generations.

Full details of our outcomes, performance commitments, and outcome delivery incentives are provided in Section C3 of our business plan.

3 Background To Our Investment Case

3.1 Context

The Resilience investment case summarises the investment in AMP7 to meet our customers' priority for operational resilience, the approach taken in developing the proposed interventions and the benefits expected to be achieved as a result. This investment case reduces the risk of population centres of greater than 10,000 being at risk of failure of the assets serving them. This investment case relates to water supply interruptions over 24 hours in the event that a critical asset (a pumping station, reservoir or critical mains) is unable to operate or a source is contaminated.

Resilience is a key theme for Ofwat and we recognise the importance of our part in "keeping the country running". Resilience is incorporated within our strategies and plans.

One of the four customer priorities is "Keeping the water flowing to your tap". Reducing the impact on our customers from asset failure is a key strand to our strategy for delivering this priority.

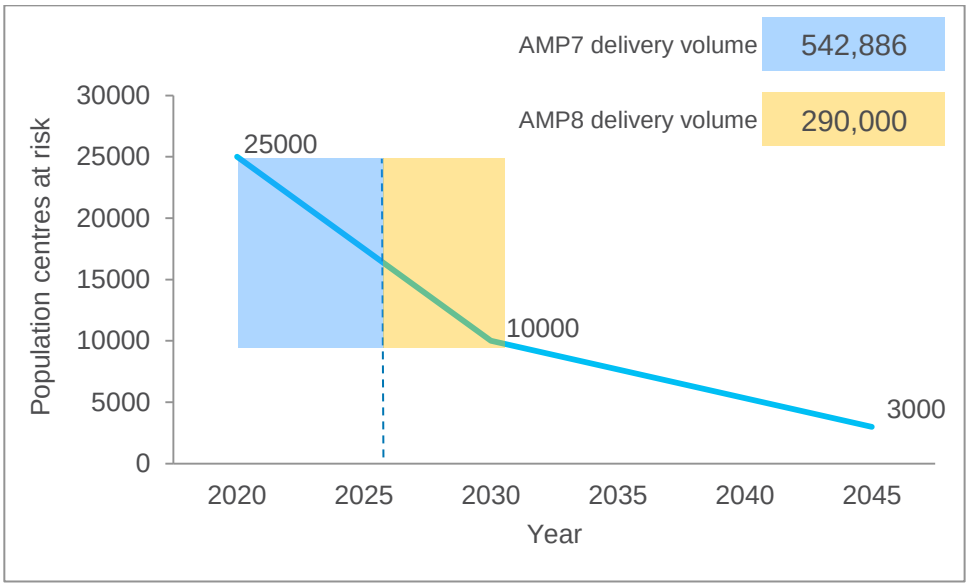
One of the key aims, as set out in our long term strategy, is the provision of Safe and Reliable Supply for our customers, and operational resilience is a key element of our plans to achieve this. We have provided industry leading approaches to the management of operational resilience in recent AMP periods, and we are looking to build upon this further in the next AMP period, having confirmed customer support for doing so. To achieve our intended outcomes we must continue to manage and reduce risks to security and quality of supply in an efficient manner.

Recent history has demonstrated that the steps we have taken in the past, such as the Northern Strategic Support and Southern Resilience Main, have been well-founded. With the impact of the discovery of Cryptosporidium at Clevedon WTW, where resilience in our system enabled us to keep our customers in supply, and with the mains burst at Willsbridge (see Section 3.1), it is evident there remains risks in our systems affecting our commitment to safeguard supplies for large population centres.

We are on a journey towards improving the population centres that are at risk of service disruption due to disruptive events outside of normal operational limits, and are seeking to ultimately achieve levels of resilience to centres of over 3,000 population by 2045 as set out in our long term strategy document Bristol Water Clearly.

By 2030, we are aiming to improve resilience for our 832,886 at-risk customers in population centres of 10,000 and over with all critical assets assessed and potential failures mitigated. By 2025 we aim to achieve this ambition for 65% (542,886 people) of the associated population. This target has been selected on the basis of assessing an achievable goal within a reasonable timescale (10 years), supporting us on the journey towards our ultimate goal. This is illustrated in Figure 2.

Figure 2: Glide path for Resilience performance commitment Targets



The scope of this investment case supports the improvement of operational resilience for population centres greater than 10,000. It does not however address wider resilience issues such as:

- Drought
- Local Community Resilience
- Corporate
- Financial
- Security of sites
- Cyber-security etc.

Wider resilience aspects such as those listed above are discussed in Section C4 of the Business Plan.

Our Resilience investment case focusses on the redundancy within the water supply system, one of the strategic components in understanding the resilience of critical infrastructure. The Cabinet Office publication 'Keeping the Country Running: Natural Hazards and Infrastructure' sets out four components of infrastructure resilience (Resistance, Reliability, Redundancy, and Response & Recovery), and states that when building resilience, the contribution made by each of these four components needs to be considered. Of these, the strategic component of Reliability of our critical assets is assumed through continued effective maintenance of operational assets to ensure fitness for purpose, and is provided for within our other investment cases. Response & Recovery is assumed through our wider operational emergency planning protocols. The investment addresses Resistance of our systems to major disruptive events. The approach complies with the methodology as set out in Cabinet Office Guidance and draws on the metrics as set out in UKWIR guidance[2].

The approach taken follows the processes as mapped out in the various Investment Planning methodologies, which are described in more detail in Section 4, and ensures that line of sight is

[2] UK Water Industry Research Ltd, 2017, "UKWIR Resilience – Performance Measures, Costs and Stakeholder Communication ".

achieved from customer priorities, through risk review, options analysis and investment optimisation, to outcomes and benefits provided for our customers.

Our resilience investment in AMP6 means that by 2020, we will have infrastructure in place to mitigate the risk of the loss of any individual water treatment works, pumping station or service reservoir affecting more than 25,000 people. However, 832,886 people will still be at risk of losing supply if one of the mains serving them fails and is unable to be fixed for a 24 hour period. These 832,886 people will be the focus of our resilience investment from AMP7. Our AMP6 and AMP7 resilience approaches and performance commitments are explained further in the following sections.

AMP6 resilience performance commitment

The performance commitment for Resilience for AMP6 is defined as "Populations in centres of greater than 25,000 who are at risk of failure of the single supply source serving them". The risk relates to water supply interruptions in the event that a critical asset such as a treatment works is unable to operate or a source is contaminated. This measure only captures customers at risk from failure of above ground infrastructure and therefore is a wholly different parameter to that for AMP7.

AMP7 resilience performance commitment

Our recent experience, particularly the Willsbridge event, has led to the company taking a more critical look at system resilience and concluded that all assets play a part in the provision of effective resilience when considering the reliability of supply to our customers.

Willsbridge Burst: July 2017

A burst main in Willsbridge, affected supplies to 35,000 properties when significant ground movement led to the failure of the main close to a pumping station. The effects of the burst raised significant concerns about the stability of the South Bristol Ring Main, which transports water between the North and South Bristol, and had to be isolated to allow the cause of the burst to be safely investigated and repaired. The proximity of gas mains, power cables, coupled with hazardous weather conditions all added complexity to the incident. The presence of the ring main and re-zoning actions meant that the total number of properties affected was reduced to 14,000 within 18 hours, reducing to 8,000 within 21 hours and all supplies being restored within 28 hours.

This metric reflects the risk of large scale interruptions to supply and represents population centres that have inadequate resilience to disruptive events outside of normal operating limits, where:

- There is no redundancy/backup (as the service disruption is a long-term issue with the asset for longer than 24 hours);
- There is a provable and non-trivial risk from an identifiable hazard that means the system cannot be repaired within a set timescale (e.g. treatment works in flood zone, inaccessible trunk main); and
- More than a given threshold of customers would be affected if the system fails (in population centres greater than 10,000).

In some limited cases, the Company has decided to take certain population centres out of the metric where for example there is already a plan in place over the next AMP(s) to improve the supply source.

Hence, we have developed the definition of the resilience for our AMP7 performance commitment as follows:

Populations in centres of greater than 10,000 population who are at risk of failure of the asset serving them. The risk relates to water supply interruptions in the event that a critical asset (either pumping station, reservoir or critical mains) is unable to operate or a source is contaminated for more than 24 hours. This is measured as number of people (population).

In order to calculate this, additional detail has been applied to ensure a robust approach is taken for both benefits quantification and annual reporting. The effect on customers is assessed as providing less than 3m water pressure for a duration greater than 30 minutes in the event of an asset failure for a minimum 24 hour period.

In seeking to improve on the reliability of water supply to our customers, we are changing the performance commitment from population centres greater than 25,000 to greater than 10,000. This is the next step towards achieving our long-term ambition of providing reliable supplies to customers in population centres of greater than 3,000.

3.2 Strategy

Developing the investment needs for resilience is underpinned by our long term corporate strategy which has the vision **"Trust beyond water-we provide excellent experiences"**. Our Outcomes Delivery Framework together with our Strategic Asset Management Plan provide the strategic framework that supports this vision and enables investment in resilience to clearly focus in delivering against outcomes and performance commitments.

Our long term strategy, as set out in the Outcome Delivery Framework (Section C3 of our Business Plan), has a focus on resilience and a growing need to ensure our assets are, and remain, fit and well and effective in meeting our performance requirements. There are three strategic drivers identified that together ensure we meet our current and future needs for customers and stakeholders. These are:

- **Operational Resilience** - which have performance commitments to reflect reliability, resilience and quality of water
- **Customer Focused** - performance commitments to reflect customer service and affordability
- **A Sustainable Business** - performance commitments to reflect the environment representing our community and sustainable resources.

Within this strategy there is a specific outcome (Safe and Reliable Supply) and specific performance commitments (Supply Interruptions and Population at Risk from Asset Failure) that have strategic targets and incentives that will be directly influenced by our investment needs for resilience.

Our Asset Management Strategy has objectives developed in alignment with the long term strategy and delivery of corporate objectives and outcomes. These objectives cover both our short-term needs and longer-term aims, and drive the capability development plan and asset planning activities. Delivery of investment in resilience will be driven through the Asset Management Framework, which is designed to enable the efficient and effective planning and delivery of all our asset related activities, to successfully deliver our business and customer outcomes. The framework

aligns to, and interacts with, our corporate drivers, which in turn are there to deliver the external expectations and requirements placed upon us by our stakeholders.

Our customers have told us that they want us to keep the water flowing to their taps. Reducing the impact on our customers from asset failure is a key strand to our strategy for delivering this priority. The improvements in resilience for AMP7 are part of our strategy to develop the resilience of our network systems, and these plans fit our long-term ambitions.

3.3 Customer Priorities

Customer priorities relating to Bristol Water's outcomes and performance commitments have been determined through our extensive programme of customer engagement and research. During the development of our business plan we have engaged with over 37,000 customers and conducted over 50 pieces of research. By delivering customer engagement, we have ensured that we can build on the customer insights that we have gained, producing a business plan influenced by our engagement events. This ensures that at Bristol Water we have engaged effectively with our customers on longer-term issues, and have taken into account the needs and requirements of different customers including those in vulnerable circumstances and also our future customers.

Through this process our customers have told us that their top priorities have remained largely unchanged from PR14 and have been identified as follows:

- You can get a bill you can afford
- Keeping the water flowing to your tap
- Help to improve your community
- Save water before developing new supplies
- You get the best possible experience every time you need us

Our engagement with our customers has resulted in the development of four specific outcomes for PR19, which capture what our customers and stakeholders have said; these are as follows:

- Excellent Customer Experiences
- Safe and Reliable Supply
- Local Community and Environmental Resilience
- Corporate Financial Resilience

In order to deliver our customers' priorities and outcomes we will measure progress via twenty six performance commitments for which we have set delivery targets.

There is a clear relationship between our investment in Resilience and one of our outcomes – Safe and Reliable Supply.

We undertook more detailed discussions at phase 2 of our engagement process; gathering evidence (see section **C1 – Customer engagement, communication and research** appendix to our business plan) which gave us a wealth of information about how our customers' view Bristol Water, our services, and long term plans. We also explored short and long-term trade-offs in decision making and asked customers to tell us how we should approach long term issues of resilience and how we could best respond to service interruptions. When discussing the Safe and Reliable Supply outcome with our customers, we found that they are understanding of one-off events and often focus

more on how we can improve our response to them. We asked them about investment in water quality and reliability and we asked what areas they felt most comfortable investing in. In our March 2018 customer panel, our customers prioritised reliability above local environment, resilience and customer experience[3]. Detailed analysis of customers' views on this area can be found in **section C3 – Delivering Outcomes for Customers.**

We consulted in three potential scenarios in relation to our Safe and Reliable Supply outcome:

			2024/25 target		
Service	**Performance Commitment**	**2020 target**	**Slower improvement plan**	**Suggested improvement plan**	**Faster improvement plan**
Water quality	Compliance risk A lower score reflects a lower risk of water quality problems	1.22	0.7	0	0
Interruptions to supply	Supply interruptions greater than 3 hours (average minutes per property)	12.2	4.2 66% improvement	1.8 85% improvement	1.5 88% improvement
Water that doesn't look clear	Number of customer contacts about the appearance of tap water (contacts per 10,000 customers)	9.3	9.3	4.3 54% improvement	3.2 66% improvement
Water that doesn't taste or smell right	Number of customer contacts about the taste and smell of tap water (contacts per 10,000 customers)	3.0	3.0	2.5 17% improvement	1.4 53% improvement
Protection against a major water supply event	Risk of a major event - population centre size protected against critical asset failure	Centres over 25,000 people*	Centres over 25,000 people	Centres over 10,000 people (10 year programme)	Centres over 10,000 people (5 year programme)
Forecast increase to the average bill from additional investment			**£5**	**£14**	**£18**

* With 5063 customers in these centres remaining at risk

Results show affordability concerns have driven some customers to choose the slower plan, whereas customers also value the service improvements in the suggested plan. In summary, we consider that a plan with a lower bill level with the suggested improvement plan is more likely to be acceptable to more customers (particularly low-income groups).

You can see more about how the feedback from our draft business plan consultation influenced each of our performance commitments in section C3.

The level of support for our plan expressed by our customers, both those we have engaged with over a period of time and those we met for the first time, gives us confidence that our final business plan strikes the right balance of delivering service improvements that customers value at a price that is acceptable to the majority.

This investment case describes how we will achieve the suggested improvement plan and associated level of performance through our investment in Resilience, specific details on our planned investment and associated performance can be found in Section 3.4.

[3] A4g: Customer online panel March 2018

3.4 Asset Health, AMP7 Performance Commitments, & Outcome Delivery Incentives

The health of our assets is a key element in delivering resilient water services to our customers. Our investment in resilience will help ensure our assets are being maintained appropriately for the benefit of current and future generations.

Additionally, our investment in resilience supports our AMP7 outcome Safe and Reliable Supply, by investing in our network and critical mains in order to provide reliable supplies for our customers.

Our Safe and Reliable Supply outcome will be measured through a set of associated performance commitments. Performance commitments associated with resilience are set out in Table 2.

Table 2: Associated performance commitments

Performance commitment	Unit	2019/20 Baseline	2020/21	2021/22	2022/23	2023/24	2024/25	Performance improvement required in AMP7
Supply interruptions	Average mins per property	12.20	4.2	3.6	3.0	2.4	1.8	10.40
Population at risk from asset failure	No. of people (population)	832,886	724,309	615,732	507,154	398,577	290,000	542,886

Full details of our outcomes, performance commitments, and outcome delivery incentives are provided in Section C3 of our business plan.

A detailed diagram illustrating the full line of sight between customers, outcomes, performance commitments, and outcome delivery incentives related to this investment case is included in Appendix A.

3.5 Compliance Obligations

There are no statutory or compliance obligations that are influencing the development of interventions in this investment case and the investment for AMP7.

3.6 AMP6 Investment and Performance

Our AMP6 investment in resilience supports our ability to meet our performance commitment for resilience of above ground assets (‘Populations in centres of greater than 25,000 who are at risk of failure of the single supply source serving them’). Unplanned customer minutes lost is included as it has been used throughout AMP6 to measure supply related interruptions. Our investment in AMP6 will underpin our performance commitments for resilience and supply interruptions in AMP7.

A summary of our AMP6 investment related to resilience is summarised in Table 3 below. We have re-categorised data used in line with the scope of our investment cases. For historic data we have used the 2016/17 wholesale cost assessment data (data tables 1 and 2). Forecast data has been derived from PR19 data (data tables WS1 and WS2).

Table 3: AMP6 capital investment

Year	Resilience capex (£m)
2015/16 actual	0.940
2016/17 actual	6.091
2017/18 actual	11.746
2018/19 forecast	1.814
2019/20 forecast	0.115
AMP6 forecast	**20.706**

As discussed in Section 3.1, our AMP6 resilience investment addresses populations in centres of greater than 25,000 who are at risk of failure of the single supply source serving them. The majority of this investment is on the Southern Resilience Scheme (£20.517m of the Table 3 values relate to the Southern Resilience Scheme investment assigned to resilience, with the remainder assigned to growth). The investment addresses risks relates to water supply interruptions in the event that a critical above ground infrastructure (e.g. a treatment works) is unable to operate or a source is contaminated.

The AMP6 performance commitments that are related to resilience investment and our performance are given in Table 4.

Table 4: AMP6 performance related to resilience investment

Performance commitment		2015/16	2016/17	2017/18	2018/19 (Forecast)	2019/20 (Forecast)
Unplanned customer minutes lost						
Bristol Water	Target performance	13.4	13.1	12.8	12.5	12.2
	Actual performance	15.5	13.1	73.7	12.5	12.2
Population in centres >25,000 at risk from asset failure						
Bristol Water	Target performance	288,589	288,589	9,063	9,063	9,063
	Actual performance	288,589	288,589	9,063	9,063	9,063

The unplanned customer minutes lost performance commitment was not met for 2017/18. The average amount of minutes lost per property per year (at 73.7 minutes) was significantly affected by an exceptional burst event at Willsbridge in July 2017, which is explained in a detailed case study in our 2017/18 mid-year performance report.

Our planning and investment in improving the resilience to customers has an extensive history with investment in various schemes such as the Northern Strategic Support Scheme in AMP4 and the Southern Resilience Scheme, which has achieved completion in March 2018. More information on the variety of schemes is presented below.

In PR14 we developed an "all-risks" model which analysed the risks associated with the loss of key non-infrastructure assets within our supply network[4]. This analysis identified five top ranked systems which were further analysed using reliability modelling. The conclusions of this analysis supported the PR14 investment for the Southern Relief Scheme.

AMP6 Southern Relief Scheme Delivery:

The SRS is a major water infrastructure project that provides improved security of supply to over 280,000 customers across our supply area, including Weston-Super-Mare, Cheddar, Burnham and Glastonbury and the southern part of Bristol, as well as providing support for growth.

The project has involved laying 30kms of new pipeline, installed in three sections from Barrow to Cheddar, as well as an upgraded pumping station at Cheddar Treatment Works.

The work allows us to move water from our northern sources to our southern supply area in the event of a loss of supply, or water back up to Bristol if we lose our northern supply.

The scheme uses gravity, rather than pumping, to get water from Barrow Gurney to Cheddar, significantly reducing energy usage.

All population centres are now protected from single asset failure on WTW sites, except for some of the population in Glastonbury / Street, and benefit from a resilient supply.

This investment has demonstrated that resilience is in place for non-infrastructure assets, for example:

Clevedon Cryptosporidium Failure: January 2018

Clevedon WTW recently experienced a Cryptosporidium failure. We were able to recover quickly from the incident due to the availability of water from elsewhere in the network, and a quick response to flush the network and affected storage in the system. While 16,000 customers were contacted and advised to boil all water for human consumption, it was possible to revoke this order within 4 days.

More recently, in experiencing extreme weather conditions, notably "the Beast from the East" in early 2018, the Resilience Mains that were available enabled us to manage the situation effectively. This is also the case at present during the 2018 summer, where the southern resilience support main is providing support to the southern area from the north where resources are less restricted.

While the above cases demonstrate the challenges our assets face, we have sought to understand the risk to our mains network through a number of investigations led by Minerva IAM. The aim of this project is to provide a robust, evidenced based approach to understanding and managing the risks associated with critical mains. The approach taken comprises the development and implementation of a framework to provide a quantitative assessment of criticality of strategic infrastructure assets.

The project undertaken consisted of two elements; a Scoping Study, and Asset Criticality profiling of mains supplying greater than 3,000 population, as described in the following two sections:.

[4] Halcrow, 2013, "PR14 Resilience Risk Assessment, Summary Report"

Scoping study

A joint review of our current practices, procedures, data and resources was completed through sharing and review of key documents and data and meetings with key stakeholders in relation to corporate structure, strategic objectives, governance, processes and procedures. A range of opportunities for improvement were identified:

- The risk profile of the trunk main inventory is largely assumed or unknown and therefore cannot be effectively and demonstrably managed;
- Investment need is currently based on burst history and anecdotal evidence alone;
- Previous business plans have been found to lack persuasive evidence to support key investment lines; and
- The corporate vision and strategic objectives as set out in our key business documents are not fully supported by a structured, analytical evidence-based approach to managing risk and optimising investment.

Asset Criticality profiling

In order to support both our long-term ambition of an integrated evidence and risk based approach to managing its assets, we worked collaboratively with Minerva IAM to develop a framework for asset criticality profiling, which has been used to provide the 'order of magnitude' of totex investment in relation to strategic trunk mains infrastructure.

More specifically the work concentrated on the following:

- Developing our corporate objectives into a set of quantifiable corporate risk statements in relation to strategic infrastructure assets, providing us with a bespoke strategy for strategic infrastructure;
- Developing a Criticality Profiling Methodology, providing a framework for quantifiable assessment of criticality based on water supply resilience, third party damage impact and cost of failure;
- Developing a criticality profile based on desktop assessment for 1,000km of strategic trunk mains, providing the Risk Appetite for individual functional length of critical mains within the overall cohort; and
- Providing a summary of estimated investment need for PR19.

Work is now progressing into integrating the results of the Asset Criticality profiling into the corporate Geographical Information System, validating the model through a number of site visits, and setting up a framework to continuously update the model will data collected through planning inspection activities.

One specific output of this analysis was the Exceptional Sites work (see Trunk Mains & Pipe Bridges investment case), which has identified areas in the network where bursts would cause significant disruption to wider societal infrastructure, such as railway crossings, and which as a result may be expected to lead to extended periods of time to fix. Several outputs of this study contribute towards our Trunk Mains investment case.

4 Developing Our Investment Plan

As we have discussed earlier, the starting point for investment case development is to understand our customers' priorities and determine associated performance commitments. We have adopted totex principles to determine how we should invest in order to deliver these priorities and associated commitments. The totex approach we have adopted considers which the best solution is because it is the lowest cost over the whole life of the asset, regardless of whether it is operational or capital expenditure.

Whilst we do not currently have health and risk indices across our asset groups, we do have a wealth of data. In some cases, analytical models such as the mains deterioration model, provides us with a view of how our assets are performing, as well as a view on their deterioration. The following section describes the process we have created and followed in order to develop our investment cases.

4.1 Investment Case Development Process

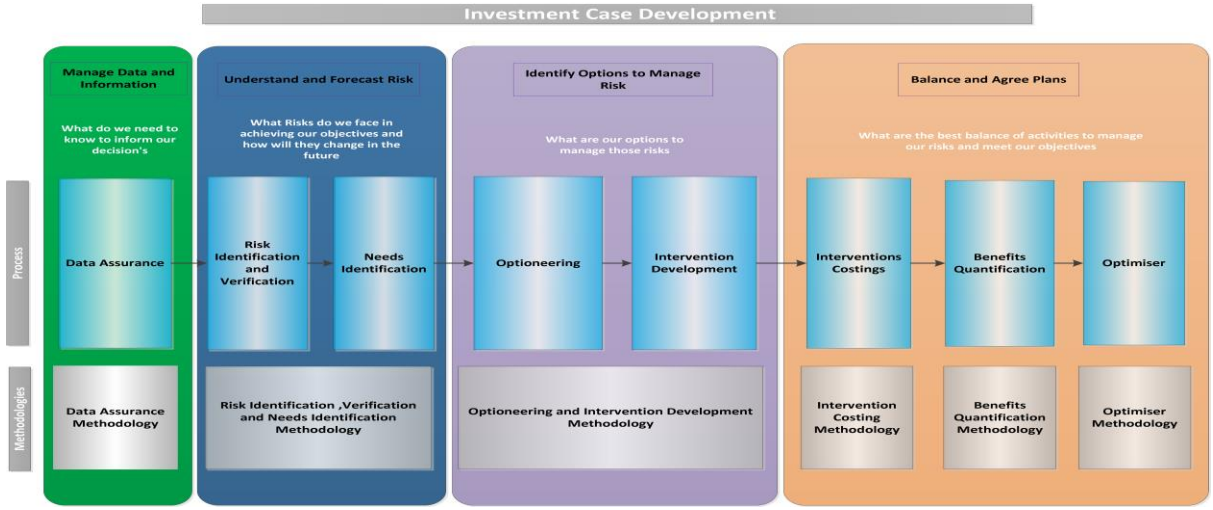
We have created and implemented a process that is supported by a set of six methodologies. When developing the methodologies, we wanted to ensure that they:

- Deliver what the customers have asked for;
- Satisfy our business needs; and
- Deliver a high quality business plan in accordance with Ofwat's Company monitoring framework.

The collective application of these methodologies has enabled us to develop investment cases that are well evidenced through a line of sight approach, ensuring our investment plan achieves the required targets at the optimal cost.

Figure 3 illustrates, at a high level, the process required to identify risks that require mitigation in AMP7, and the subsequent development of appropriate interventions.

Figure 3: Investment case process overview- level 1 diagram



An overview of each of the key stages is described below and all of the methodologies are provided in the PR19 Investment Cases Summary Document.

4.1.1 Data & Data Assurance

The development of our investment cases is dependent on having consistent, accurate and assured data. We therefore recognise that we must be able to demonstrate the quality of the data and information used in the development of our investment cases.

Wherever possible, we have utilised data from our core company systems in order to undertake our analysis and we have sense checked the quality of data as we have used it.

However, in addition we have applied a data assurance methodology. We have assessed data quality in terms of completeness, accuracy and reliability. In addition, the methodology also assesses whether data is used as part of the annual performance report to Ofwat, and hence already subject to existing annual performance report assurance mechanisms.

In total we have developed twenty one investment cases. The values of these investment cases range from less than £1m to over £37m. Our overall capital investment plan totals circa £212m.

We have selected a sample of nine investment cases, and have applied detailed data assurance based on their value and complexity. The total capital investment value of these nine investment cases represents 66% (circa £140m) of the total capital investment plan, and represents 286 individual data types. We have evaluated all 286 data types and we have evaluated them for quality and their use in the annual performance report process. The overall data quality assessment identified 93% of the data as being good quality, and 55% as having been used and assured through the annual performance report process.

The following sections detail the results of the data assurance and APR assessments undertaken for this investment case.

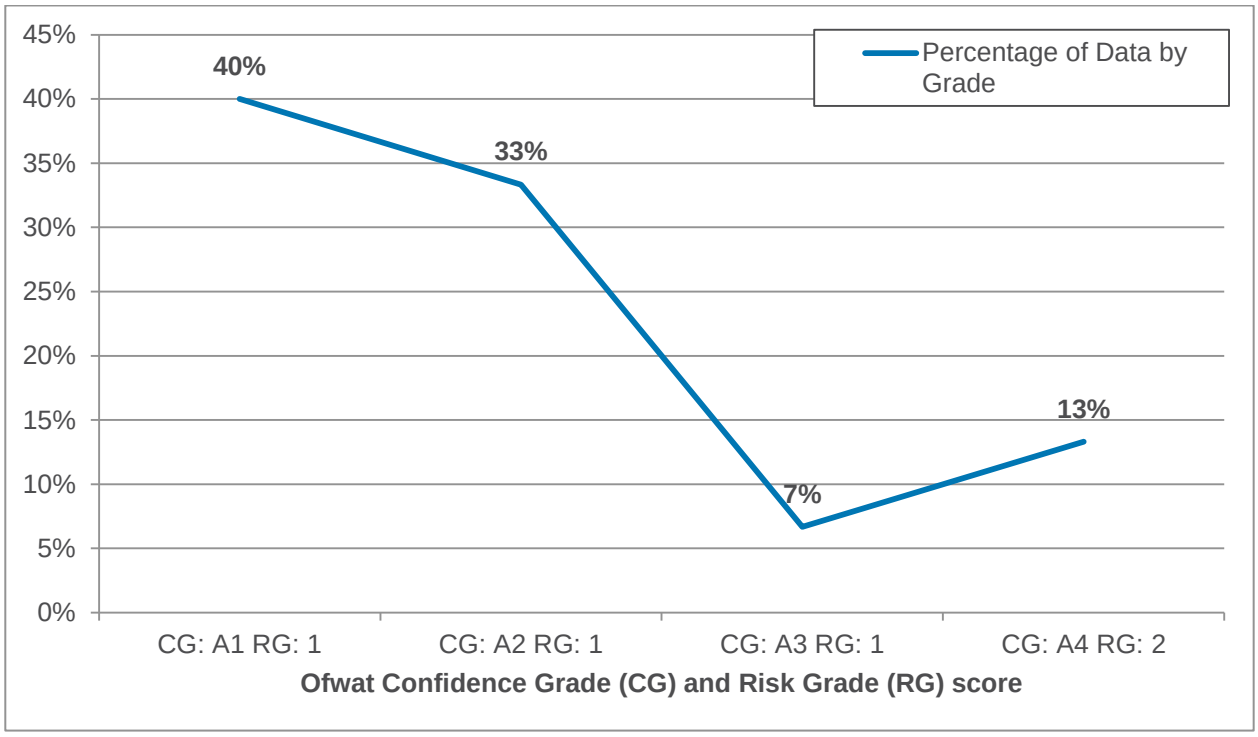
Quality Assessments

For each data point used in this investment cases, it has been assured for completeness, accuracy, and reliability, and has been given an overall score for quality in terms of a Risk Grade (RG) score between 1 and 5 (1 being good quality, 5 being poor quality). The risk grade has subsequently been aligned to the equivalent OFWAT Confidence Grade (CG) scores A1-D6 (A1 being highest confidence, D6 being lowest confidence.

A list of data used is provided in Appendix B (actual data sets can be provided upon request). A total of 17 specific data types were identified of which 100% have been assessed as having good quality (Confidence Grade A1-B4 and Risk Grade 1-3).

Figure 4 summarises the number of data types scored against Ofwat Confidence Grades and Risk Grades.

Figure 4: Percentage of Data Types by OFWAT Confidence Grade and Risk Grade



Annual Performance Report Assessments

The 17 data types have also been assessed in their utilisation in the APR. This process is subject to both internal and external assurance and has governed methodologies that are applied in the provision of APR data tables. The assessment of the APR submission and application of the methodologies are formally governed and recorded.

Of the 17 data types, 5 (29%) were assessed as having already been required for APR reporting and therefore subject to the assurance requirements as set out in APR Methodologies.

4.1.2 Risk Identification, Verification & Needs Assessment Methodology

The purpose of our risk identification, verification and need assessment is to ensure that:

- The risks that we are currently facing are captured in a single risk register; and
- Each risk is assessed and verified to determine details about the nature and magnitude of the risk and whether any mitigation is currently planned in this AMP period; and
- Each risk is scored on a common basis to allow risks to be compared; and
- The most significant risks are identified, and that for each a clear and uniquely referenced statement of need is produced to define the problem as clearly as possible, and to identify what benefits or performance commitments mitigation of this risk will achieve.

The risk score is the product of the likelihood and consequence, each is scored 1 to 5 and then multiplied together to provide a potential maximum risk score of 25.

Risks scoring 15 to 25 are the most significant strategic risks, and these were developed into needs statements.

Those scoring 10 or 12 were subject to a further round of review and where it was considered that mitigation of the risk will enhance our ability to meet our performance commitments, the risk was selected and developed into a needs statement.

The risks scoring 1 to 9 were considered to be risks of a lower priority and were therefore not considered further as part of the PR19 investment planning process.

Unselected risks will continue to be monitored and assessed as part of the live business and on-going business as usual risk management process. Where there is a need to mitigate these risks within the AMP, we will respond with appropriate action, i.e. base maintenance.

Further development of our business as usual risk management process is on-going and we are looking to innovate by developing smarter systems to optimise this process.

We developed need statements for all selected risks.

4.1.3 Optioneering & Intervention Development Methodology

The next stage in our process is to develop options of how we could meet the needs of the selected risks.

To generate the options, data was gathered from a number of sources (see Appendix B). This included meetings with stakeholders and historical records, including reviews following operational events, previous scheme proposal reports and previous options assessment reports.

We then progressed to data assimilation, analysis and consultation with key stakeholders. Multiple options were developed and recorded. These options were reviewed and all options identified as not viable were discarded.

All viable options were identified as proposed interventions with a unique reference number and were taken forward for further scope development, benefits calculation and costing.

4.1.4 Intervention Costing Methodology

In order to provide assurance of our investment costs and to ensure standardisation, we engaged ChandlerKBS as our costing partner. They were selected in part due to their ability to provide us with industry comparable cost data, often at intervention level. They supported us in several ways:

- In some instances development and analysis of intervention costs, and
- Support of build our cost database

Indirect overheads, such as contractor costs, design costs, contract management, and our overheads have been applied at intervention level. Wherever possible we used our data or if unavailable, we used industry average costs. Therefore we have to assess the expected capital cost of each intervention.

Expected Capital Ependiture (capex after)

If we deliver the capex intervention in a planned way, we have labelled it as 'capex after'. This is the expected capital cost of the intervention. Cost estimates were usually based on high level scopes, which contained activity schedules, and were developed using the cost model we procured from ChandlerKBS.

4.1.5 Benefits Quantification Methodology

The benefits for each intervention are those which are considered to affect company performance during subsequent AMP periods.

Benefits can be assessed as either being:

- Direct – savings in reactive capex or savings in operational expenditure (opex); or
- Indirect – improvement in performance commitments or other resultant effects on the company's performance.

Both direct and indirect benefits are considered and quantified.

Direct Benefits

We have a totex approach which considers both capex and opex.

Expected Capital Cost (capex before)

If we deliver the capex intervention in an unplanned way, we have labelled it as 'capex before'. This is the reactive cost that would potentially arise if we had to deliver the intervention in an unplanned way.

We could respond to this scenario in one of two ways:

- 'Patch and Repair' or
- Implementation of the intervention in an un-programmed accelerated manner.

The capex before was determined for each intervention. For most interventions the estimate is site specific. A risk factor, taken from the likelihood score recorded in the risk register, was applied to the initial capex value to produce the final capex before value.

Where a 'patch & repair' solution would not be appropriate, should the risk materialise, this would lead to the immediate implementation of the intervention. The cost of the intervention in this scenario is the expected capital cost of the intervention (capex after), with the application of a suitable uplift to cover the costs associated with fast-tracking the intervention, for example, the cost of labour at premium rates.

The expected capex before effectively formed the 'Do Nothing' option.

Expected Opex Before & Opex After

In most cases we have made an estimate of the opex levels either with investment - opex after or without investment - opex before. Opex includes power, chemicals, materials, contract hire and in house labour.

Opex before represents the opex expenditure associated with not mitigating a risk through capital investment, for example, increased maintenance visits or replacement of components.

Opex after represents the additional opex cost to the business after the implementation of an intervention. These could include negative values associated with predicted savings associated with increased plant efficiency or performance, or positive values where there is an operational cost increase, for example greater inspection levels.

Indirect Benefits

To measure our performance against our customers' priorities and the associated performance enhancements associated with interventions; we measure the impact that each intervention had on the performance commitment measure.

Other Benefits

In addition to the performance commitments described above, other indirect benefits which do not relate to performance commitments were calculated and recorded in the benefits calculations where appropriate. This includes avoidance of health and safety penalties, customer compensation payments, and environmental penalties. These benefits have been monetised.

Once the benefits were prepared, the interventions were put forward for investment optimisation.

4.1.6 Investment Optimisation & Intervention Selection

The investment optimisation process determines which interventions are selected to provide the optimal AMP7 investment plan, by delivering the targeted performance commitment improvements, at the lowest cost. We have utilised a water industry standard system (Servelec 'Pioneer') to optimise our AMP7 investment plan. Pioneer provides the functionality for us to assess all interventions developed across all of the investment cases. It will assess the interventions both individually and in comparison to other interventions. It is a decision support tool that produces an optimal investment plan to meet the targeted performance commitment improvements required in AMP7.

The Pioneer investment optimisation model assesses interventions primarily on the overall benefit, which takes account of performance and whole life costs. The investment optimisation calculates the

whole life cost as the net present value over 40 years. This determines if an intervention is cost beneficial.

We will select interventions for one or more of the following reasons:

- The intervention is mandated (i.e. Drinking Water Inspectorate - water quality requirement).
- The intervention is cost-beneficial
- The intervention is required to achieve the performance commitment targets.

Any performance commitment improvement obtained from mandated or cost-beneficial interventions will contribute to overall performance improvement.

A series of business reviews and sense checks of the investment optimisation results have been undertaken prior to finalising the AMP 7 investment plan.

We can of course model any number of scenarios, and during the process of engaging our customers we ran three scenarios as described in Section C1 of our business plan (slower improvement plan, suggested improvement plan and faster improvement plan).

4.2 Applying the Investment Process to Resilience

Each of the following sections describes the specific details associated with the application of the investment case development process for Resilience.

4.2.1 Risk Identification, Verification & Needs Assessment

There were three risks identified in the strategic risk register associated with this investment case. Every risk went through a process of assessment, scoring, and review

These three risks were selected and developed into need statements. The risk descriptions, scoring and associated needs statements are captured in the Strategic Risk Register[5]. Details of the selected risks are provided in Appendix C.1.

The 'Line of Sight' for the whole process, beginning with the selected risks, the source of the risk, a record of source documents used to verify the risks, and the needs statements, is captured in the Resilience Interventions Register.

Risk Associated With Current Situation

As at the end of AMP6 year 3, and the successful completion of the Southern Relief Main, all customers in population centres greater than 25,000, except for 9,063 in the Glastonbury area will benefit from resilient supplies in the event of critical infrastructure failure of above ground assets. However, it is appreciated that in the event of a mains burst in a location presenting engineering difficulties that would require greater than 24 hours to fix, then customers may suffer from loss of supplies. The definition of critical assets has therefore been extended to understand the parts of the network that present these risks.

[5] Bristol Water, 2018. *NTPBP-CAL-STR-0127 Strategic Risk Register (WIP).xlsx*

The redefinition of the performance commitment to broaden the scope of critical assets, as well as reducing the size of the population centres considered from 25,000 to 10,000, has led to a review of all risks arising from failure of critical assets:

1. Treatment Works:

   The provision of the Southern Relief Scheme now addresses all resilience risks for population centres greater than 25,000. A review has been undertaken to establish that this remains valid for population centres greater than 10,000 as well, and this has been confirmed as being the case, having rerun the Resilient Supply Report.

2. Pumping Stations:

   All pumping stations have been reviewed in accordance with the Resilience Methodology developed for PR19, which has confirmed that all pumping stations have sufficient resilience mitigation in place, for example, transformers, standby pumps etc.

3. Service Reservoirs:

   All Service Reservoirs have been reviewed in accordance with the Resilience Methodology developed for PR19 which has confirmed that all service reservoirs have sufficient resilience mitigation in place.

4. Mains:

   All mains have been reviewed in accordance with the Resilience Methodology developed for PR19. This is discussed in more detail below. At present, the risk of loss of a particular main for an extended period of time (longer than 24 hours) has not been robustly analysed, but the Exceptional Sites identified in the Minerva study can be used to determine the identity of mains where repair would extend beyond a 24 hour period.

All risks have been captured, and analysed to ensure evidence exists to provide validation. In all cases the needs have been articulated against the risks and then options developed to mitigate the risks to ensure that line of sight is provided.

Coincident Risks

Risks in combination, including likelihood of issues occurring in the water supply network during planned outages, have not been robustly analysed. Historically there has been a premise that coincident risk (double jeopardy) is not designed for. However, as customer expectation of reliability increases, and as reliance on performance of systems increases to meet resource demand and other performance commitments, the resilience of the systems becomes more complex, and coincident risk needs to be considered. Further analysis is planned to improve the understanding of risk to reliability of supplies to investigate complex combinations of risks for various operational and demand scenarios.

Population Centres at Risk

Analysis of our trunk mains and distribution network[6] has been undertaken to determine those customers at risk of loss of supply in the event of a significant event in the network.

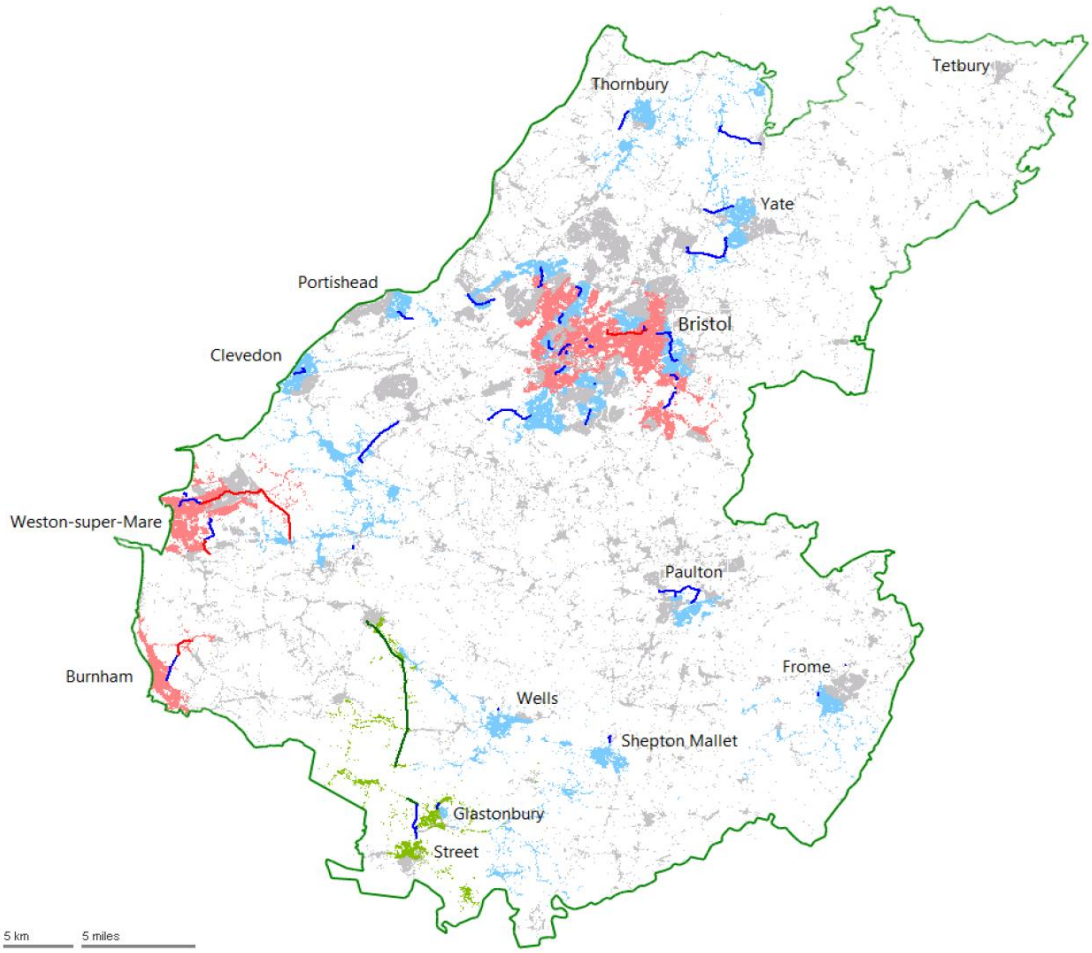
The outcome of this analysis has identified properties at risk as shown in Figure 5, which categorises properties into:

- Population centres greater than 25,000 (not including Glastonbury / Street);
- Population centres greater than 25,000 (Glastonbury / Street); and
- Population centres greater than 10,000.

Furthermore, it has identified those mains that are considered critical.

[6] Bristol Water, 2018, Critical Pipe Analysis Methodology

Figure 5: Population Centres at Risk



KEY

Mains at Risk serving ≥ 25 000 population	16.3 km
Mains at Risk serving ≥ 10 000 < 25 000 population	59.0 km
Mains at Risk serving ≥ 25 000 population (Mitigated by Glastonbury/Street scheme)	13.2 km
Population at Risk ≥ 25 000	
Population at Risk ≥ 10 000 < 25 000	
Population at Risk ≥ 25 000 (Mitigated by Glastonbury/Street scheme)	

BRISTOL WATER

Bristol Water Asset Management

Investment Case Need

Resilience for the purposes of this investment case has focussed on the reliability of supply to customers in the event of failure of critical assets. The definition of critical assets has been broadened from the current definition which only includes non-infrastructure assets, to now include pipework network assets. This has been defined as “pipelines supplying populations of equal or greater than 3,000 people” as part of Phase 1 of the Minerva Criticality Profiling Project, which has been used to support the Trunk Mains investment case. While the outputs of this study (as discussed in Section 3.6) are useful as a means of understanding the risk presented to population centres, it does not fully explore the impact of loss of mains to population centres greater than 10,000, as the Minerva project has not investigated the existing operational mitigation of impacts of loss of mains, such as storage in reservoirs and the ability to rezone. A separate approach has therefore been adopted to develop the scope of critical mains for this investment case, including the operational mitigation, which is described as follows:

A Criticality Assessment has been undertaken using latest network models to interrogate the pipework that will affect supply to customer properties (experiencing less than 3m pressure for a minimum period of 30 minutes) if damaged for a period of 24 hours or more. The analysis includes provisions of storage in reservoirs and open network connectivity. The approach is detailed within the Critical Pipe Analysis Methodology.

The company has committed to providing resilience to ensure that any issue lasting for more than 24 hours with one of our critical assets will not affect more than 10,000 people (by 2030).

There is no base maintenance element of this investment case as once mains and other resilience measures are constructed, the assets are then considered under other investment cases. Reliable supplies depend not only on appropriate resilience measures being implemented, but also the availability of all production and network assets. Furthermore, there is also an assumption that there is effective and on-going investment in their performance. Hence, resilience relies upon the base and strategic maintenance of other investment cases, including treatment works strategic maintenance.

Mandatory Needs

While Section 3.5 confirms there are no statutory, regulatory or Drinking Water Inspectorate obligations associated with this investment case, we have planned to undertake remedial works on Whitchurch Stowey 21” main, due to the condition of this main and its criticality in providing supplies in the event of a failure at Stowey WTW. While customers can be supported from other sources in the network, this main is relied upon to provide a reliable supply to the Stowey zone from Knowle at 18.1 Ml/d. The condition of this main is known to have deteriorated and corrosion is present with water quality proven to be a concern.

Historically, the main has been rehabilitated with a structural lining in the approaches to the Belluton Narrows, on the B3130 road, which itself has a non-structural polyurethane lining. This polyurethane lining has failed and therefore the main is considered at increased risk of bursting, with customers in the Stowey zone at risk. While this risk is currently being managed by limiting pressures, the situation will continue to deteriorate and any repair in this location would be major works requiring

extended programme due to access and the proximity of retaining walls. The situation is presented in more detail in the Renovation of 21" Stowey to Knowle Trunk Main Design Report[7].

Figure 6: Belluton Narrows (B3130)

Additionally, the Forum Millmarsh main has been identified as a known constraint in the provision of resilient supplies to the Oldford zone in the event of losing Oldford Treatment Works. In such a case, supplies from Millmarsh reservoir would be required to feed the Oldford zone, at greater pressures than this main is designed to accommodate. The replacement of this main to a higher pressure specification is required to mitigate the risk of burst and loss of resilient supplies for the Oldford zone.

4.2.2 Optioneering & Intervention Development

Three risks were selected and developed into needs statements. Further investigation of these needs included data assimilation, analysis and consultation with key stakeholders. Multiple options were developed and recorded for each of the three needs statements. These options were peer reviewed and all options identified as not viable were discarded.

For example, against the selected risk regarding the loss of a main serving a zone with 4,000 connections or more, seven options were identified and one of these was developed into an intervention, as shown in Table 5.

[7] Bristol Water, 2005, Renovation of 21" Stowey to Knowle Trunk Main Design Report.

Table 5: Example of Options Selection

Strategic Risk Register (SRR) Reference	SRR Revised Risk Description	Risk Need		Identification & Viability of Options		
		SRR Need ID	Need Description (from SRR)	Proposed Option Name	Proposed Option Description	Option Viability?
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >25k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >25k in case of single asset failure	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, duplicating those at risk to protect areas of supply to population centres >10k in case of single asset failure	N
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, duplicating those at risk, with reduced diameter to achieve minimum required levels of service to protect areas of supply to population centres >10k in case of single asset failure	N
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	System Resilience Assessment	develop on the PR14 Resilience Risk Assessment using System Resilience Assessments to include all assets and all hazards.	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical	new mains, boundary control valves, and manual valves to protect areas of supply to population centres >10k in case of single asset failure. Mains with IDs: 33258286, 116492397, 651627388, 651631852	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y

All viable options were identified with a unique reference number as proposed interventions and were taken forward for further scope development, benefits calculation and costing. A total of seven interventions were identified in this way. These included in some cases, multiple interventions against a single selected risk and these were identified as mutually exclusive during intervention selection. A summary of all selected risks and their associated options is included in Appendix D.

For the Resilience investment case the process has been split into three work streams, namely:

- Specific interventions;
- Generic interventions (network wide resilience); and
- Network risk analysis.

The methodologies described in Section 4.1 ensure that we use the best available evidence to objectively assess and prioritise diverse risks and consequences. A more detailed description of the approach taken for the Resilience investment case is summarised in the PR19 Resilience Methodology.

Specific Interventions

Two discrete resilience schemes have been identified from risks that have been presented and evidence provided where engineering difficulties and existing pipework condition data support this.

Generic Interventions

Network analysis has been undertaken to develop network wide solutions to address resilience deficiencies in the network serving population centres of 25,000 and greater and 10,000 and greater, where a single network failure may occur lasting at least 24 hours. In both cases population in the Glastonbury / Street area are identified as being at risk.

Five generic options were considered to mitigate any resilience deficiency identified by the network analysis. These are:

- to lay a duplicate pipeline of similar diameter to the critical main,
- to lay a duplicate pipeline of reduced diameter to the critical main, ensuring that minimum pressure and service commitments are met,
- to install intelligent dynamic valves in the network to allow rezoning automatically,
- To install manual valves in the network to allow rezoning where this can be achieved simply, and
- To install turbidity monitors in the network where rezoning is possible but known issues exist where reverse flows are considered to cause a risk of discolouration.

Installation of valves will generally be lowest cost option and therefore a duplicate pipeline was only proposed where the valve option did not work. The size of a duplicate main was also investigated to determine the minimum diameter necessary to provide the required levels of services. Solutions were then developed for the 81 critical mains which comprise combinations of the above options to develop the generic interventions.

Network Risk Analysis

The analysis undertaken to date has established the above and below ground assets where the consequence of failure is understood to affect population centres of 25,000 and greater and 10,000 and greater. However, the likelihood of failure is not fully understood.

Furthermore, the challenge of understanding the risks presented with combinations of risks and operational activities is not understood. Good practice currently dictates that plans are made to mitigate any risks of operational issues occurring during planned operational events.

For example:

- A service reservoir compartment taken out for cleaning reducing storage in a zone will be mitigated by selecting the appropriate season and time to undertake this work and filling of neighbouring reservoirs as a precaution; or
- Rezoning and ensuring pumping stations are fully maintained during slip-lining operations within the network.

It is often the case that the most impactful situations arise when critical assets fail elsewhere in the system during such planned operational activities, when planning places more reliance upon the performance of other assets. While rigorous 'what if' analyses can assist in the planning of such operational activities, it is considered that a more detailed investigation is required to help understand where pinch points may exist, or where certain combinations of operational activities may place additional stresses on the system. A System Resilience Assessment study is included in the plan, to build on the studies already undertaken and to develop a support tool to assist with operational planning activities.

Options Assessed

Details of all of the options considered within the Resilience investment case are presented in Appendix D. This includes commentary and rationale for why some options were not taken forward for optimisation. The results of the generic interventions network analysis are presented in the figures in Appendix G, and summarised in Table 6.

Table 6: Network analysis - generic interventions

Option	Scope
Population Centres greater than 25,000 (new mains)	2.0 km
Population Centres greater than 25,000 (new valves)	13 no. dynamic valves 15 no. manual valves
Population Centres greater than 10,000, less than 25,000 (new mains)	8.9 km
Population Centres greater than 10,000, less than 25,000 (new valves)	50 no. dynamic valves 55 no. manual valves
Population Centres greater than 25,000 in Glastonbury Street	8.0 km

4.2.3 Intervention Costing

In this investment case costs interventions were calculated in collaboration with ChandlerKBS, based on activity schedules supplied by us. Indirect overheads (contractor on-costs including preliminaries, design costs, contract management) and our overheads have then been applied at intervention level. These overheads are based on our data where available, or using industry average, where our in-house data was not available.

The exceptions to this approach included costs for System Resilience Assessments, discussed below.

Resilience investment case cost estimation

We have identified a total of seven interventions (including mutually exclusive options for the same risk) to be taken forward for scope development and cost estimation. For six of the seven interventions, high level scope documents were developed including an activity schedule. ChandlerKBS utilised a water industry unit cost data base to complete estimation in accordance with their own assured methodology.

The costed activity schedules were returned to us for peer review, leading to further refinement in collaboration with ChandlerKBS. Often, we used historical data to cross check through this process. An example of this is the Glastonbury Street intervention developed to address loss of a strategic main serving population in the Glastonbury Street area. This scheme has been previously costed by contractors in AMP6 and we were able to make this cost information available to ChandlerKBS to further inform the cost estimations for the proposed AMP7 Critical Asset Resilience Interventions.

Chandler KBS were unable to cost the System Resilience Assessments, and therefore this intervention has been costed by us using costs of a study by CH2M Hill into critical assets and adding on an allowance for risk. Additional allowance was made for expanded scope as the CH2M Hill quote only concerned above ground assets, allowing for critical mains, and to address challenges around operational constraints such as reservoir cleaning or planned works at treatment works or pumping stations.

Resilience investment case cost evaluation

The expected intervention duration, expected costs pre and post investment, together with the expected impact on operating costs are used to generate whole life costs for the various interventions. Interventions that show beneficial whole life costs, together with interventions which provide the most cost-beneficial means of achieving the performance commitment, are selected by the investment optimisation.

The investment optimisation calculates the investment cost as the net present value (NPV) over 40 years of the capital and change in operational expenditure associated with implementing the intervention less the 40 year net present value of any monetary benefits associated with the avoidance of reactive capital expenditure (capex) and incidental operational costs.'

The cost for each intervention that has been developed is presented in Appendix E. An example of how those costs have been developed is outlined below:

Cost Example: Forum to Millmarsh 8" Main

The pressure class of the 8" main between Forum and Millmarsh limits the flow that can be transferred to Millmarsh. Investment is required to improve this transfer rate so that the full rather than partial resilience to the Oldford zone can be achieved. Approximately 3,000 connections serving approximately 7,000 people are at risk of losing their water supply without this intervention to improve the available transfer rate of this main.

We have established the cost of undertaking the required works as £0.491m; this includes labour and materials as well as contractual costs. The latter includes items such as (but not limited to) contractor accommodation, contractor management, contractor overhead and profit, and design. We have then applied Bristol Water's overhead of £0.109m for internal activities associated with the intervention, such as project management, land and compensation, legal, environmental costs, commissioning/handover, contract management, operations and system support, consultants and administration.

All of the direct costs above gave us an intervention cost of £0.600m to implement the intervention in a planned way (the capex after).

If we did not undertake the work to restore the mains' capacity proactively, and if the main were to fail as a result of over-pressurisation due to exceeding the current transfer rate, a reactive emergency repair would be needed. This work reactively it would be completed as a 'patch and repair'. We have therefore used the patch and repair cost, calculated as £0.020m, and have applied a factor to account for the likelihood of the risk materialising within the 5 year AMP. The risk is current so we have assessed this likelihood as 50% (1 in 2), giving a reactive cost of £0.010m (£0.020m multiplied by 50%). However a reactive emergency patch and repair does not address the underlying resilience need which this intervention addresses (as determined through the optioneering and intervention development process).

We have established that regardless of whether we undertook the above intervention in either a planned or reactive way, there would be no change in operational expenditure (opex after).

Once interventions were costed, benefits could be calculated which are discussed in Section 4.2.4.

4.2.4 Benefits Quantification

Seven resilience interventions were assessed for direct and indirect benefits. These are presented in Appendix E. In terms of indirect benefits the performance commitments that relate to this investment case are discussed below.

Resilience

The Resilience for the Critical Asset Resilience interventions was based on the outputs from the Critical Pipe Analysis (Resilience population count). Resilience for the two specific interventions were calculated based on downstream population fed by these assets.

Interruptions to Supply

Two of the interventions contribute to supply interruptions by replacing critical mains which have historically failed and which may fail in future. The reduction in supply interruptions has been calculated based on the burst history.

5 Outcome

5.1 Selected Interventions

The seven interventions developed within the Resilience investment case were assessed through the investment optimisation process. Of these seven interventions, four have been selected.

When it comes to delivering our programme of works we know that we must continue to be innovative and efficient. We have set ourselves a challenging target of reducing our costs by 8% during AMP7. This will be achieved by delivery of our business transformation programme.

We see innovation as integral to our everyday working at Bristol Water: We have deliberately embedded it within the business-as-usual processes of our asset management teams, by embracing the full flexibility that totex and outcomes enables. We will look to be innovative in the following ways:

- **Open Innovation:** We have defined our strategic innovation challenges and run events such as our “Innovation Exchange” that invite suppliers to present their innovative solutions to predefined challenges that we set
- **Market Scanning:** We conduct market scanning through for cutting edge technology against our strategic innovation challenges and feed this into our optioneering process. In particular we subscribe to the Technology Approval Group which regularly scans and meets with water companies to unearth the most promising innovations for the sector
- **Partnering:** we undertake leading research into areas that we provide effective solutions for the future.

We will specifically look for innovations that mean we can contribute to our 8% efficiency challenge and keep our customers’ bills low into the future

Innovations specific to this investment case is discussed below.

- **Critical Pipe Analysis**

  Critical Pipe Analysis, where the identification of critical mains has involved the innovative use of modelling software, has identified individual mains where reservoir storage and valve arrangement limitations exist prohibiting the provision of a reliable supply in the event of a single catastrophic failure in the network. During the development of the modelling process using InfoWorks, it was found we were pushing the modelling software further than had been done by any user before. As a result some system bugs were identified and suggestions made for fixes and enhancements. The vendors, Innovyze, took these on board and sorted the issues in impressively quick time. The whole process has challenged us and our supply chain, but has resulted in ground breaking and innovative modelling solutions.

- **Dynamic Valve Arrangements**

  Asset resilience is often achieved by the installation of secondary assets to introduce redundancy into the system. As such, initial plans included duplication of mains, which were then challenged to explore more cost effective solutions: First by challenging whether a like for like sizing is required, or a reduced diameter main could provide minimum service performance;

and then to explore whether automatic rezoning could be achieved by the introduction of Dynamic Valve arrangements. This comprises remote operated valves, instrumentation to determine pressure and flows, and in some cases instrumentation to establish turbidity to understand whether risks to appearance is increasing.

These dynamic valve installations employ sector leading technology. Data from the monitors are transmitted back to centralised software which marshals and analyses the received data to determine whether there are risks to minimum levels of service being achieved. This approach, known as Resilient and Dynamically Adaptive Water Distribution Networks, has been developed by us in collaboration with Cla-Val and Imperial College London. The technology has been deployed at test sites within our supply area, and has been shortlisted for Water Industry Awards 2018 in the "Water Resilience Initiative of the Year" category.

- **System Resilience Assessments**

  We introduced the innovative approach of the "all risks model" in AMP5 as part of the PR14 process, which analysed a comprehensive range of hazards, detailed consideration of critical assets, and of system resilience. It is proposed to build on this approach, broadening the scope of assets considered to include all above and below ground assets, and consider risks in the event of planned maintenance activities. This will draw on the outputs of the Minerva Asset Criticality Profiling Project. This will enable both the prioritisation of risks identified from the critical pipe analysis, and to support more rigorous operational planning of asset outage.

The four selected interventions are set out in Table 7, along with details of the associated costs.

Table 7: Selected interventions, costs, and % performance contribution

ID	Intervention Title	Capex (£)	Change in Opex per annum (£)	Supply interruptions	Population at risk from asset failure
31.001.01	Whitchurch to Stowey 21" improvements	£963,370	£0	0.56%	14.70%
31.001.02	Forum to Millmarsh replacement	£600,036	£0	2.22%	-
31.003.03	System Resilience Assessments	£294,674	£0	-	-
31.003.04	Critical Pipe Resilience >10k, 50% delivered in AMP7[8]	£12,116,220	£0	-	85.30%
Resilience capital investment (pre-efficiency)		**£13,974,300**	**£0**	**2.78%**	**100%**
Resilience capital investment with 8% capex efficiency		**£12,856,356**			

[8] Intervention 31.003.04 Critical Pipe Resilience includes the Glastonbury Street Main

Critical Pipe Resilience (greater than 10,000, 50% delivered in AMP7, including the Glastonbury Street Main) and Whitchurch to Stowey 21" improvements are selected because they are required to achieve our population at risk from asset failure target, and also contribute to our interruptions to supply target.

Whitchurch to Stowey 21" improvements and Forum to Millmarsh replacement are selected because they are required to support our population at risk from asset failure target.

The System Resilience Analysis intervention is selected because it is cost-beneficial, helping to offset future bill increases for our customers.

The individual interventions are described in detail in the following sections.

Critical Pipe Resilience greater than 10,000, 50% delivered in AMP7

As discussed in Section 4.2.2 Network Risk Analysis, network analysis has identified network wide solutions to address resilience deficiencies in the network serving population centres greater than 10,000. A programme of mains, dynamic valves, manual valves and turbidity meters to mitigate the risk of significant loss of supply for half the population centres greater than 10,000 (resilience to be achieved over 2 AMP periods). This will comprise scope in the region of 13.4km of main (including 12.8km as part of the Glastonbury Street main), 34 no. dynamic valve installations, 40 no. manual valve installations and 23 no. turbidity meters.

The Critical Mains Analysis has not considered the condition and performance of the mains, and likelihoods of failure have not been considered at this stage. The Minerva Criticality Profiling Project and subsequent investigations will assist us in developing this data in the future.

Whitchurch to Stowey 21" improvements

Customers in the Stowey Zone rely upon the availability of the Whitchurch Stowey 21” main to provide resilience in the event that Stowey WTW fails for an extended period. This main has a history of failing and has previously been relined for a proportion of its length. This intervention will install a sliplined pipe for 550m within the Belluton Narrows to ensure customers in the Stowey Zone are provided with resilient water supplies and to reduce the risk of Interruptions to their Supplies.

Forum to Millmarsh replacement

The existing main 8" main between Forum and Millmarsh is rated Class C. The pressure rating of the main limits the flow that can be transferred from the Stowey system to the Oldford system for resilience to about 9Ml/d which is not sufficient to provide full resilience to Oldford. This intervention will install 1km of 400mm pipe across fields to replace the existing main.

System Resilience Assessments

As discussed in Section 4.2.2, while the impact of critical asset failure is understood, system resilience assessments will allow us to fully understand the likelihood of failure requires further investigation and analysis. This in turn will support our resilience investment decisions, in relation to the effective roll-out of critical pipe resilience works. System resilience assessments will accurately inform where we should invest in resilience by fully exploring the risks associated with mains supplying population centres greater than 10,000. This investment will support both AMP7 and AMP8 resilience programmes.

The total Resilience capital investment, including Water Service and Business Unit Allocation, is summarised in Table 8. This investment case is aligned to the Water Network Plus Wholesale Control

category of our Business Plan. Costs are allocated to the Treated Water Distribution Business Units. Investment is all related to infrastructure assets and is a mixture of maintenance and other capital expenditure.

Table 8: Water Service and Business Unit Allocation

Wholesale Control	Water Network Plus	Total Capital Investment
Business Unit Allocation	***04 Treated Water Distribution***	
Resilience capital investment (%)	**100.0%**	**100%**
Resilience capital investment	**£13.974m**	**£13.974m**
Maintaining the long term capability of the assets - infra	**£1.858m (13.3%)**	**£1.858m (13.3%)**
Other capital expenditure - infra	**£12.116m (86.7%)**	**£12.116m (86.7%)**
Network Ancillaries - capital investment with 8% capex efficiency		**£12.856m**

5.2 Contribution to Performance Commitment

Table 9 sets out the overall contribution to performance commitment improvement provided by the selected resilience interventions. Further detail is provided in Appendix E.

Table 9: Resilience – Contribution to performance commitment targets from selected interventions

Performance commitment	Unit	2019/20 Baseline	2020/21	2021/22	2022/23	2023/24	2024/25	Total performance improvement required in AMP7	Resilience contribution to performance improvement
Supply interruptions	Average mins per property	12.20	4.2	3.6	3.0	2.4	1.8	10.40	2.78%
Population at risk from asset failure	No. of people (population)	832,886	724,309	615,732	507,154	398,577	290,000	542,886	100%

Our AMP7 investment in resilience will help ensure our assets are being maintained appropriately to deliver resilient water services to current and future generations.

5.3 Non-Selected Interventions

Of the seven interventions developed within this investment case, three were not selected because they did not provide the most cost beneficial way of meeting performance commitment targets compared to other interventions available as assessed through the optimisation process. The risks associated with these interventions represent residual risks that will be carried during AMP7. We will continue to monitor these residual risks throughout AMP7. Details of the three non-selected interventions are given in Appendix C.2.

An example is ‘Resilience in Critical Mains serving population greater than 10,000’ (intervention 31.003.02), which was not selected due to the strategy of delivering resilience to population centres over a two AMP period, and magnitude of cost.

5.4 Assumptions

There are a number of general assumptions that have been made in the development of our investment cases. These are discussed in detail in section 11 of the PR19 investment cases Summary Document. Assumptions specific to this investment case are discussed below.

The Critical Pipe Analysis has utilised a new all mains model, one for each treatment works zone, calibrated to a trunk mains level with all of the demand area analysis complete. However, the models were not at the stage of having full control functionality so were run with all pumps ‘on’, except for transfer pumps. The model software assumes that all customers downstream of an empty reservoir would be affected until it begins to fill again, which is not necessarily the case due to stored water in the pipe system downstream.

5.5 AMP 8

The Resilience investment case has been developed to improve resilience to population centres greater than 10,000 over a two AMP period. It is planned that resilience for the remaining population (290,000 people) will be provided in AMP8.

5.6 Base Maintenance

This investment case covers all activities related to resilience performance improvement and therefore no assessment of base maintenance investment is required.

5.7 Historic & AMP7 Investment Comparison

A summary of historical investment in resilience is provided in Table 10, along with the planned AMP7 investment value from resilience interventions. We have re-categorised data used in line with the scope of our investment cases. For historic data we have used the 2016/17 wholesale cost assessment data (data tables 1 and 2). Forecast data has been derived from PR19 data (data tables WS1 and WS2).

Table 10: Historical & AMP7 capital investment

AMP	Capital investment values	Investment (£m)
AMP5	AMP5 actual	0.183
AMP6	2015/16 actual	0.940
	2016/17 actual	6.091
	2017/18 actual	11.746
	2018/19 forecast	1.814
	2019/20 forecast	0.115
	AMP6 forecast[9]	20.706
AMP7	AMP7 pre-efficiency	13.974
	AMP7 8% capex efficiency applied	12.856

Our resilience focus since AMP5 has evolved. Our AMP5 resilience investment is comparatively lower as we addressed investment needs elsewhere (e.g. upgrades of treatment works), having completed a number of strategic resilience schemes in AMP4 (including the Southern Bypass Ring Main and Northern Relief Main).

In AMP6, the Resilience performance achieved as a result of our investment will be 9,063 population in centres greater than 25,000 at risk from supply site failure (based on AMP6 Resilience definition). This remaining population is located in Glastonbury and Street, and comprises a population equivalent to the shortfall in supply in the event of the loss of Cooks Corner Pumping Station that cannot be supplied from other areas of the network. Our AMP7 investment will address this remaining population through the Glastonbury Street main proposed as part of our resilience interventions.

Following the change in definition of the Resilience performance commitment for PR19, the initial resilience measure will be 832,886 population in centres greater than 10,000 at risk from asset failure, at the start of AMP7, reducing to 290,000 as a result of our AMP7 investment.

[9] The AMP6 forecast includes the Southern Resilience Scheme investment. This investment addresses both resilience and growth. £20.517m of the Southern Resilience Scheme investment is allocated to resilience.

6 Conclusions

To ensure the critical network mains continues to deliver our customers' priorities we will measure progress via performance commitments for which we have set delivery targets.

In AMP7, the operational resilience measures are the population at risk from asset failure (target 290,000) and supply interruptions (target 1.8 average minutes per property).

An initial list of three risks generated a total of seven potential interventions. These interventions have developed and assessed through our asset management totex focused processes as set out in this investment case, and put forward for investment optimisation. Of these, four interventions were selected, two on the basis that they met our customer priorities and associated performance commitments. The remaining two were selected on the basis that they are required to sustain existing performance and form the basis for performance improvement.

We plan to invest £13.974m in strategic interventions to improve operational resilience. We have set ourselves a challenging target of reducing out costs by 8% during AMP7. This will be achieved by delivery of our business transformation programme, resulting in a post-efficiency investment of £12.856m.

The interventions proposed contribute to ensuring our assets are maintained appropriately for the benefit of current and future generations. The interventions proposed are also expected to contribute 75% of our target for customers in population centres of 10,000 or greater at risk of asset failure, and 2.78% of our supply interruptions target.

If we fail to invest in the resilience of our critical mains, the key risk is that we will not be able to provide resilience to customers in population centres greater than 10,000 if a critical asset fails for an extended period of time. Consequently we will not provide our customers with the Safe and Reliable Supply that is a key outcome for them

In addition, given the function of some of our critical mains, we must ensure that these assets are fit and well in terms of providing operational resilience to our customers. Therefore there is a risk that if we fail to invest in resilience of critical mains we will not be able to provide resilience to customers in relation to two specific assets (near Millmarsh reservoir and in the Belluton Narrows area), if these assets were to be relied upon to provide resilience in the event of an extreme event, and subsequently fail

Our business plan provides assurance to both deliver and monitor the delivery of its outcomes, it will meet relevant statutory requirements and licence obligations imposed by the UK Government.

7 Appendices

- Appendix A: Line of Sight
- Appendix B: Datasets
- Appendix C.1: Selected Risks
- Appendix C.2: Non-Selected Risks
- Appendix D: Options Considered
- Appendix F: Non-Selected Intervention
- Appendix G: Generic Interventions Summary Diagrams

7.1 Appendix A: Line of Sight

Resilience Line of Sight

Investment Case
NTPBP-EXT-IC3-0519

Customer Priorities

Top Quality Water Supplies

Performance Commitments

Optimiser Input Form Reference

NTPBP-CAL-RES-0365

Slower Plan
Suggested Plan
Faster Plan
Based on Lockdown 5

Safe and Reliable Supply of Water

Reliability

Resilience -Population at Risk From Asset Failure

0 | 0 | 0

Customer High Priority

ODI: Bespoke Reward and Penalty

Reliability

Supply Interruptions

4.2 | 1.8 | 1.5

Customer High Priority

ODI: Common Reward and Penalty

Interventions

- 31.001.01 Whitchurch to Stowey 21" Improvements
- 31.001.02 Forum to Millmarsh replacement
- 31.003.01 Critical Pipe Resilience >25K
- 31.003.02 Critical Pipe Resilience >10k
- 31.003.03 System Resilience Analysis
- 31.004.01 Glastonbury to Street Main
- 31.001.01 Whitchurch to Stowey 21" Improvements
- 31.001.02 Forum to Millmarsh replacement

OFWAT Initial Assessment Tests

OFWAT Initial Assessment Tests	Test Area
What is the quality of the Company's customer engagement and participation and how is it incorporated into the companies business plan and ongoing operations	Engaging Customers
How well has the company used the best available evidence to objectively assess and prioritise the diverse range of risks and consequences of disruptions to its systems and services and engaged effectively with customers on its assessment of the risks and consequences	Securing long term resilience
How well has the company objectively assessed the full range of mitigating options and selected the solutions that represent the best value for money over the long term and support from customers	Securing long term resilience
To what extent has the company clearly demonstrated that it has considered whether all relevant projects are technically suitable for direct procurement for customers. Where it has one or more such projects, to what extent has the Company provided a well reasoned and well evidenced value for money assessment	Targeted controls , markets and innovation
To what extent does the company have a good track record of producing high quality data, taking into account the company's data submission, assurance process and statement of high quality , and our 2018 assessment of the company under the Company Monitoring Framework	Securing Confidence and Assurance

Board Requirements

Board Requirements	Test Area
Assurance that the company's business plan has been informed by customer engagement and feedback from the company's CCG about the quality of its customer engagement and how this has been incorporated into the plan	Customer Engagement
Assurance that the company's business plan has been informed by a robust and systematic assessment of the resilience of the company's systems and services; customer views on managing resilience and a comprehensive and objective assessment of interventions to manage resilience in customers long term interests	Resilience
How has it challenged an satisfied itself that the overall strategy for data assurance and governance processes delivers a high quality data	Business Planning
How has it challenged and satisfied itself that the business plan will enable the company to meet its statutory and licence obligations , now and in the future and take account of the UK and Welsh governments strategic policy statements.	Business Planning
How has it challenged and satisfied itself that its plan will deliver operational financial and corporate resilience over the next control period and the long term through its governance and assurance processes, taking into account of its track record of performance	Business Planning

Performance Commitment Key

- Common Performance Commitment
- Common New Performance Commitment
- Bespoke Performance Commitment
- Bespoke New Performance Comittment

Document Number: NTPBP-MET-RES-0642

7.2 Appendix B: Datasets

This appendix show the data used in this investment case and where and how it has been applied

Dataset File Name	Data Summary	Process In Which Data Has Been Used			
		Risk Idenfitication, Verification and Needs Assessment	Optioneering	Intervention Costing	Benefits Quantification
REQ-0151 PR19 - Forum to Millmarsh - resilience to Oldford TW zone.pdf	Cost of repairs following burst in the Portway (A4) in Bristol, 2001	-	-	✓	-
REQ-0160 Modelling population affected by bursts.xlsx	Critical pipe model runs to determine the number of properties affected (defined as experiencing less than 3m pressure head for more than 3 hours) and the duration of the interruption in 27 locations. Asset IDs to locate the isolation zones and duration of the isolation of the main	-	-	✓	✓
REQ-0212 Pipe Criticality - High Level Resilience Schemes.xlsx	Pipe Criticality	-	-	✓	✓
REQ-0224 PR19 Resilience - Scope of works for final Critical Pipework Analysis - K Henderson 31.01.18.msg	Critical Pipework Analysis	✓	-	-	✓

7.3 Appendix C.1: Selected Risks

This appendix shows the 3 selected risks of the 5 relevant risks.

SRR ID	Location/Zone	Revised Risk Description	Likelihood	Human Health / Environment	Ease to Resolve	Publicity & Reputation	Regulatory Impacts	Customers Impacted	Max Impact	Risk Score
SRR662	Whitchurch to Stowey 21"	IF the Whitchurch to Stowey Main fails due to the failed lining THEN more than 25,000 customers in the Stowey zone will lose water supplies for extended periods of time. Full resilience to Stowey cannot be provided. The 21" Whitchurch to Stowey main is a key resilience main for Stowey. It has burst in a difficult to repair location. The burst has caused the PU lining in the pipe to fail. The failed PU lining makes another burst more likely.	3	2	3	3	4	4	4	12
SRR663	Forum	IF the aquifer serving Oldford borehole is polluted THEN more than 10,000 customers in the Oldford Zone will lose water supplies for an extended period of time. The existing main 10" main between Forum and Millmarsh is rated Class C. The pressure rating of the main limits the flow that can be transferred from the Stowey system to the Oldford system for resilience to about 9Ml/d which is not sufficient to provide full resilience to Oldford.	3	2	3	3	4	4	4	12
SRR665	Various water supply zones	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	3	2	2	3	4	4	4	12

7.4 Appendix C.2: Non-Selected Risks

Not applicable – all risks were selected.

7.5 Appendix D: Options Considered

This appendix shows the 11 options considered from the 3 selected risks

Strategic Risk Register (SRR) Reference	SRR Revised Risk Description	Risk Need		Identification & Viability of Options		
		SRR Need ID	Need Description (from SRR)	Proposed Option Name	Proposed Option Description	Option Viability?
SRR662	IF the Whitchurch to Stowey Main fails due to the failed lining THEN more than 25,000 customers in the Stowey zone will lose water supplies for extended periods of time. Full resilience to Stowey cannot be provided. The 21" Whitchurch to Stowey main is a key resilience main for Stowey. It has burst in a difficult to repair location. The burst has caused the PU lining in the pipe to fail. The failed PU lining makes another burst more likely.	SRRN41	The 21" Whitchurch to Stowey main provides resilience to Stowey TW works in the event of failure of Stowey TW. South of Bellution narrows the pressure in the main is greater and the main was sliplined with a structural liner in 2006. At Belluton narrows only a 1.5mm 'quality' PU liner was applied to prevent discoloration of the water through corrosion. In 2008 the main at Belluton narrows burst and damaged the PU lining over a long length. Repair of the main at Belluton narrows is very difficult because it is between to high (4m+) retaining walls. The main at Belluton is therefore known to burst and no more vulnerable due to the damaged PU lining. Failure of the main will be most likely when full resilience flows are put through the main. This will be the time when the main is needed the most ie when an event has taken Stowey TW out of service. A resilience flow of some 16Ml/d is required. This equates to a population of approx 76,800 at risk (at 2000 connections per Ml and 2.4 people per connection). Investment is therefore required to strengthen or replace the main through Belluton narrows to secure the resilience for Stowey TW zone and therefore a population of approx 76,800. Stanton Drew is also fed off this main so investment will secure uninterrupted supply to Stanton Drew.	1) Business As Usual	1) This option involves leaving the main as is and fixing the main on failure.	N
	IF the Whitchurch to Stowey Main fails due to the failed lining THEN more than 25,000 customers in the Stowey zone will lose water supplies for extended periods of time. Full resilience to Stowey cannot be provided. The 21" Whitchurch to Stowey main is a key resilience main for Stowey. It has burst in a difficult to repair location. The burst has caused the PU lining in the pipe to fail. The failed PU lining makes another burst more likely.	SRRN41	The 21" Whitchurch to Stowey main provides resilience to Stowey TW works in the event of failure of Stowey TW. South of Bellution narrows the pressure in the main is greater and the main was sliplined with a structural liner in 2006. At Belluton narrows only a 1.5mm 'quality' PU liner was applied to prevent discoloration of the water through corrosion. In 2008 the main at Belluton narrows burst and damaged the PU lining over a long length. Repair of the main at Belluton narrows is very difficult because it is between to high (4m+) retaining walls. The main at Belluton is therefore known to burst and no more vulnerable due to the damaged PU lining. Failure of the main will be most likely when full resilience flows are put through the main. This will be the time when the main is needed the most ie when an event has taken Stowey TW out of service. A resilience flow of some 16Ml/d is required. This equates to a population of approx 76,800 at risk (at 2000 connections per Ml and 2.4 people per connection). Investment is therefore required to strengthen or replace the main through Belluton narrows to secure the resilience for Stowey TW zone and therefore a population of approx 76,800. Stanton Drew is also fed off this main so investment will secure uninterrupted supply to Stanton Drew.	2) Slip-line	Slip-line a 550m length with SDR17 500mm outside diameter main (id 439mm)	Y
SRR663	IF the aquifer serving Oldford borehole is polluted THEN more than 10,000 customers in the Oldford Zone will lose water supplies for an extended period of time. The existing main 10" main between Forum and Millmarsh is rated Class C. The pressure rating of the main limits the flow that can be transferred from the Stowey system to the Oldford system for resilience to about 9Ml/d which is not sufficient to provide full resilience to Oldford.	SRRN42	The pressure class of the 8" main between Forum and Millmarsh limits the flow that can be transferred to Millmarsh. Investment is required to improve this transfer rate so that the full rather partial resilience to the Oldford zone can be achieved. Some to 3000 connections, amounting to some 7000 people are at risk of losing their water supply without this intervention.	1) Business As Usual	This option involves leaving the main as is and should a resilient event in the Oldford zone occur, over pressursing the main to meet the Oldford demand or risk a large number of customer losing their water. Neither is an acceptable option.	N
	IF the aquifer serving Oldford borehole is polluted THEN more than 10,000 customers in the Oldford Zone will lose water supplies for an extended period of time. The existing main 10" main between Forum and Millmarsh is rated Class C. The pressure rating of the main limits the flow that can be transferred from the Stowey system to the Oldford system for resilience to about 9Ml/d which is not sufficient to provide full resilience to Oldford.	SRRN42	The pressure class of the 8" main between Forum and Millmarsh limits the flow that can be transferred to Millmarsh. Investment is required to improve this transfer rate so that the full rather partial resilience to the Oldford zone can be achieved. Some to 3000 connections, amounting to some 7000 people are at risk of losing their water supply without this intervention.	2) Replace the existing main	Lay approx 1km of 400mm pipe across fields	Y

Strategic Risk Register (SRR) Reference	SRR Revised Risk Description	Risk Need		Identification & Viability of Options		
		SRR Need ID	Need Description (from SRR)	Proposed Option Name	Proposed Option Description	Option Viability?
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >25k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >25k in case of single asset failure	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, duplicating those at risk to protect areas of supply to population centres >10k in case of single asset failure	N
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, duplicating those at risk, with reduced diameter to achieve minimum required levels of service to protect areas of supply to population centres >10k in case of single asset failure	N
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	System Resilience Assessment	develop on the PR14 Resilience Risk Assessment using System Resilience Assessments to include all assets and all hazards.	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical	new mains, boundary control valves, and manual valves to protect areas of supply to population centres >10k in case of single asset failure. Mains with IDs: 33258286, 116492397, 651627388, 651631852	Y
	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y

7.6 Appendix E: Interventions Developed

This appendix shows the 7 interventions developed from the 11 options

Strategic Risk Register (SRR) Reference	SRR Revised Risk Description	Risk Need		Identification & Viability of Options			Proposed Interventions		Costs	Benefits		
		SRR Need ID	Need Description (from SRR)	Proposed Option Name	Proposed Option Description	Option Viability?	Ref No	Intervention Title	Capex After (£)	Change in Opex (£)	Supply Interruptions (mins/prop/year (all interruptions >3 hours))	Resilience (No.)
SRR662	IF the Whitchurch to Stowey Main fails due to the failed lining THEN more than 25,000 customers in the Stowey zone will lose water supplies for extended periods of time. Full resilience to Stowey cannot be provided. The 21" Whitchurch to Stowey main is a key resilience main for Stowey. It has burst in a difficult to repair location. The burst has caused the PU lining in the pipe to fail. The failed PU lining makes another burst more likely.	SRRN41	The 21" Whitchurch to Stowey main provides resilience to Stowey TW works in the event of failure of Stowey TW. South of Bellution narrows the pressure in the main is greater and the main was sliplined with a structural liner in 2006. At Belluton narrows only a 1.5mm 'quality' PU liner was applied to prevent discoloration of the water through corrosion. In 2008 the main at Belluton narrows burst and damaged the PU lining over a long length. Repair of the main at Belluton narrows is very difficult because it is between to high (4m+) retaining walls. The main at Belluton is therefore known to burst and no more vulnerable due to the damaged PU lining. Failure of the main will be most likely when full resilience flows are put through the main. This will be the time when the main is needed the most ie when an event has taken Stowey TW out of service. A resilience flow of some 16Ml/d is required. This equates to a population of approx 76,800 at risk (at 2000 connections per Ml and 2.4 people per connection). Investment is therefore required to strengthen or replace the main through Belluton narrows to secure the resilience for Stowey TW zone and therefore a population of approx 76,800. Stanton Drew is also fed off this main so investment will secure uninterrupted supply to Stanton Drew.	2) Slip-line	Slip-line a 550m length with SDR17 500mm outside diameter main (id 439mm)	Y	31.001.01	Whitchurch to Stowey 21" improvements	£963,370	£0	0.069	79804
SRR663	IF the aquifer serving Oldford borehole is polluted THEN more than 10,000 customers in the Oldford Zone will lose water supplies for an extended period of time. The existing main 10" main between Forum and Millmarsh is rated Class C. The pressure rating of the main limits the flow that can be transferred from the Stowey system to the Oldford system for resilience to about 9Ml/d which is not sufficient to provide full resilience to Oldford.	SRRN42	The pressure class of the 8" main between Forum and Millmarsh limits the flow that can be transferred to Millmarsh. Investment is required to improve this transfer rate so that the full rather partial resilience to the Oldford zone can be achieved. Some to 3000 connections, amounting to some 7000 people are at risk of losing their water supply without this intervention.	2) Replace the existing main	Lay approx 1km of 400mm pipe across fields	Y	31.001.02	Forum to Millmarsh replacement	£600,036	£0	0.271	0
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >25k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >25k in case of single asset failure	Y	31.003.01	Critical Pipe Resilience >25k	£2,734,870	£0	N/A	417000
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y	31.003.02	Critical Pipe Resilience >10k	£24,232,430	£0	N/A	753082

Strategic Risk Register (SRR) Reference	SRR Revised Risk Description	Risk Need		Identification & Viability of Options			Proposed Interventions		Costs	Benefits		
		SRR Need ID	Need Description (from SRR)	Proposed Option Name	Proposed Option Description	Option Viability?	Ref No	Intervention Title	Capex After (£)	Change in Opex (£)	Supply Interruptions (mins/prop/year (all interruptions >3 hours))	Resilience (No.)
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	System Resilience Assessment	develop on the PR14 Resilience Risk Assessment using System Resilience Assessments to include all assets and all hazards.	Y	31.003.03	System Resilience Analysis	£294,674	£0	N/A	N/A
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical	new mains, boundary control valves, and manual valves to protect areas of supply to population centres >10k in case of single asset failure. Mains with IDs: 33258286, 116492397, 651627388, 651631852	Y	31.004.01	Glastonbury to Street Main	£7,700,500	£0	N/A	28000
SRR665	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than 10000 people) will be without water.	SRRN48	There approximately 30 locations where a water main burst could cause greater than 4000 connections to lose their water supply. Investment is need to provide resilience to the areas and to ensure that BW meet their performance commitment on Resilience.	Critical Asset Resilience >10k	new mains, boundary control valves, manual valves and turbidity monitors to protect areas of supply to population centres >10k in case of single asset failure	Y	31.003.04	Critical Pipe Resilience > 10k, 50% delivered in AMP7	£12,116,220	£0	N/A	463082

7.7 Appendix F: Non-Selected Intervention

This appendix shows the 3 non-selected interventions. See appendix D for costs or performance commitments.

Ref No	Intervention Title	Expected Capex after (£)	Change in Opex (£)	Residual Risk
31.003.01	Critical Pipe Resilience >25k	£2,734,870	£0	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than10000 people) will be without water.
31.003.02	Critical Pipe Resilience >10k	£24,232,430	£0	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than10000 people) will be without water.
31.004.01	Glastonbury to Street Main	£7,700,500	£0	IF a water main feeding this zone bursts THEN greater than 4000 connections (equating roughly to a population of greater than10000 people) will be without water.

7.8 Appendix G: Generic Interventions Summary Diagrams

The diagrams presented in this Appendix provide the basis for the options that have been developed for the Generic Interventions, as follows:

- Figure 7: Generic Interventions for Population Cenres greater than 25,000 (new mains)
- Figure 8: Generic Interventions for Population Centres greater than 25,000 (new valves)
- Figure 9: Generic Interventions for Population Centres greater than 10,000, less than 25,000 (new mains)
- Figure 10: Generic Interventions for Population Centres greater than 10,000, less than 25,000 (new valves)
- Figure 11: Specific Intervention for Population Centres greater than 25,000 in Glastonbury Street

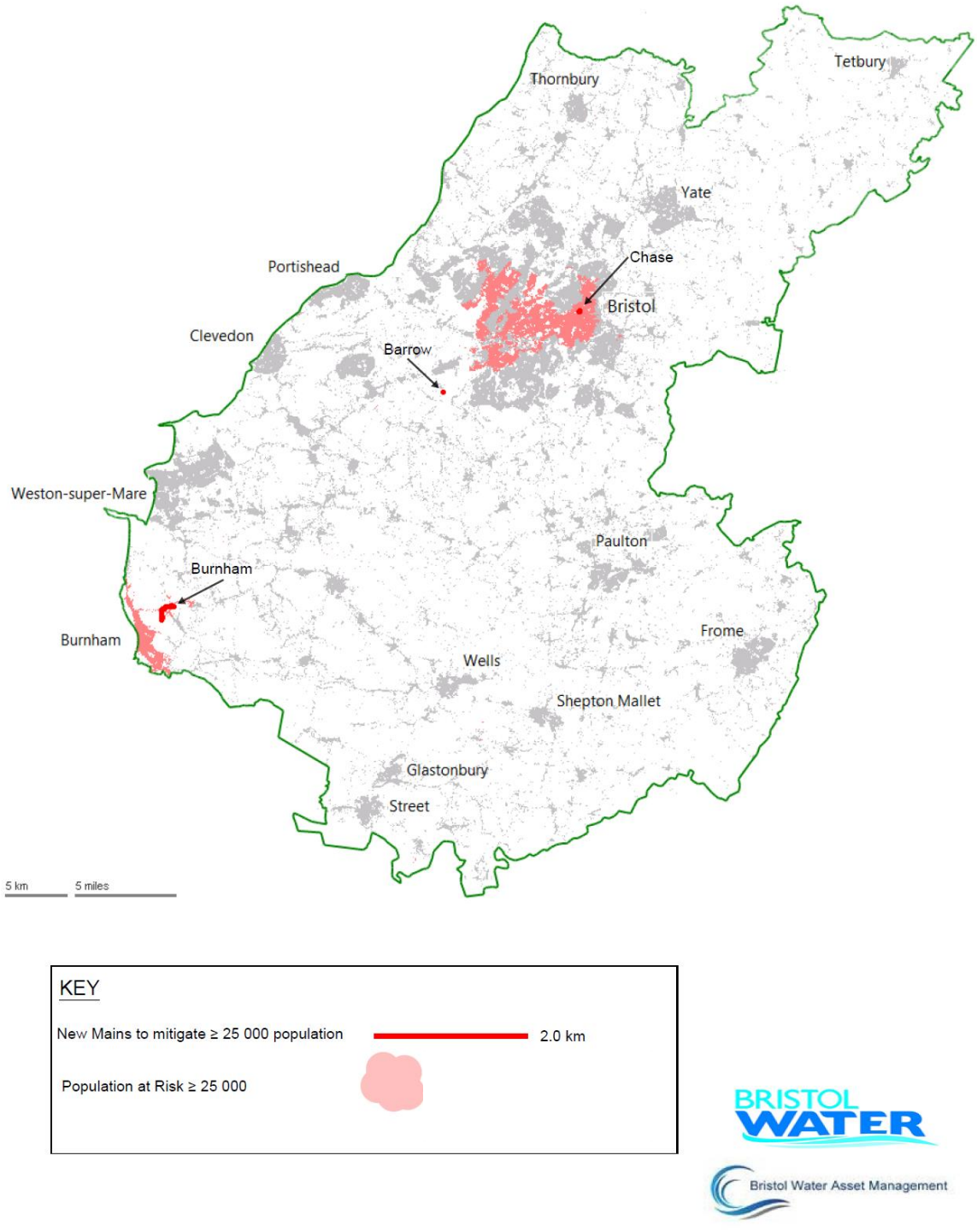


Figure 7: Generic Interventions for Population Cenres greater than 25,000 (new mains)

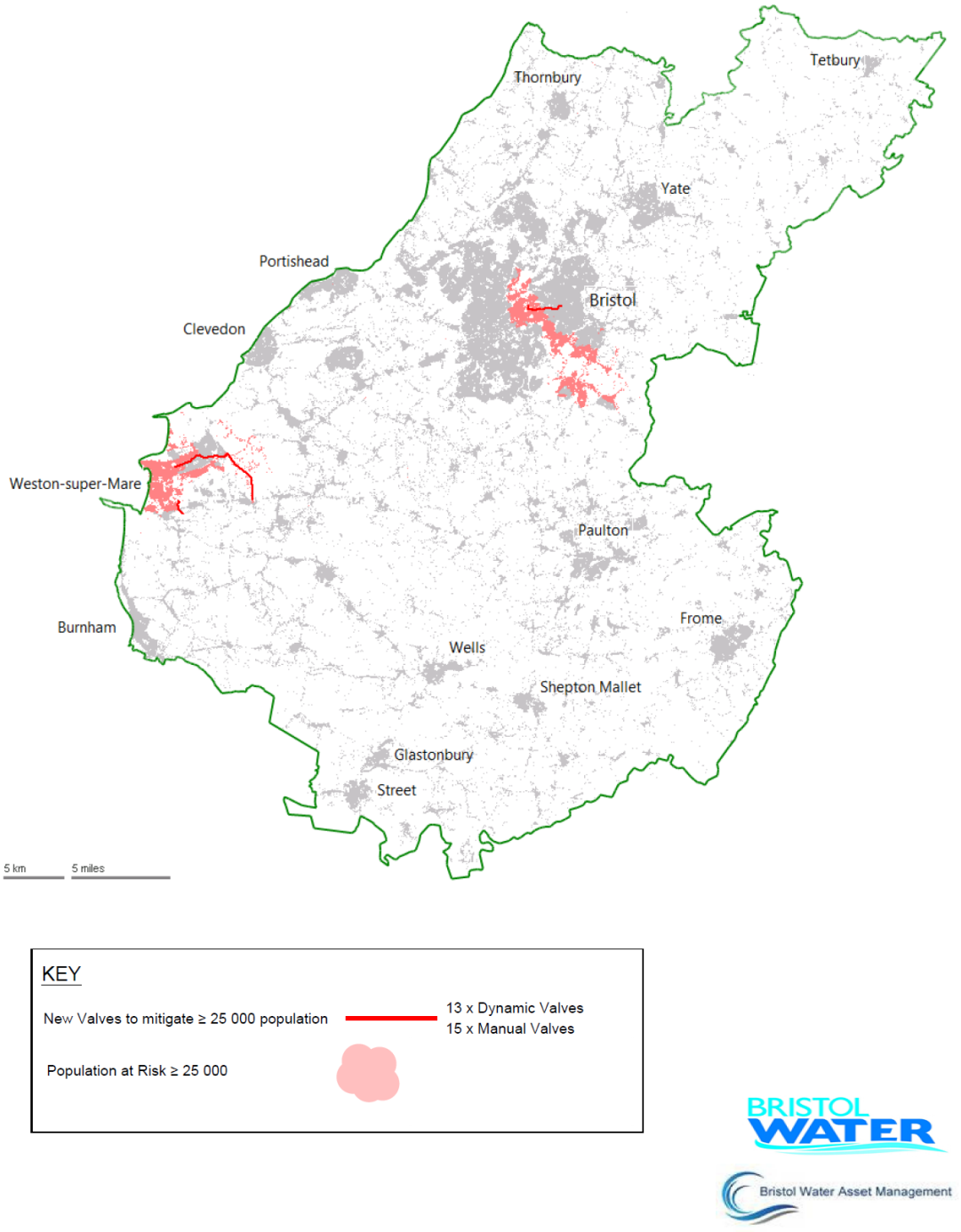


Figure 8: Generic Interventions for Population Centres greater than 25,000 (new valves)

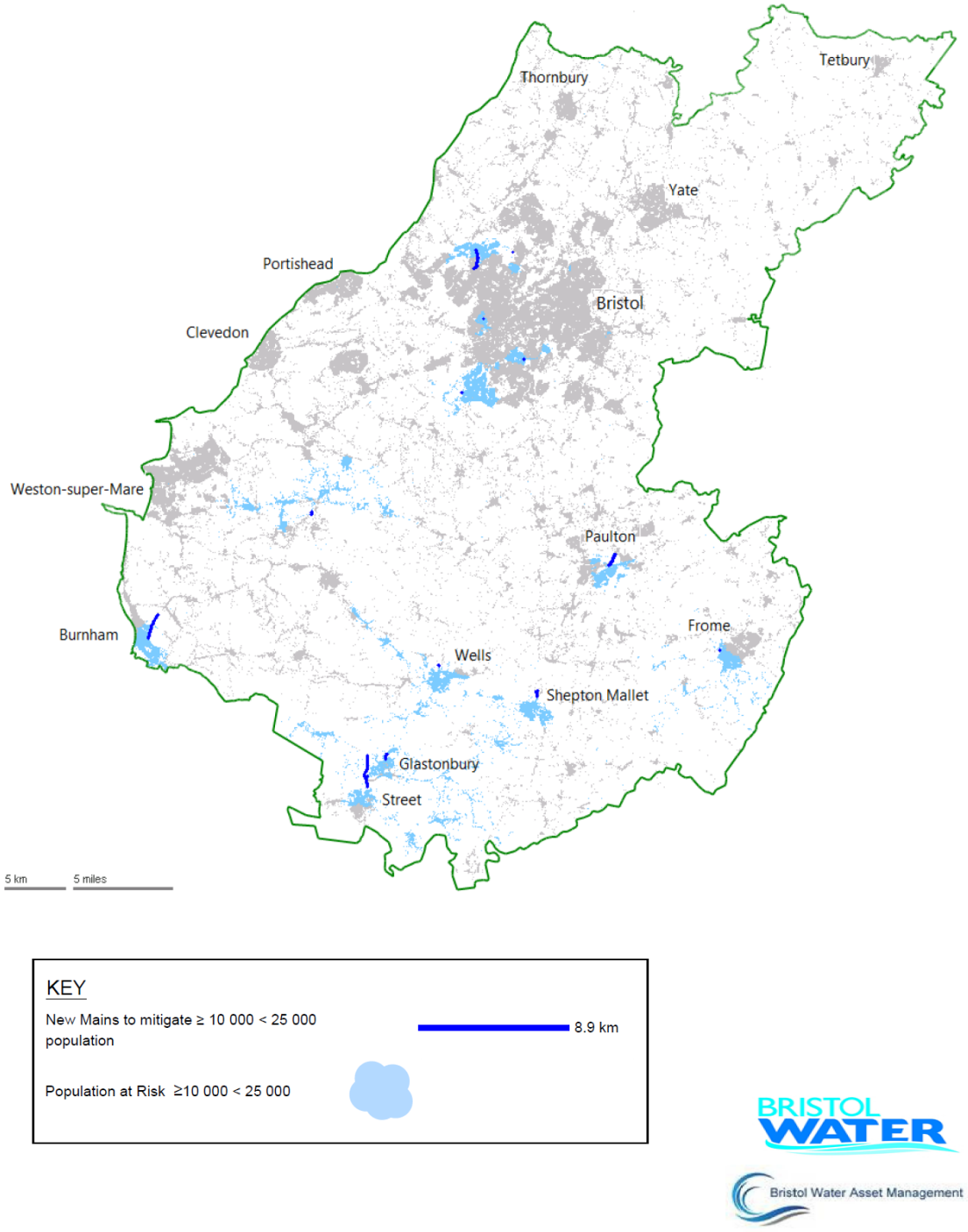


Figure 9: Generic Interventions for Population Centres greater than 10,000, less than 25,000 (new mains)

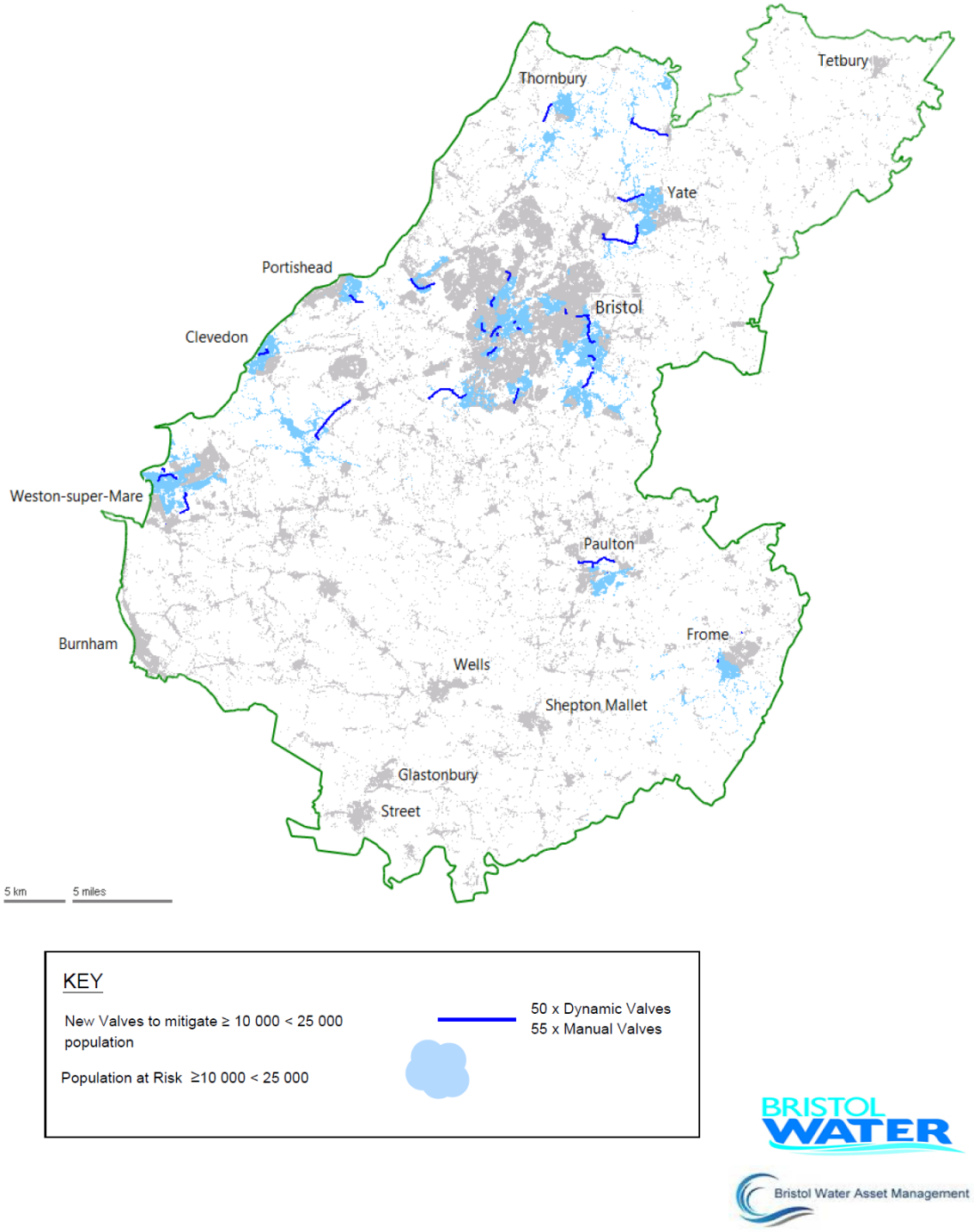
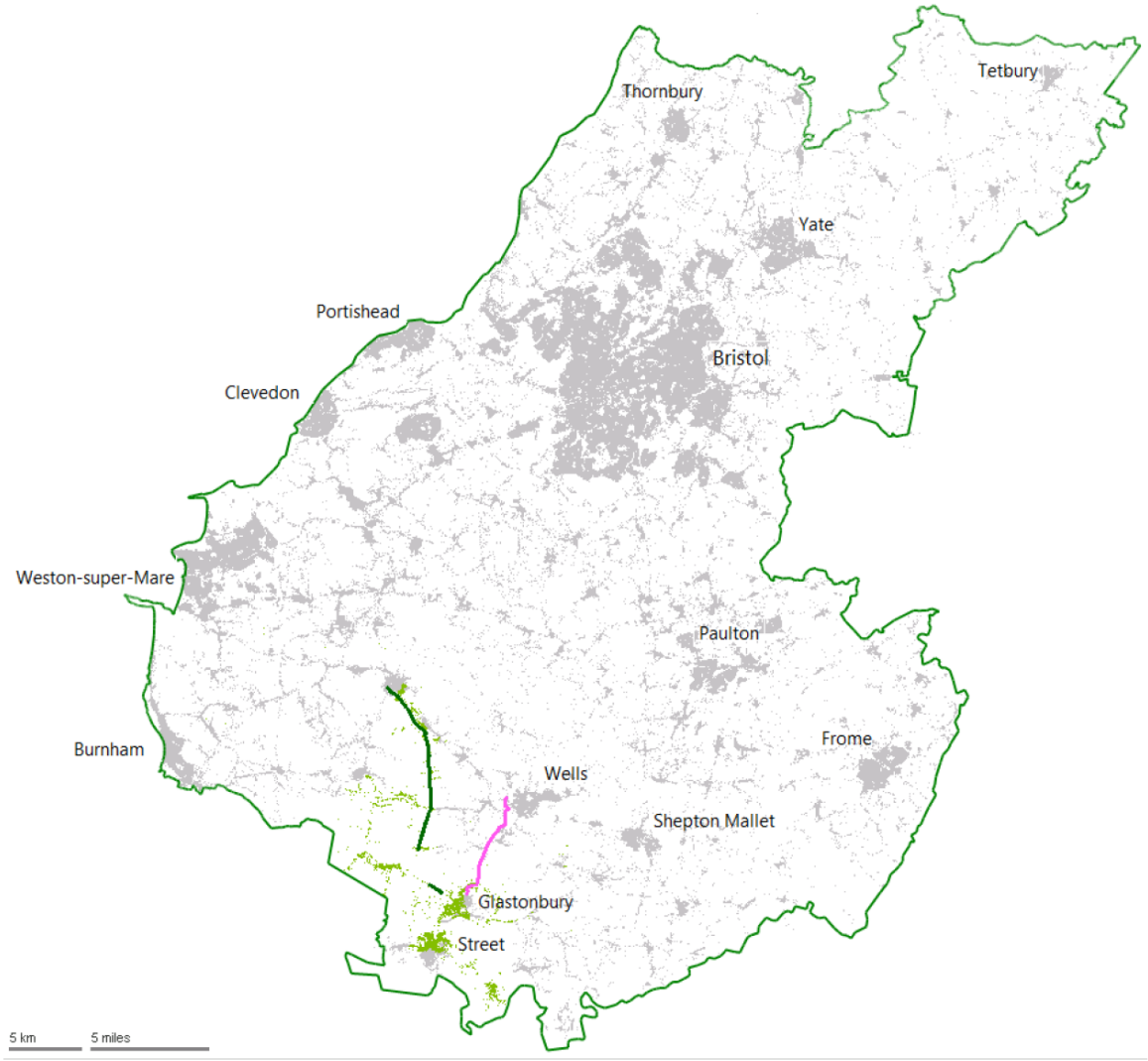


Figure 10: Generic Interventions for Population Centres greater than 10,000, less than 25,000 (new valves)



KEY

Mains at Risk ≥ 25 000 population — 13.2 km

Route of proposed Glastonbury/Street Resilience main to mitigate — 8.0 km

Population at Risk ≥ 25 000

Bristol Water Asset Management

Figure 11: Specific Intervention for Population Centres greater than 25,000 in Glastonbury Street