Appendix C

C1 The uncertainty modelling approach

The Environment Agency's 2016 Water Resources Planning Guidelines (WRPG) state that water companies should "analyse and quantify the variability and uncertainty that are built into… calculations for the dry year annual average demand and critical period scenarios" in their target headroom assessment.

Since the publication of our 2014 Water Resources Management Plan (WRMP14), new methodologies have been published by UKWIR relating to risk-based planning approaches and decision making using a decision making framework. The WRPG highlights four documents, which set out the different approaches:

- UKWIR (2016) WRMP19 Methods – Risk Based Planning
- UKWIR (2016) WRMP19 Methods – Decision Making Process
- UKWIR (2002) An Improved Methodology for Assessing Headroom
- UKWIR (1998) A Practical Method for Converting Uncertainty into Headroom

In preparation for our 2019 WRMP (WRMP19) we applied the UKWIR problem characterisation approach to assess the size and complexity of the supply demand situation from 2020 to 2045 and concluded that we have a large, complex problem to solve. We have further developed our WiSDM (Water Infrastructure Supply and Demand) model to enable us to consider multiple scenarios simultaneously and take into account uncertainties in key aspects of the plan, such as supply scheme costs, time to benefit and yield whilst optimising leakage and demand management. This sophisticated modelling tool (known as the Decision Making Upgrade or DMU) has helped us to create a "least regrets" plan for overcoming any supply demand balance deficits. Our modelling approach, including the scenarios we considered, is discussed in more detail in Appendix E.

To inform the baseline plan we have adopted a risk-based approach for assessing uncertainty based on the methodology outlined in 'An Improved Methodology for Assessing Headroom – Final Report' (UKWIR, 2002). This is consistent with the approach taken to inform our WRMP14. The approach we have followed and our assumptions are described in detail in the remainder of this chapter.

C1.1 Target Headroom

Target Headroom represents the minimum buffer that companies should plan to maintain between supply and demand for water in order to cater for current and future uncertainties.

It is important for water companies to plan for an appropriate level of risk in their WRMPs. If target headroom is too large it may drive unnecessary expenditure, a small target headroom could mean companies are unable to meet their planned level of service.

To derive the range of target headroom uncertainty for our WRMP19 we have adopted a risk-based approach to assessing headroom uncertainty, using Monte Carlo simulation. The approach taken combines the uncertainties around supply and demand to derive an overall probability of supply and demand being in balance.

We have included the following inputs, which are discussed in detail in section C2:

- Supply uncertainty:
    - S5: Groundwater sources at risk of gradual pollution

   - S6: Accuracy of supply side data
   - S8: Uncertainty of the impact of climate change on supply

- Demand uncertainty, based on the demand forecast:
   - D1: Accuracy of sub-component demand
   - D2: Demand forecast variation
   - D3: Uncertainty of the impact of climate change on demand

In accordance with the EA's WRPG (2016) we have made no allowances for S1 (vulnerable surface water licences) and S2 (vulnerable groundwater licences). The data inputs for the models are discussed in more detail in section C2.

In order to derive the level of target headroom that we plan to maintain, we first need to assess the scale of uncertainties around the components for our projected supply / demand balance and decide on what is the appropriate level of risk to accept in the forecast period.

The biggest contributors to our overall supply / demand balance uncertainty are:

- Short term - issues around our assessment of deployable output
- Medium to long term - the impacts of climate change
- Medium to long term - worsening gradual pollution trends impacting on our groundwater deployable output.

A discussion of the target headroom profile or 'glidepath' we have chosen to adopt in the can be found in section C2.3.

To calculate target headroom for the Chester WRZ (formerly part of Dee Valley Water) a different approach has been taken. This is described in Appendix F10.

C2 Target Headroom modelling assumptions

Target headroom is intended to provide a buffer that allows for the unavoidable uncertainties involved in estimating future changes to the various components of the supply and demand balance. As previously discussed, the calculation of target headroom follows an established best practice approach, set out in UKWIR publication '*An improved methodology for assessing headroom*' (UKWIR, 2002). The key components of the target headroom assessment as described in the UKWIR publication are as follows:

Supply-side components

S1 Vulnerable surface water licences
S2 Vulnerable groundwater licences
S3 Time limited licences
S4 Bulk transfers
S5 Groundwater sources at risk of gradual pollution
S6 Accuracy of supply side data
S7 Not used
S8 Uncertainty of the impact of climate change on supply
S9 New sources

Demand side components

D1 Accuracy of sub-component data
D2 Demand forecast variation
D3 Uncertainty of the impact of climate change on demand
D4 Uncertainty in the outcome from demand management measures

We have assessed each component to estimate the likely range of uncertainty in each case. The range of uncertainty around each component follows the shape of a probability distribution from which such likelihoods are drawn. Since it is these distributions which are co-sampled to create the combined (cumulative) probability distributions from which an appropriate target headroom value is ultimately taken, we have taken care to ensure they are as well-founded as possible. We have also undertaken sensitivity tests on the assumptions we have made on the likely range of uncertainties, and on the shape of input distributions, so as to explore the consequences of our choices.

Since we published our draft WRMP we have improved our overall assessment of target headroom to better account for uncertainty in both supply side and our demand projections. The overall impact on total target headroom is a reduction of approximately 5Ml/d across the first 10 years of the planning period. We reviewed the inputs to our target headroom model to ensure that we were not double counting any uncertainty. As described in Appendix C1 of our WRMP, we made an allowance for supply side data uncertainty, groundwater sources at risk of gradual pollution, impacts of climate change, accuracy of sub-component demand and demand forecast variation. We did not make an additional allowance for time limited licences or bulk supplies as we had already made an allowance for uncertainty of supply side data under UKWIR publication '*An improved methodology for assessing headroom*' key component S6 (accuracy of supply side data) issues. More detail around our assumptions is provided in section 2.1.

C2.1 Supply-side

S1 and S2 – licensing vulnerabilities

The Environment Agency's Water Resources Planning Guidelines (2016) instruct water companies not to include any allowances in target headroom for uncertainty related to sustainability changes to permanent licences. The guidelines state that the Environment Agency and Natural Resources Wales will work with water companies to ensure that sustainability changes will not impact on security of supply, and so there is no need for a headroom allowance to be made.

In accordance with the Environment Agency's planning guidelines, we have made no allowances for S1 (vulnerable surface water licences) or S2 (vulnerable groundwater licences) issues in our target headroom assessment. All sustainability changes are dealt with outside of target headroom, as part of the supply demand balance calculation. To assess the potential impacts and risks of possible sustainability changes we have carried out sensitivity analysis which has considered a number of alternative future scenarios. This is described in detail in Appendix A4 and E.

S3 Issues – time limited licences

Although the Environment Agency's Water Resource Planning Guidelines now allow companies to make an allowance for uncertainty around non-renewal of time limited licences we have made no explicit allowance for it in our headroom assessment. The majority of our time limited licences are non-public water supply, such as for wash water or to enable us to provide flow augmentation. A limited number of our public water supply licences have time limited conditions on them, however, these mostly affect small volumes of the total licence quantities. As we have made an allowance for uncertainty of supply side data under S6 (accuracy of supply side data) issues we have made no further allowance to avoid possible double counting. We have assumed that the reduction of time limited licences would form part of the EA's WINEP, with the abstraction licences being restricted to recent actual abstraction. The risks associated with this have been accounted for in our scenario modelling.

S4 Issues - uncertainties relating to bulk transfers

Any significant bulk transfers are included within the modelled deployable output, and so any corresponding uncertainty is allowed for under S6 (accuracy of supply side data) issues. Consistent with our 2014 WRMP, no explicit allowance has been made for S4 issues in our headroom assessment.

S5 Issues - sources affected by gradual pollution

In our target headroom assessment, we have made an allowance for groundwater sources at risk of gradual pollution, where worsening water quality will affect the ability of the source to maintain the current deployable output.

The starting point for identifying S5 issues was the list of sources that had been identified through our Drinking Water Safety Plans as being at risk of deteriorating water quality. Through an initial screening assessment, these sources were then investigated further in order to determine what, if any, impact the deteriorating water quality would have upon the source deployable output. If there was no risk of DO being affected, or the source fulfilled one or more of the criteria below, the sources were excluded from the headroom risk assessment.

- there is no reference to water quality problems by area managers or in Severn Trent's lists of sources at risk or in the Water Framework Directive Article 7 list of pollution risks;
- the source is no longer in use and is not contributing to deployable output;
- the issue presented an outage risk rather than a loss of deployable output.

Table C2.1 presents changes in baseline deployable output due to gradual pollution based on the initial screening assessment.

Table C2.1: Forecast change in Deployable Output caused by deterioration of water quality based on the initial screening assessment

	Potential change in baseline DO due to deteriorating water quality (Ml/d)					
Water Resource Zone	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**
Shelton	-4.32	-4.32	-13.44	-18.02	-23.00	-23.00
Strategic Grid	-12.82	-12.82	-28.33	-28.33	-31.61	-31.61
Wolverhampton	0.00	0.00	0.00	0.00	0.00	0.00
Forest and Stroud	-2.49	-2.49	-2.49	-2.49	-2.49	-2.49
Whitchurch & Wem	0.00	-3.11	-3.11	-3.11	-3.11	-3.11
Nottinghamshire	-7.37	-7.37	-7.37	-11.63	-12.33	-12.33
North Staffordshire	0.00	0.00	-2.26	-2.26	-2.26	-2.26
Mardy	0.00	0.00	0.00	0.00	0.00	0.00
Bishops Castle	0.00	0.00	0.00	0.00	0.00	0.00
Kinsall	0.00	0.00	0.00	0.00	0.00	0.00
Stafford	0.00	0.00	0.00	-7.72	-16.27	-16.27
Ruyton	0.00	0.00	0.00	0.00	0.00	0.00

Further assessment has been made around the uncertainties concerning the loss of deployable output due to increasing trends in groundwater nitrate concentrations. Many of our groundwater sources have rising nitrate concentrations, which prompted a review of all groundwater nitrate trends to be undertaken in 2016. The results of this investigation were then used to indicate which blends or individual sources would be at risk of breaching the prescribed concentration value (PCV) by 2045. Where a risk had been identified a blend calculator was constructed and a high resolution study into the potential impacts and mitigations was made.

Our analysis suggests that several blends and individual groundwater sources could be severely impacted by rising nitrate concentrations before 2045. An estimate of these potential impacts to deployable output has been made using projections of existing trends for all groundwater sources at potential risk of exceeding the PCV of 50 mg/l.

For nitrate-related issues, there is considerable uncertainty in the values used for all sources, especially those beyond 2025, because the nitrate trend projections are based on linear profiles that have been determined from water quality data taken over a limited period. These trends are not capable of capturing/illustrating the potential changes to the trend profile by actions such as changing land use or climatic conditions.

For this WRMP19 we have assumed the changes in deployable output due to gradual pollution shown in Table C2.1, with an uncertainty of +/- 10%.

S6 Issues – uncertainties in supply-side data

This component reflects the scale of uncertainty around our calculation of deployable output. The target headroom assessment of supply side data uncertainty has considered groundwater and surface water issues separately. The updated groundwater deployable output assessment also included a review of the constraints on deployable output for each source. The assessment has sought to categorise the sources of uncertainty as follows:

S6-1 Abstraction licence constraints

Consistent with our assessment for WRMP14, for our abstraction licence constrained groundwater sources we have assumed a triangular distribution with a mean error of 1%, with a maximum of 4% (i.e. a 4% reduction in deployable output) and a minimum of -2% (i.e. a 2% gain in deployable output).

All of our surface water abstractions on the River Severn are considered to be licence constrained. For these sources, we have adopted the same triangular distribution as licence constrained groundwater sources, with a maximum potential loss of output of 4%, with a mean value of 1% and a potential gain of 2%.

S6-2 Aquifer constraints

For groundwater sources where the constraint is considered to be the aquifer, uncertainty is assumed to be a maximum of +/-20%, following a normal distribution. The relatively high figure reflects the uncertainty in establishing the safe yield of groundwater sources and is, again, the same as was included in the WRMP 14.

S6-3 Infrastructure constraints (e.g. pumping capacity, treatment capacity)

For sources constrained by infrastructure, uncertainty is assumed to be a maximum of +/-10%, and follow a normal distribution, as it was in the WRMP14. Most infrastructure constrained sources are limited by pumping capacity, although in a few cases the capacity of the transmission main from the source is the limiting factor.

S6-4 Source yield constraints (Surface Water DO)

Where the constraint has been identified as the yield of the source, the adequacy of the data used in the assessment has been reviewed in order to arrive at a reasonable figure for uncertainty. As per the 2003 method, for our surface water sources uncertainty is assumed to be between +/-10% for sources with good long flow records and +/-20% for sources with short flow records or dependent on simulated flows.

Uncertainties for source yield constrained supplies are ascribed a normal distribution as it is considered more appropriate for uncertainty that may be represented as a random distribution about a mean.

In preparation for the WRMP19 we have reviewed the constraints on each of our sources, leading to some sources changing category. This has resulted in a minor change in the total target headroom for some water resource zones. The changes are shown in section C2.3.2.

S8 Issues – uncertainty of the impact of climate change on source outputs

As discussed in Appendix A3, we have assessed the potential impacts of climate change across our region by applying the methodology recommended in the EA's Water Resource Planning Guidelines. Our deployable output modelling of the wide range of climate change impacted scenarios, using the UK Climate Projections 2009 (UKCP09) 2030s time slice, has shown us that this remains the dominant area of uncertainty in our WRMP 19. This is reflected in the large impact this issue has on target headroom.

The methodology we have applied uses 100 UKCP09 projections for our region, from which we have taken a representative sample of 20 for deployable output modelling. To maintain consistency with our WRMP 14 we have used the median scenario (50th ranked scenario) from the 100 UKCP09 outputs to represent our central estimate of deployable output impacts. This is used in our Water Resources Planning tables as our reduction to baseline deployable output. We have tested two different approaches to representing the broad range of uncertainty around this central estimate in target headroom. As part of our analysis we considered whether other distributions might also be applicable, however, based on the data we have available, triangular and custom discrete distributions are the most suitable options for the assessment required. These options are outlined below.

Option 1: Using a triangular distribution

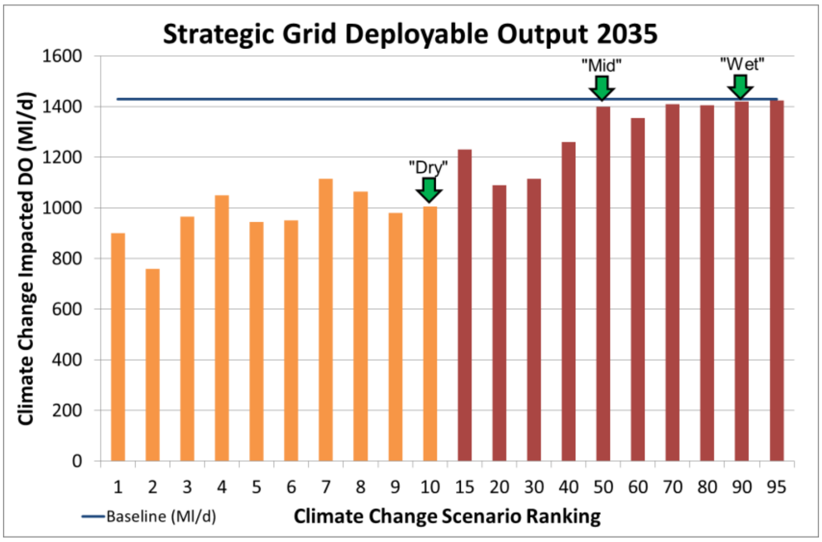
As a result of our sensitivity analysis for our WRMP14 we opted to use a triangular distribution around our central climate change estimate, with the 10th and 90th ranked impacted scenarios from the 100 UKCP09 projections being used to derive the maximum and minimum changes in deployable output. This approach was consistent with the last formal guidance from the EA, given in the 2008 Water Resources Planning Guidelines, on how to accommodate climate change uncertainty in target headroom, which stated:

"…we expect companies to use uncertainty in S8, assume a triangular distribution, with the upper and lower limits defined by the "wet" and "dry" scenario results. The maximum loss is equal to DOmid-DOdry, and the minimum loss is equal to DOmid-DOwet; the "best" estimate of loss is equal to zero, because the "mid" scenario is used in the calculation of resource zone deployable output".

In keeping with these principles we used the 10th ("dry"), 50th ("mid") and 90th ("wet") ranked scenarios, assuming the maximum loss to equal DOmid-DOdry, the minimum loss to equal DOmid-DOwet and the "best" estimate to equal zero as this was used in the calculation of the water resource zone water available for use.

For consistency with our WRMP14 we have adopted the same approach in our sensitivity analysis for this WRMP19. By using the 10th and 90th ranked scenarios, the drier and wetter scenarios produced by the UKCP09 projections for our region are represented but it avoids skewing of the distribution by not including the more extreme scenarios which have a low probability of occurring. Figure C2.1 below illustrates for the Strategic Grid zone how these 10th, 50th and 90th ranked scenarios sit within the range of the 20 modelled deployable output scenarios.

Figure C2.1: Deployable Output in the Strategic Grid zone by 2035 under the 20 UKCP09 scenarios. Arrows indicate the 10th, 50th and 90th ranked scenarios



Within our target headroom models, we can include uncertainty around the impact of climate change on supply as a series of triangular distributions, using a value for minimum, most likely and maximum impact for each year of the planning period. The probability distributions for individual years are derived using the scaling equations (which are described in section A3.4 of the climate change chapter), which produces a range reflecting the increasing uncertainty around climate change as we move through the planning period.

Option 2: Using a custom discrete distribution

From the deployable output (DO) modelling, we have derived 20 sets of climate change impacted DO figures for each conjunctive use WRZ using the sub-sampled UKCP09 projections. The custom discrete distribution uses the change in DO relative to the central estimate DO, along with the relative weighting of the particular UKCP09 projection it has been generated from.

An example of the impacts and distribution around the central estimate of the Strategic Grid zone is shown in Table C2.2.

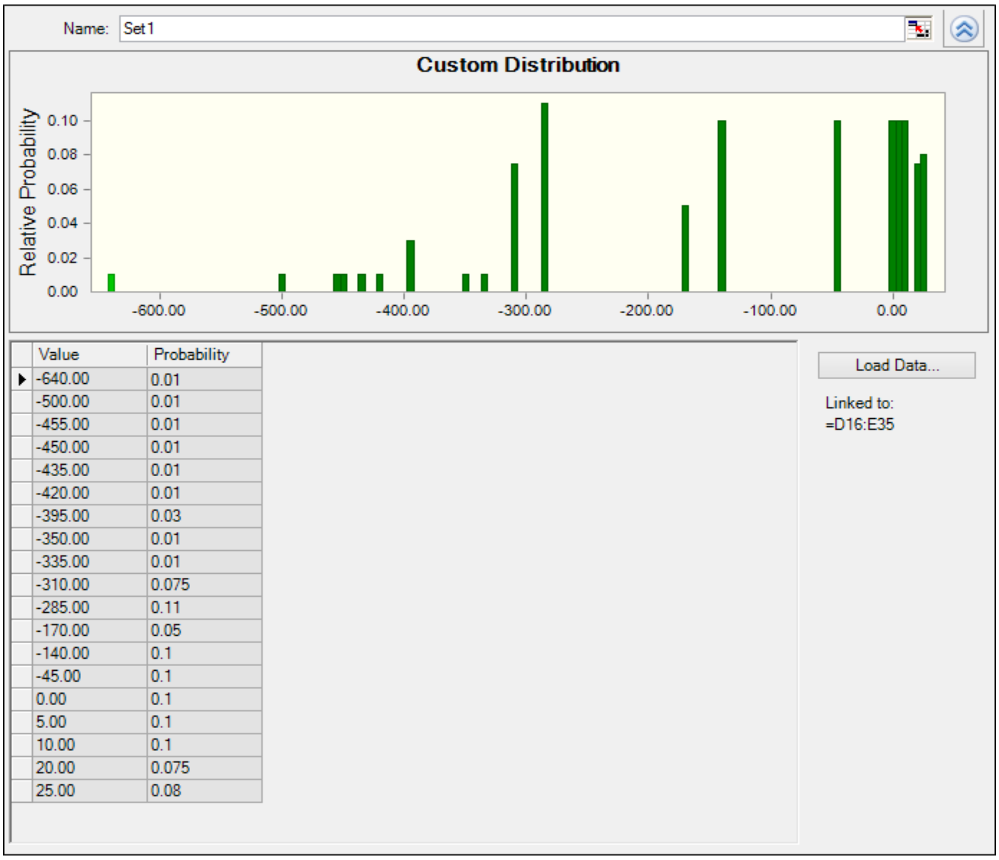
Table C2.2: Example of distribution used in the Strategic Grid zone Target Headroom model for the uncertainty around climate change

Index	UKCP09 ID	Change in zonal DO around central estimate (Ml/d)	Weight
1	8632	-500	0.010
2	9855	-640	0.010
3	3111	-435	0.010
4	6108	-350	0.010
5	1090	-455	0.010
6	2203	-450	0.010
7	1345	-285	0.010

Index	UKCP09 ID	Change in zonal DO around central estimate (Ml/d)	Weight
8	8282	-335	0.010
9	6461	-420	0.010
10	684	-395	0.030
15	2726	-170	0.050
20	9701	-310	0.075
30	3521	-285	0.100
40	281	-140	0.100
50	3903	0	0.100
60	2745	-45	0.100
70	3306	10	0.100
80	9623	5	0.100
90	1467	20	0.075
95	8764	25	0.080

These 20 change factors have been used to create a custom discrete distribution within our target headroom model, as shown in Figure C2.2. On each iteration of a model run, the model will select one of the 20 climate impacted DOs; their probability of being selected is based on the weightings that the user has entered. This gives the climate change impact value for the year 2035 and the impact for the other years in the planning period is automatically calculated by the model (based on scaling equations discussed in Appendix A3).

Figure C2.2: Custom distribution incorporating the 20 climate change scenarios in our Strategic Grid zone target headroom model*



* (note there are not 20 separate factors in the table as those with the same impacted value have been automatically combined, resulting in a larger probability)

The sampling methodology recommended by the EA's 2013 report "Climate change approaches in water resources planning – Overview of new methods" requires us to focus on samples from the dry end of the UKCP09 climate change projections. While these drier scenarios are given a lower weighting in the methodology, they still produce a distribution that is skewed towards showing a high impact on deployable output. Some of the extreme scenarios suggest deployable output reductions in the Strategic Grid zone in the range of 315 to 670Ml/d (22% to 46%) by 2035 from our current baseline. This assumes our network and reservoir control curves remained the same as the 2020 baseline starting position (described in Appendix A2).

To maintain consistency with our WRMP14 plan, our preferred approach is to use the triangular distribution using the 10th, 50th and 90th ranked UKCP09 scenario for our region. Using this approach avoids skewing the headroom uncertainty analysis towards the extremely dry end of the range created by the sampling methodology required by the WRMP guidelines.

If we were to include the full range of the more extreme scenarios in our WRMP19 assumptions, these would trigger the need for significant future investment in new supply capacity. We do not believe it is appropriate to promote large scale capital investment purely on the basis of the uncertainties implied by this methodology.

We believe it is more appropriate to use all 20 climate change projections as 'alternative futures' through our DMU analysis (described in Appendix E3) to test the robustness of our plan against each of the equally likely climate futures. The DMU process highlights decision points where we may need to change our plan to accommodate a change in the future e.g. if we find in reality we are actually faced with a rank 40 climate future what steps would we need to take to ensure resilience of our supply demand balance. The DMU also allows us to explore which climate change scenarios drive different investment programme decisions.

To improve transparency regarding the climate change allowance in our target headroom for the final WRMP we are now stating the 'relative' contribution of the climate change component compared to the other components. This is discussed in more detail in section C2.3.2. Having reviewed the other water companies' draft WRMPs, we have found this change brings us more in line with the wider industry. The climate change component of our target headroom at a company level has reduced to a maximum 10% of total water available for use (compared to an industry average of 8%). We also note that several other companies were asked to review their draft WRMP methodologies as the Regulators believe their assessments of climate change uncertainty are too low. In preparation for this final WRMP we have updated the WRMP tables to reflect this change to the climate change contribution.

C2.2 Demand side

D1 Issues: Accuracy of sub-component demand

Uncertainty in the number of meter optants

Table C2.3 below shows the past rate of uptake of the free meter option from 2005/06 to 2014/15. The table shows that the rate of uptake has fluctuated over recent years in response to factors such as changes in average unmeasured bills and the economic climate.

Table C2.3: Rate of metering from 2005/06 to 2012/13

	2005/06	2006/07	2007/08	2008/09	2009/10
Unmeasured household properties opting for a meter each year	1.45%	1.75%	1.53%	2.09%	1.98%
	2010/11	2011/12	2012/13	2013/14	2014/15
Unmeasured household properties opting for a meter each year	1.58%	1.63%	1.85%	2.16%	1.89%
Average rate of opting 2005 - 2015	1.79%				

For the WRMP19 our central forecast is for baseline free meter optants (FrOpts) to continue at the observed average rate of 1.79% p.a. (average of AMP4 and AMP5 (2005/06 to 2014/15)).

For demand headroom analysis, a triangular distribution has been assumed around the central rate with upper and lower parameters set as follows

- Lower bound – 1.45% of unmeasured customers opt per annum, based on 2005/06 rate of metering.
- Upper bound – 2.16'% of unmeasured customers opt per annum, based on 2013/14 rate of metering.

Uncertainty in the number of new property connections

The 2019 EA WRMP guidelines explicitly instruct water companies to account for the local council projections of household growth for supply capacity planning purposes. In light of this, we are adopting Local Council projection of growth from AMP7 onwards for the WRMP19 central housing growth forecast.

However, the local authority forecasts for our region represent a stepped increase in new households over historic and current observed numbers. For uncertainty analysis we have assumed a triangular distribution using the LPA growth projections and historically observed growth in our region.

- Upper/central assumption- LPA projections
- Lower bound – Historic average observed growth rate (1997 to 2016)

Uncertainty in population numbers

For population projections we have used the latest Government projections for England and Wales. These are taken from the 2014 base sub-national population projections for England from the Office of National Statistics (ONS) and from Welsh Assembly Government based local authority population projections for Wales. The annual percentage rates of change for local authorities are applied to the base year population estimates at postcode level and then aggregated up to Water Resource Zone level. This gives the underlying change in population due to births, deaths and migration in the Severn Trent region.

Population uncertainty is based on high and low population projections, each of which are based on projections combining variants of births, deaths and migration for England and Wales.

D2 issues: demand forecast variation

Uncertainties in household demand

Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption:

- Sustainable development - in this most extreme efficiency scenario, we have assumed that water saving is driven by both technological advancements and attitudinal changes. Sophisticated filtration technology would allow recirculation of shower water saving both energy and water. Waste water and washing functions are fulfilled by greywater recycling, aided by hydrophobic frictionless surfaces. Bathing is pretty much obsolete.

- Market trend - this scenario assumes that the projected trend in micro-components does not continue beyond 2022. This would require a situation such as Brexit where UK building regulations may be de-coupled from current standards and the logical decline in flush volumes is curtailed. The observed upward trend in showering continues to increase.

Uncertainties in measured non-household water consumption

For measured non-household water consumption, we have based uncertainty bounds on a high and low economic growth scenario forecast for our region, relative to the central estimate. Plausible economic scenarios were constructed to provide a range of possible outcomes. These involved variations in the macro assumptions to create alternative water demand forecasts as explain below.

High economic growth scenario

The high scenario envisages that the UK economy will quickly recover after a modest initial post-referendum dip. This assumes that the rapid formation of the new government reassures investors and leads to good early progress on negotiating new trade arrangements with the EU, perhaps similar to the existing EEA member status for the UK but including a provision for some emergency brakes on migration. It also assumes promising initial discussions with other major trading partners such as the US, China and the Commonwealth countries, although actual deals would take longer to agree.

In the medium to long-term, the UK economy will slowly return to long-term growth rates of 2.5 per cent projected by the Office for Budget Responsibilities[1] (OBR) which was produced prior to the EU referendum and represents a more optimistic outlook for the UK's long-term growth path. The inflation pressure has soon subsided following the recovery of the value of Sterling, stronger economic fundamentals allow the Bank of England to raise interest rates at a faster pace than the central scenario.

Low economic growth scenario

The low scenario assumes that negotiation with the EU has proved difficult, raising concerns for a possible 'hard-Brexit' and the UK perhaps relying on WTO rules to trade with the EU. This has led to a further fall of the value of Sterling, which in turn leads to a further increase in inflation coupled with the loss of consumer and business confidence which undermine both consumer spending and business investment. In this case, the UK could enter a period of recession for the next 12-24 months and permanently lower the nation's growth potential. The Bank of England keeps the interest rates low in support of economic growth despite a period of higher inflation, the pace of interest rates rises is likely to be slow and gradual. The UK economy finally emerges from the recession stabilising at a below trend growth trajectory until the end of the forecast period.

D3 issues: uncertainty impact of climate change on demand

No uncertainty has been attached to the best estimate of climate change impact on demand.

---

[1] The assumptions are set out in the OBR's fiscal sustainability report June 2015. http://budgetresponsibility.org.uk/fsr/fiscal-sustainability-report-june-2015/

D4 issues: uncertainty of the outcome from demand management measures

No uncertainty has been attached to demand management measures.

C2.3 Target headroom Profile

One of the most important elements of our WRMP19 is the decision around how to deal with uncertainty in our long term plan. Using the traditional Economic Balance of Supply and Demand (EBSD) approach, uncertainty is dealt with using target headroom. The amount of target headroom we include determines the scale of investment needed to maintain an adequate buffer between future supply and demand for water in order to accommodate the uncertainties outlined in the sections above.

C2.3.1 The target headroom profile

In the short term, the main uncertainty in our planning assumptions is around the accuracy and reliability of our source deployable output rather than any major external factors. For most of our water resource zones, the only additional sources of longer term uncertainty are around the trajectory of future demand for water and the potential impacts of gradual pollution. In most zones we are adopting a target headroom profile that maintains a high degree of planning confidence across the full period. Our strategy is to maintain this high level of confidence in these zones through our leakage and demand management plans, and making best use of our existing sources of supply.

In our Strategic Grid and Nottinghamshire zones, the longer term uncertainty around the impacts of climate change increases significantly and dominates our uncertainty analysis. As already described, we have chosen an approach to estimating climate change uncertainty that excludes the more extreme, drier scenarios suggested by UKCP09 for our region. Our chosen risk profile in these zones reflects the fact that we have already discounted some of the higher impact/lower probability scenarios by adopting a triangular distribution around the rank 10 (dry), rank 50 (mid) and rank 90 (wet) climate projections in our assessment. As a result, we have adopted a target headroom risk profile that gives us high confidence in the short to medium term that we can meet our planned levels of service while coping with the range of planning uncertainties.

The climate change reduction from baseline in 2035 for the Nottinghamshire zone is approximately 18% of the total deployable output for the zone. However, the bands of uncertainty around this are relatively narrow meaning that the 95% reducing to 90% profile used for the other water resource zones is also valid for this zone.

The long term headroom profile for the Strategic Grid zone changes to accept an increasing and manageable degree of risk over time. The longer term uncertainties around climate change can be managed using the flexible adaptation responses we have set out in our plan, and through the five yearly update of our water resources strategy. Therefore it would be inappropriate to plan to maintain a high level of target headroom throughout the whole 25 year planning period.

The target headroom profile or 'glidepath' used in our WRMP19 is set out in Table C2.4. The target headroom risk percentile shown in the table represents the level of confidence we have of achieving our target level of service.

Table C2.4: Target headroom profiles used in the WRMP19

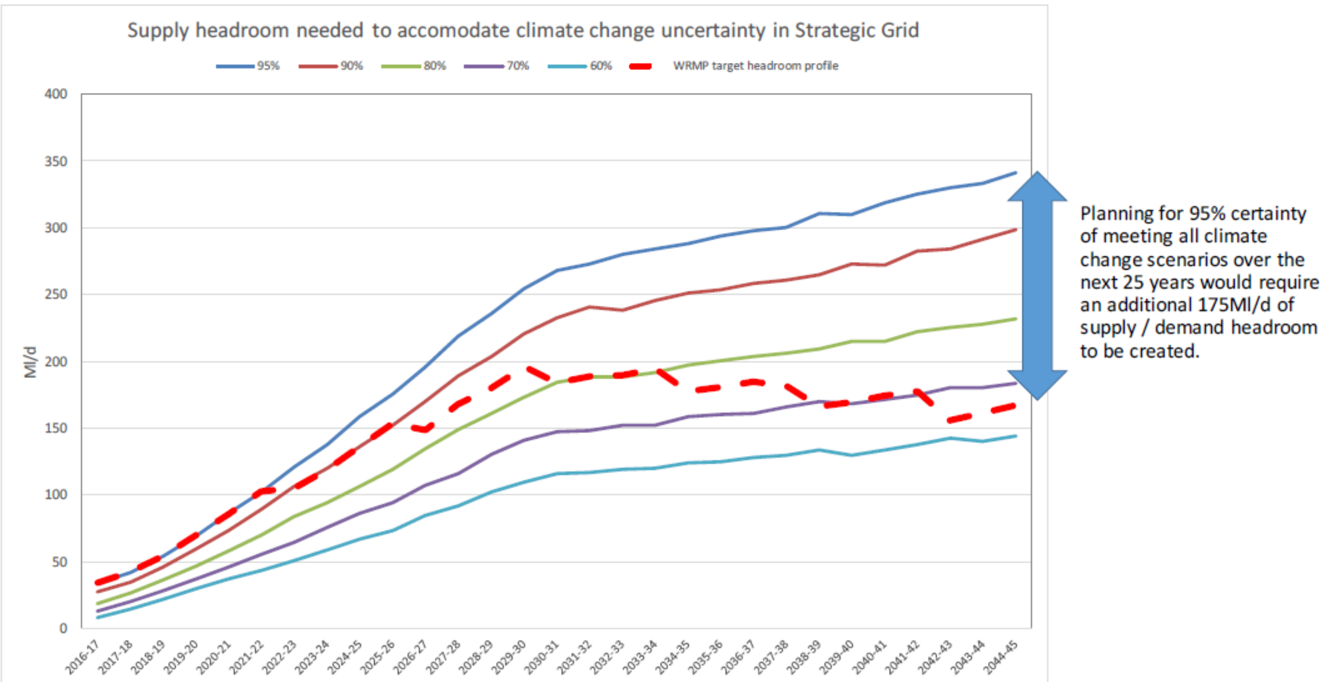
Water Resource Zone	AMP7 2020-2025	AMP8 2025-2030	AMP9 2030-2035	AMP10 2035-2040	AMP10 2040-2045
Bishops Castle	95%	90%	90%	90%	90%
Forest & Stroud	95%	90%	90%	90%	90%
Kinsall	95%	90%	90%	90%	90%
Mardy	95%	90%	90%	90%	90%

Water Resource Zone	AMP7 2020-2025	AMP8 2025-2030	AMP9 2030-2035	AMP10 2035-2040	AMP10 2040-2045
Newark	95%	90%	90%	90%	90%
North Staffordshire	95%	90%	90%	90%	90%
Nottinghamshire	95%	90%	90%	90%	90%
Rutland	95%	90%	90%	90%	90%
Ruyton	95%	90%	90%	90%	90%
Shelton	95%	90%	90%	90%	90%
Stafford	95%	90%	90%	90%	90%
Strategic Grid	95%	90%	80%	70%	60%
Whitchurch & Wem	95%	90%	90%	90%	90%
Wolverhampton	95%	90%	90%	90%	90%

The stepped shape of the target headroom profile over time, most notable in the Strategic Grid zone, is a result of the headroom risk glidepath shown in Table C2.4. The glidepath we have adopted causes a step reduction in target headroom at the start of each AMP. Between these glidepath changes target headroom continues to increase due to the climate change uncertainty which increases over time. We will review the options for smoothing the glidepath in our preparations for WRMP24.

Figure C2.3 illustrates how our target headroom profile compares with other potential profiles that could have been adopted to accommodate an even wider range of uncertainty around the 2030s climate change outlook, ranging from 95% certainty to 60% certainty.

Figure C2.3: Planning for climate change uncertainty



Our approach to managing climate change risk and uncertainty, means we avoid having to commit to potential large scale investment decisions in AMP7 that would be driven by very uncertain long term scenarios. Our WRMP delivers a high level of confidence for AMP7 and AMP8, but accepts an increasing amount of climate risk beyond that. If we were to require the same level of planning certainty throughout the long term planning horizon, we would need to commit to even more investment to achieve this. Instead, Figure C2.3 illustrates that for the Strategic Grid zone, our approach avoids the need to invest in approximately 175Ml/d of supply / demand headroom capability by 2045.

Our strategy is based around delivering a target headroom that provides a 95% level of confidence that we will meet our target levels of service during AMP7. Over the 25 year horizon, our target headroom profile varies to reflect the fact that many of the medium to long term uncertainties can be managed over time. We believe this profile is appropriate given that:

- A degree of the uncertainty in our AMP7 headroom assessment is related to data issues and our assessment of deployable output. It would not be appropriate to plan significant capital investment to deliver the maximum level of confidence when the uncertainty around the supply / demand balance gap could be reduced through better data and further analysis.

- The growing long term uncertainties can be managed over time through a flexible adaptation response. If we were to plan to maintain a very high target headroom requirement over the 25 years, this would create large scale headroom shortfalls and would likely trigger the need for significant new water resources investment that would need to begin in the next AMP period. Instead, the timing and scale of the leakage reduction, demand management and new water supply enhancements proposed in our draft WRMP mean we will be able adapt the delivery of our strategy as our understanding of the long term planning uncertainties improves over time. The nature of the options we are proposing for the next five to ten years mean that these are 'no regret' decisions that will improve security of supply, as well as reduce the amount of water we abstract from the environment and reduce the likelihood of us causing future environmental deterioration. The water resources planning process requires that WRMPs be reviewed and updated every five years, and we believe that the long term planning risks can be managed and mitigated within this structured process. Therefore, we have adopted a target headroom profile that accepts an increasing amount of uncertainty over the 25 year period.

C2.3.2 Relative contributions of headroom components

Figures C2.4 to C2.16 illustrate, for each of our water resource zones, the relative contributions that the different headroom components make to the overall target headroom requirement.

In the graphs the S6 issues (uncertainty around supply-side data) have been separated into the four categories discussed in section C2.1, where:

- S6-1 is uncertainty around licence constrained sources,
- S6-2 is uncertainty around aquifer constrained sources.
- S6-3 is uncertainty around infrastructure constrained sources.
- S6-4 is uncertainty around surface water sources.

Many of our WRZs are supplied by small groups of groundwater sources, which our climate change assessment has shown will be resilient to future changes in climate. In these zones, the sources of uncertainty are limited to demand-side, supply-side and gradual pollution data. However, the overall target headroom in these zones is relatively small. As mentioned in section 2.1, in preparing for our WRMP19 we have reviewed the constraints on each of our sources of supply, leading to some sources changing category. The most notable change has occurred in the Shelton zone, where some of the sources have changed from being infrastructure constrained (S6-3) to aquifer constrained (S6-2), making S6-2 the dominant contributor of uncertainty in the zone.

In two of our WRZs (Forest and Stroud and the Strategic Grid) components provide a "positive" contribution to headroom, meaning that they effectively reduce the total target headroom. In the Strategic Grid zone the demand modelling shows a positive contribution to headroom in the last 15 years of the planning period (i.e.

there is more demand than the base case). In the Forest and Stroud zone climate change provides a positive contribution as the "dry" and "mid" climate change projections are similar but the "wet" rank 90 climate change projection increases deployable output so skews the distribution to a positive contribution.

As discussed in Appendix A3.2, our conjunctive use zones (those which use a combination of impounding reservoirs, river abstractions and groundwater sources to supply our customers) are likely to be impacted by climate change in future years. For the final WRMP we used our revised baseline North Staffordshire model to carry out climate change modelling for the North Staffordshire zone. Our target headroom assessment has been updated to incorporate this new data. As can be seen in Figures C2.9, C2.10 and C2.14, which show North Staffordshire, Nottinghamshire and the Strategic Grid water resource zones respectively, the relative contribution of uncertainty around climate change increases through the planning period and becomes the dominant factor by 2045.

Figure C2.4: Components of target headroom – Bishops Castle WRZ

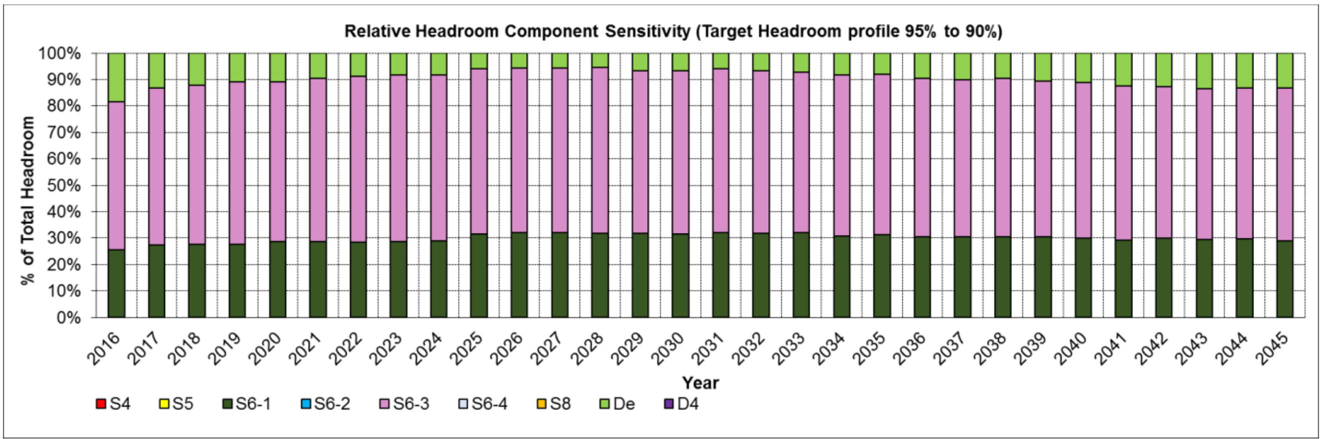


Figure C2.5: Components of target headroom – Forest and Stroud WRZ

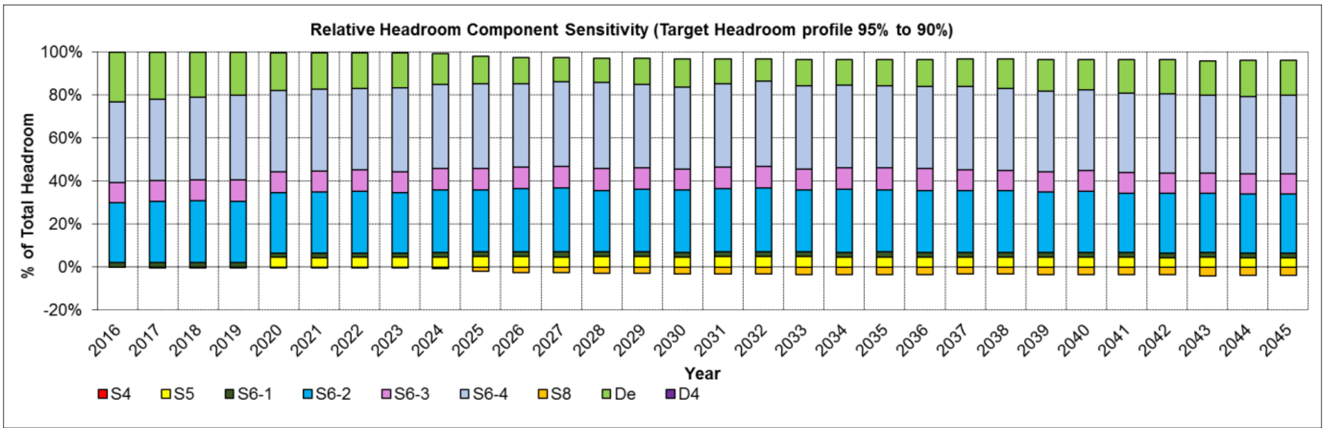


Figure C2.6: Components of target headroom – Kinsall WRZ

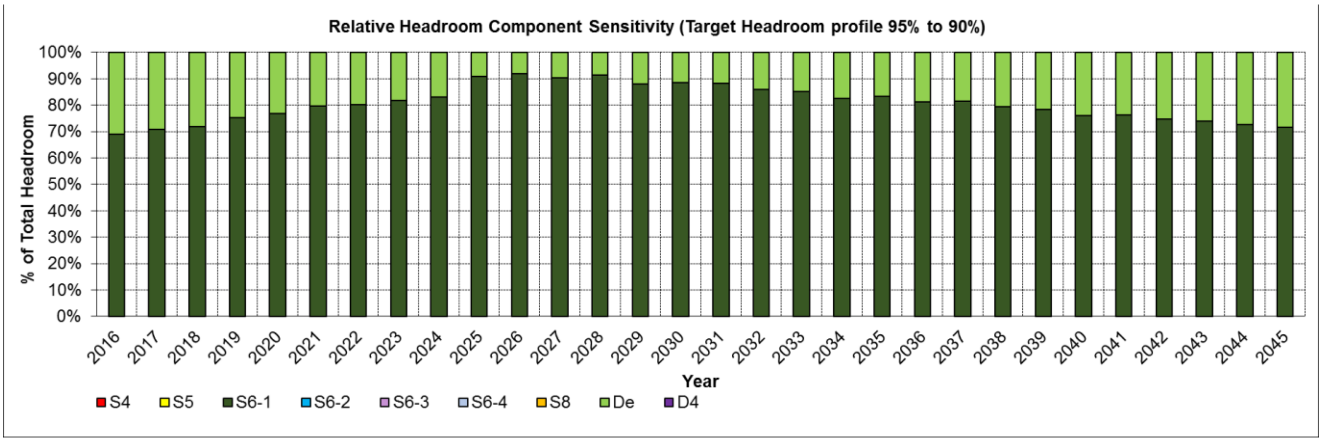


Figure C2.7: Components of target headroom – Mardy WRZ

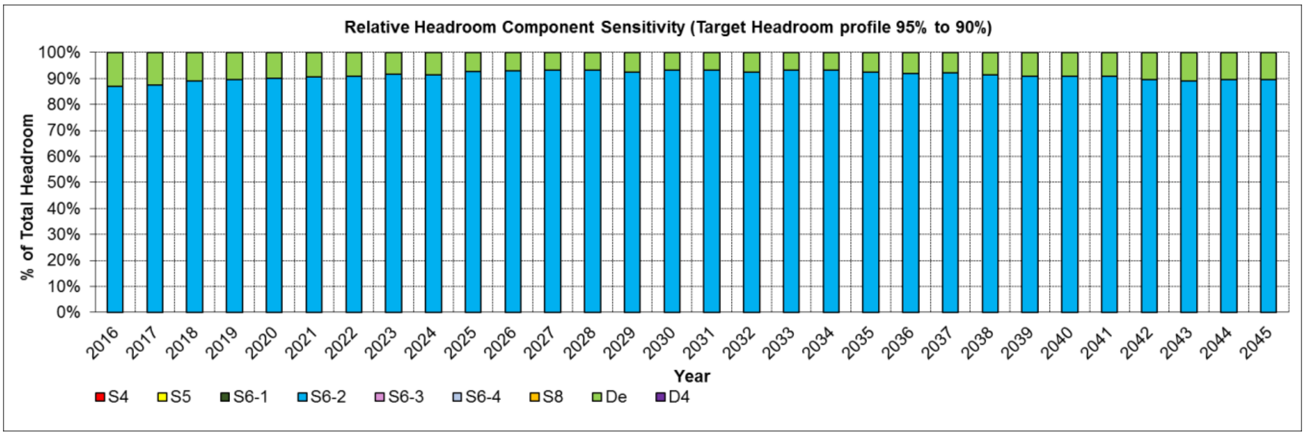


Figure C2.8: Components of target headroom – Newark WRZ

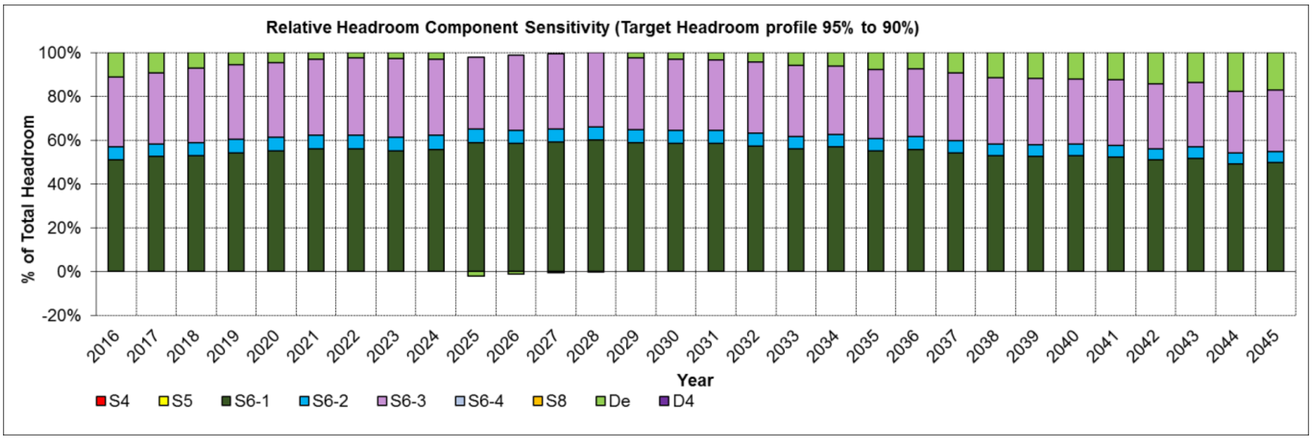


Figure C2.9: Components of target headroom – North Staffordshire WRZ

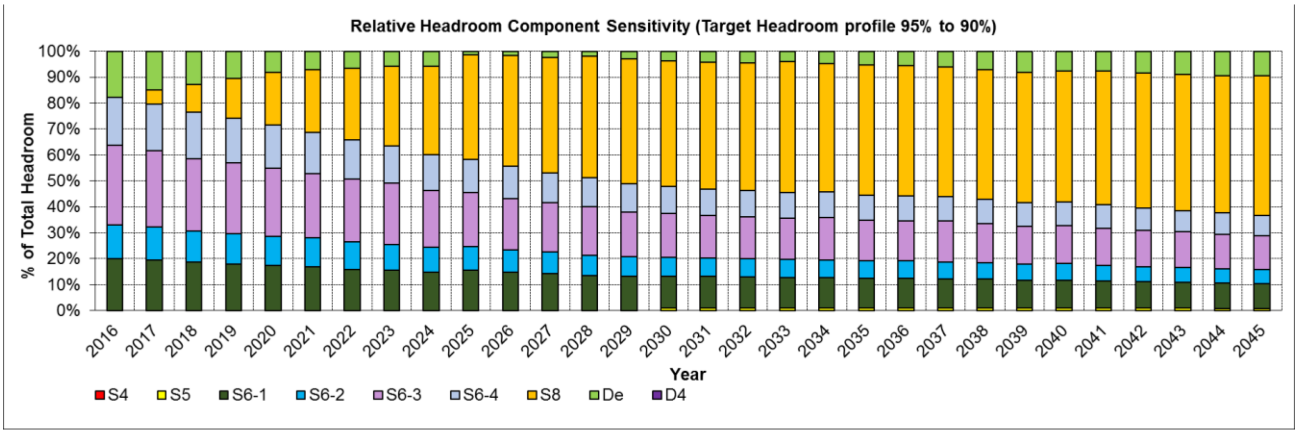


Figure C2.10: Components of target headroom – Nottinghamshire WRZ

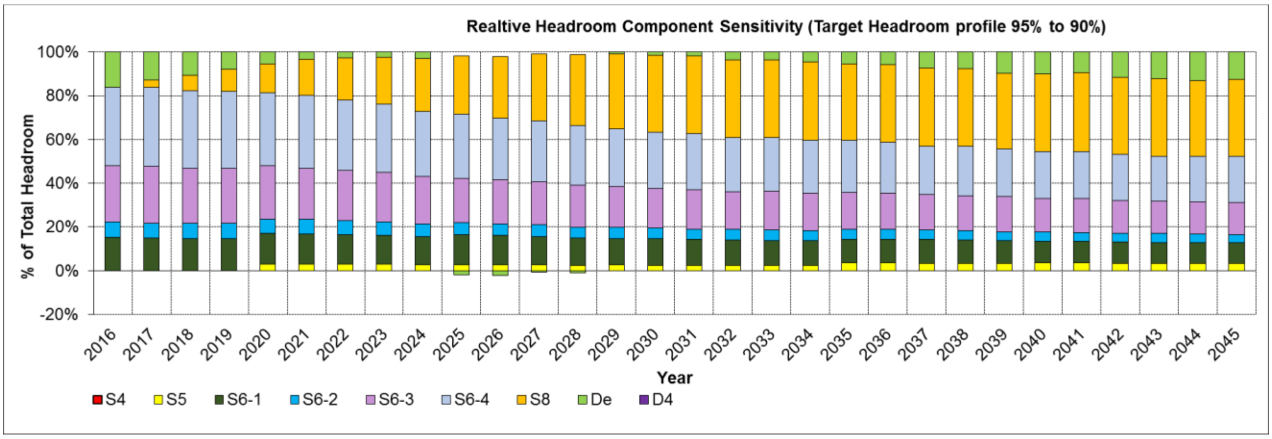


Figure C2.11: Components of target headroom – Ruyton WRZ

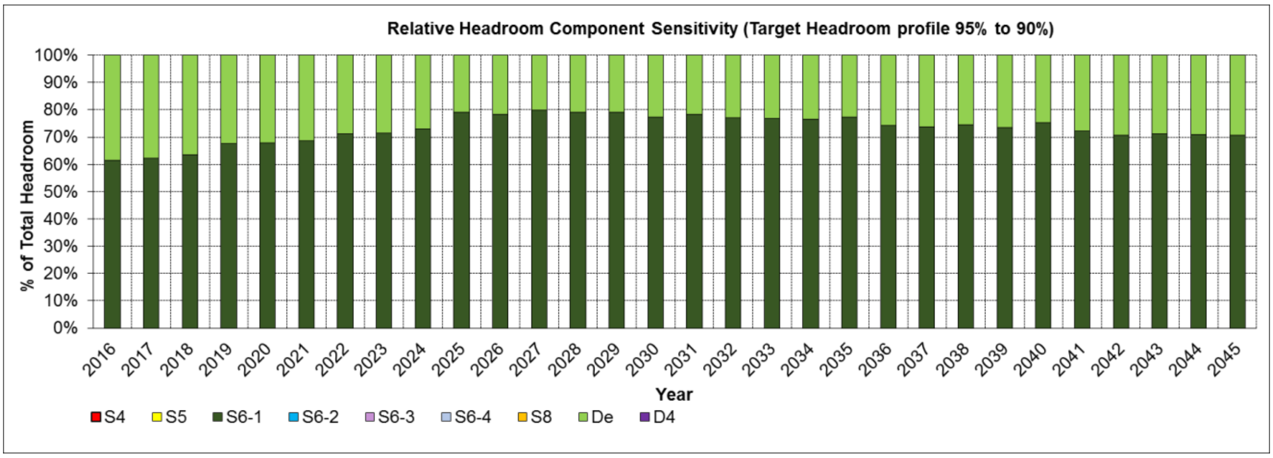


Figure C2.12: Components of target headroom – Shelton WRZ

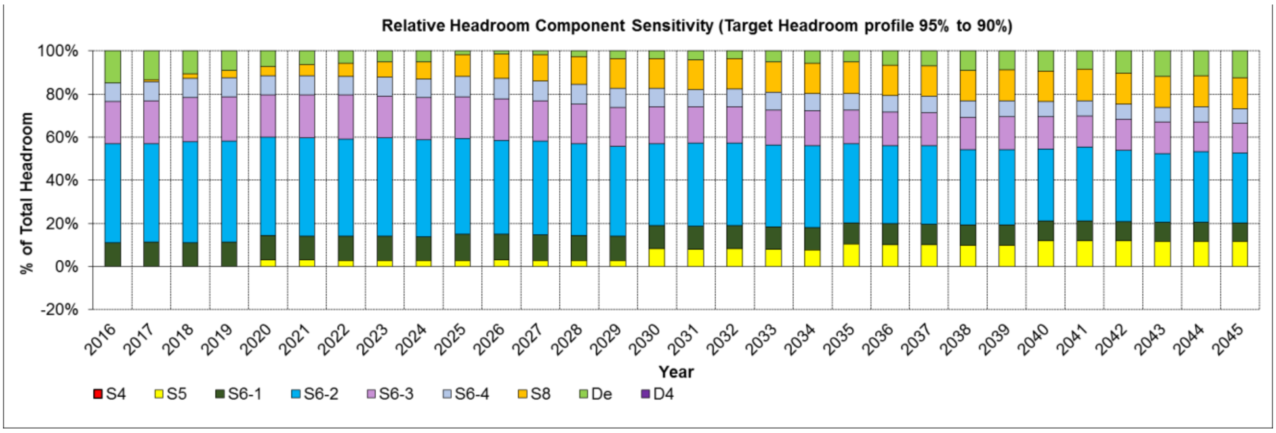


Figure C2.13: Components of target headroom – Staffordshire WRZ

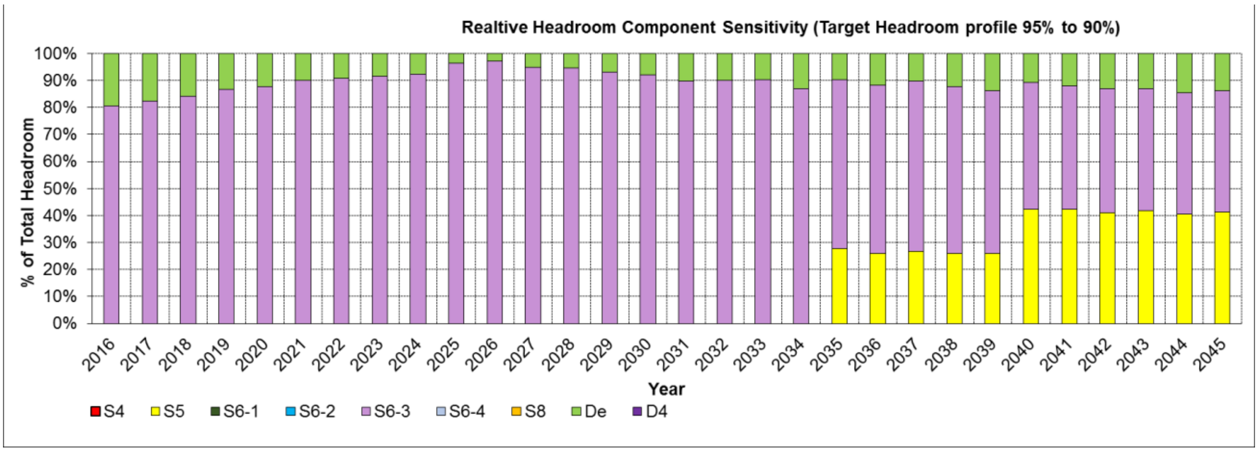


Figure C2.14: Components of target headroom – Strategic Grid WRZ

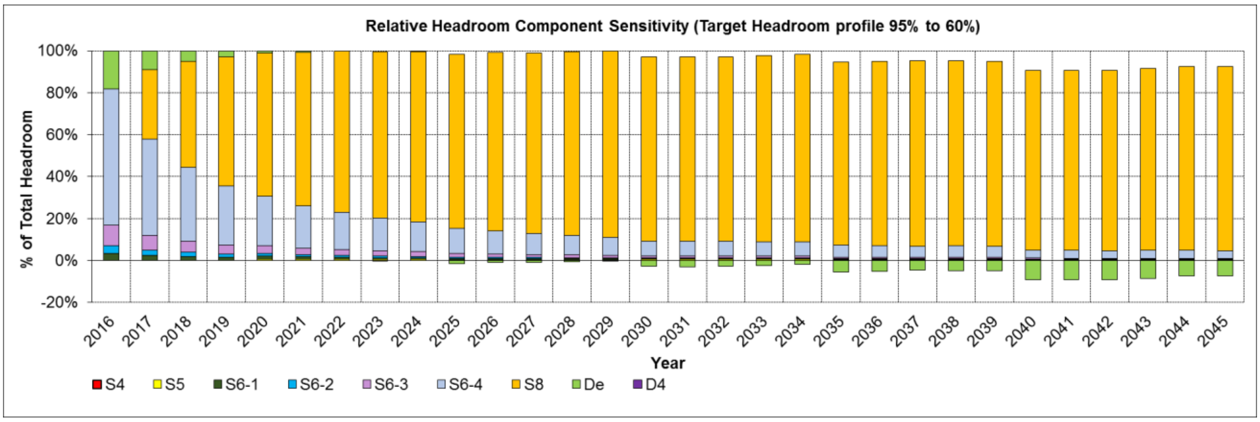


Figure C2.15: Components of target headroom – Whitchurch and Wem WRZ

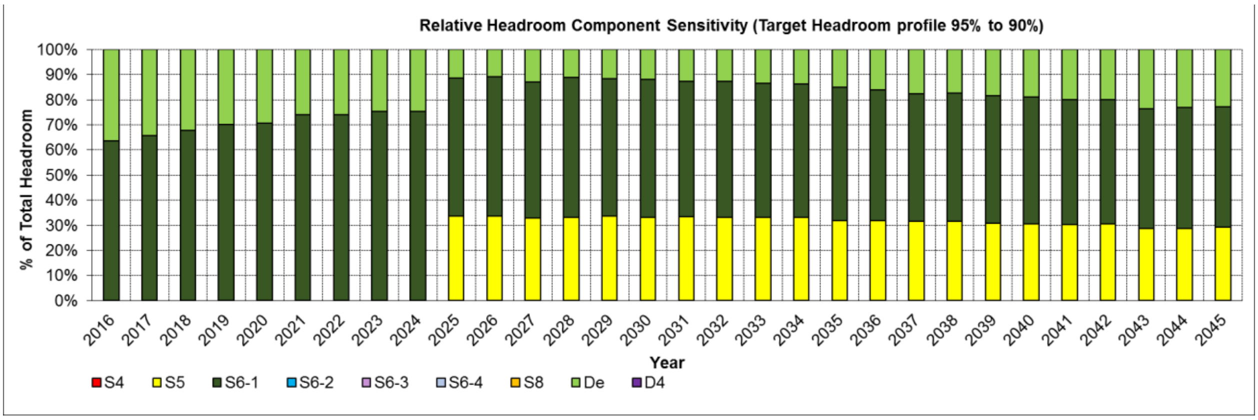
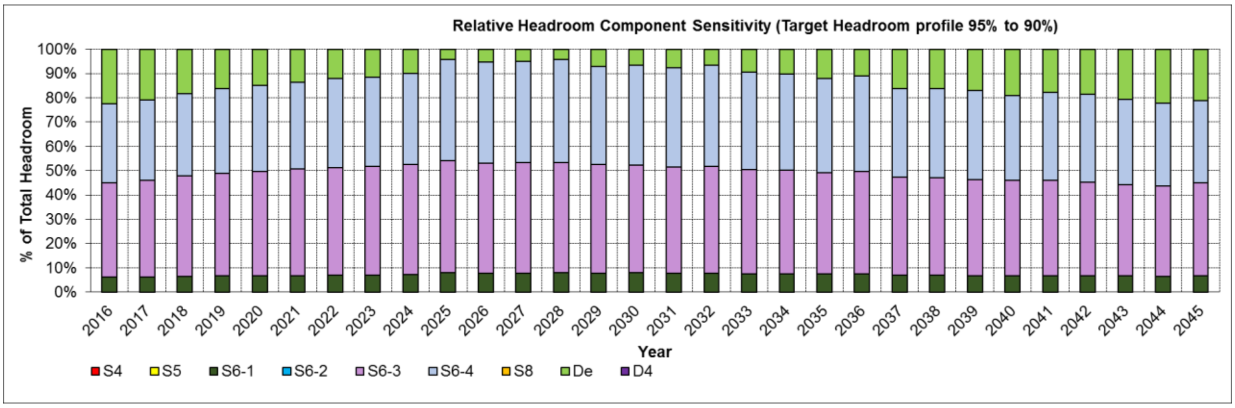


Figure C2.16: Components of target headroom – Wolverhampton WRZ



C3 Baseline supply/demand balance projections

The methodologies and assumptions behind our projections of the future demand for water across our region, our supply capability, our outage risks and our headroom uncertainties are described in detail in Appendices A, B and C. The analysis of these issues comes together in our assessment of the overall balance of water supply and demand over the next 25 years. Below we discuss our assessment of the "baseline" supply demand balance position from now until 2045.

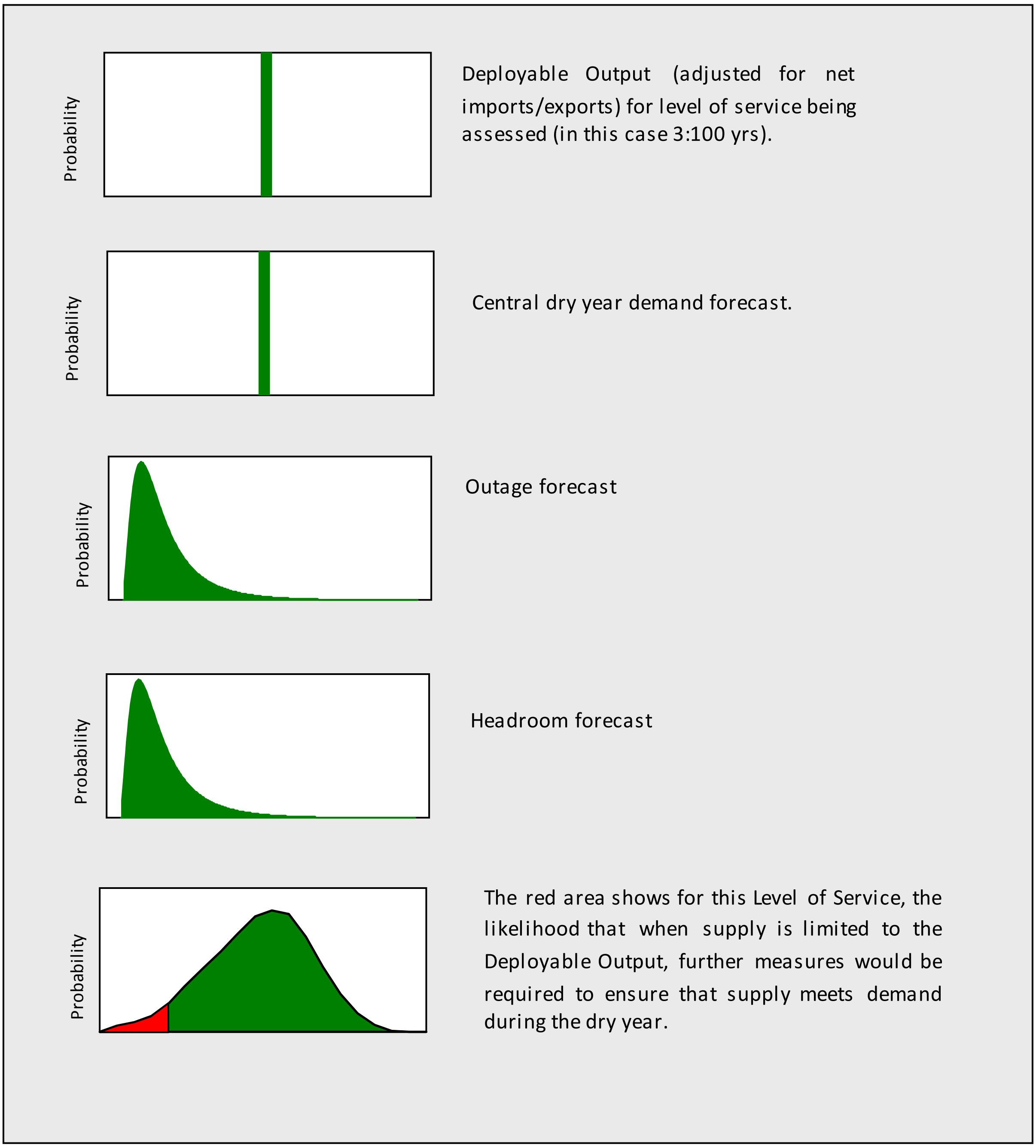
The "baseline" scenario demonstrates what the supply / demand outlook would be based on our projected changes to future demand and water available for use, but assuming no future investment in new supplies and no change from our current AMP6 demand management and leakage policies. It depicts a scenario in which a dry year could occur in any year between now and 2045. Under that scenario we have assessed the demand for water we would expect to have to meet using the resources we could rely upon under those conditions, with the likely outage and headroom requirements taken into account. This scenario is used to test whether future investment will be required to maintain the balance of supply and demand and to ensure that we can meet our target levels of service.

The principal equation governing the calculation of the supply demand balance is:

Balance of Supply =Deployable Output – Exports + Imports – Outage – Headroom – Demand

Using this approach, the balance of supply is calculated for each year in the planning period (2020 - 2045). Both the headroom and outage requirements have been assessed on a probabilistic basis. The impact of this probabilistic assessment on the calculated supply demand balance is illustrated in Figure C3.1. Our analysis has been carried out over the 25 year planning period to derive the mean balance of supply in each year along with the range of uncertainty around the mean. The range of uncertainty has been plotted to show the probability that the supply and demand will be in surplus, in balance or in deficit.

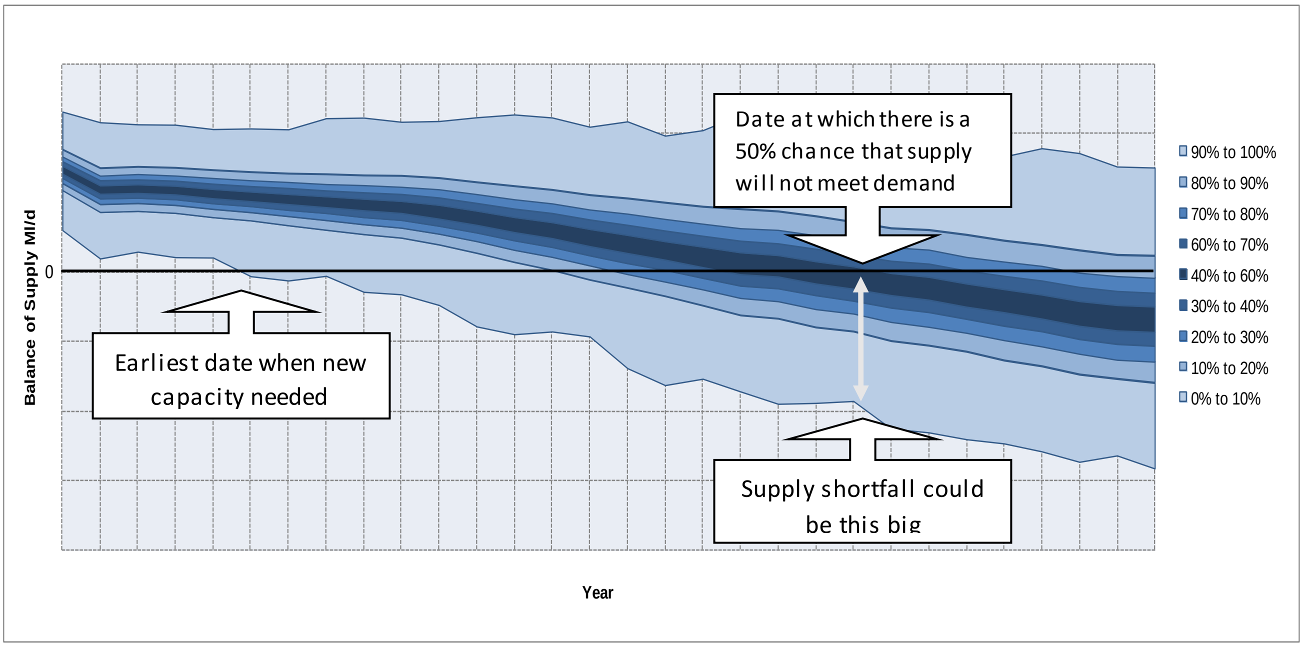
Figure C3.1: Calculating the Balance of Supply and Demand in a WRZ



C3.1 Interpreting Supply Demand Balance Uncertainty

Figure C3.2 below shows a typical result from the supply demand balance uncertainty analysis. The percentile ranges show the probability of supply meeting demand in future years given the uncertainties that have been assessed for each of the key planning components.

Figure C3.2: The supply demand balance with different levels of certainty / uncertainty



The example shown in Figure C3.2 above shows a general trend of loss of deployable output over time combined with a growth in demand for water, resulting in a worsening supply /demand position. The percentile distribution about the mean projection increases through the planning period reflecting greater uncertainty going forward.

Generally the supply demand balance graph can be used as the basis for investment planning for a resource zone. We make our investment decisions on the need for additional demand management measures (including leakage reduction, metering and water efficiency) and new water sources based on maintaining a given level of certainty in the balance of supply.

The point at which the 0%ile crosses the 0 Ml/d axis in Figure C3.2 above shows the earliest point at which new sources or demand management measures could be required to ensure the level of service will be met, accounting for all identified uncertainty in the resource zone. The larger the risk the company is prepared to accept that supply may not meet demand; the longer it will be before these measures will need to be implemented.

The size of any supply / demand shortfall, and the scale of any resulting investment, is to some extent determined by the level of planning uncertainty that the company is prepared to accept. As explained in section C2.3.1, for our WRMP19 we have adopted a target headroom requirement that reduces over time. The target headroom profile reflects the fact that medium to long term uncertainties can be managed over time, and so it would be inappropriate to plan to maintain a high level of target headroom throughout the whole planning period. Instead, we plan to accept a manageable degree of risk in our AMP7 supply demand balance and to accept an increasing level of risk in our longer term planning horizon.

C3.2 Baseline supply demand balance results for individual WRZs

The results of our baseline supply demand balance assessment 14 of our water resource zones (WRZ) are shown in Figures C3.3 to C3.17. The Chester WRZ can be found in Appendix F10. In several of our zones we see a step change within the balance of supply graph as a result of the changes that we are proposing to make to our abstraction licences as part of our plan to reduce unsustainable abstraction and prevent future environmental deterioration. The resultant loss of deployable output is represented within the supply demand balance. We make no allowance for the loss of these abstraction licences in our target headroom assessment.

The figures show that for the Forest and Stroud, Kinsall, North Staffordshire, Strategic Grid and Nottinghamshire zones, there is a high probability that without new investment, either in demand management or supply options, we will not have sufficient supplies available to meet expected water demand from our customers. In the Mardy, Shelton and Whitchurch and Wem zones there is some risk in the later AMP periods that we may need to take measures to ensure we can maintain our target levels of service. However, the risk may be reduced by our leakage and demand management programmes in these zones.

For all other zones, the figures illustrate that we have high confidence that we will be able to meet expected demand from our customers without the need for investment in new sources of water.

Figure C3.3: Balance of supply for Bishops Castle WRZ

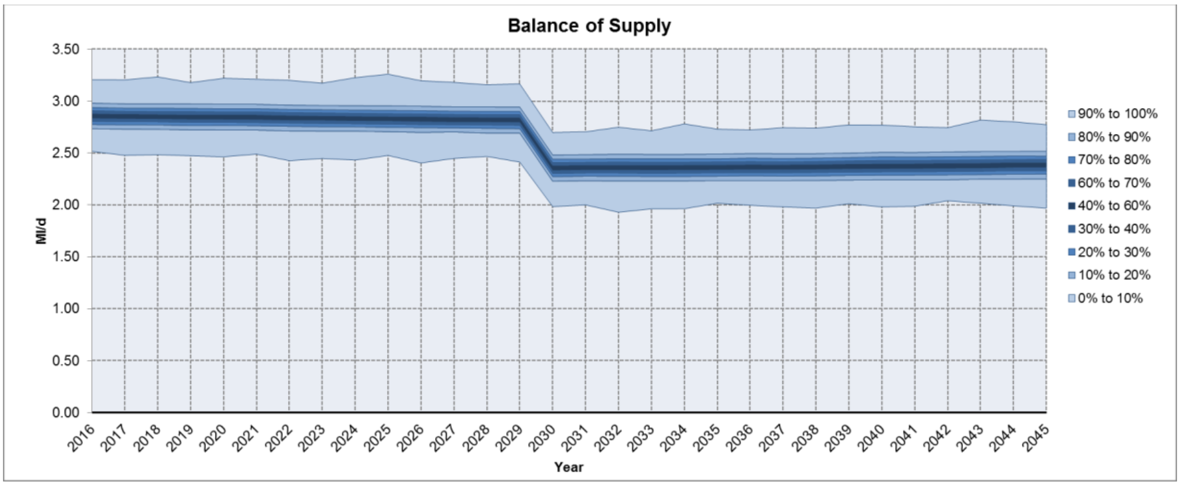


Figure C3.4: Balance of supply for Forest and Stroud WRZ

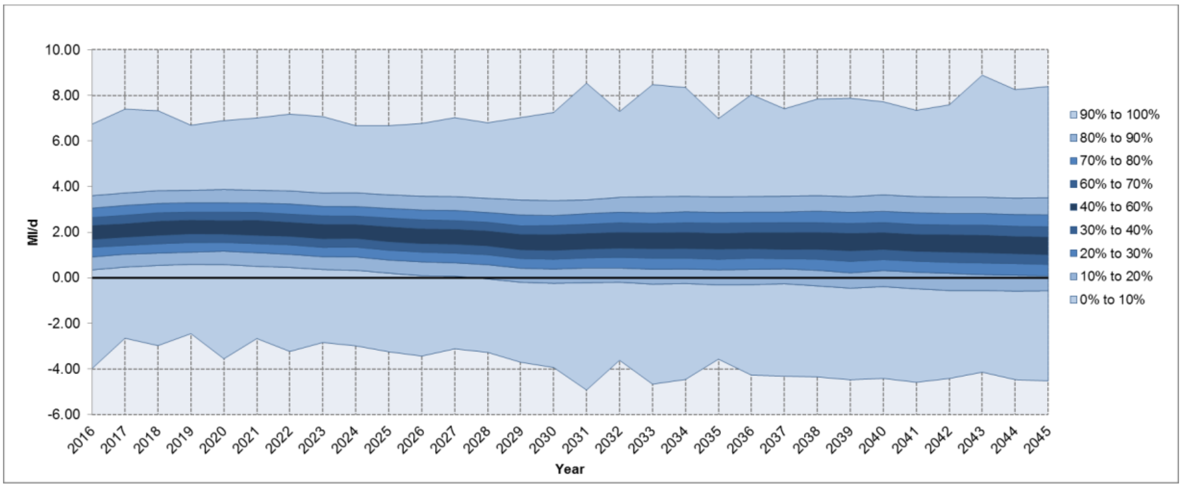


Figure C3.5: Balance of supply for Kinsall WRZ

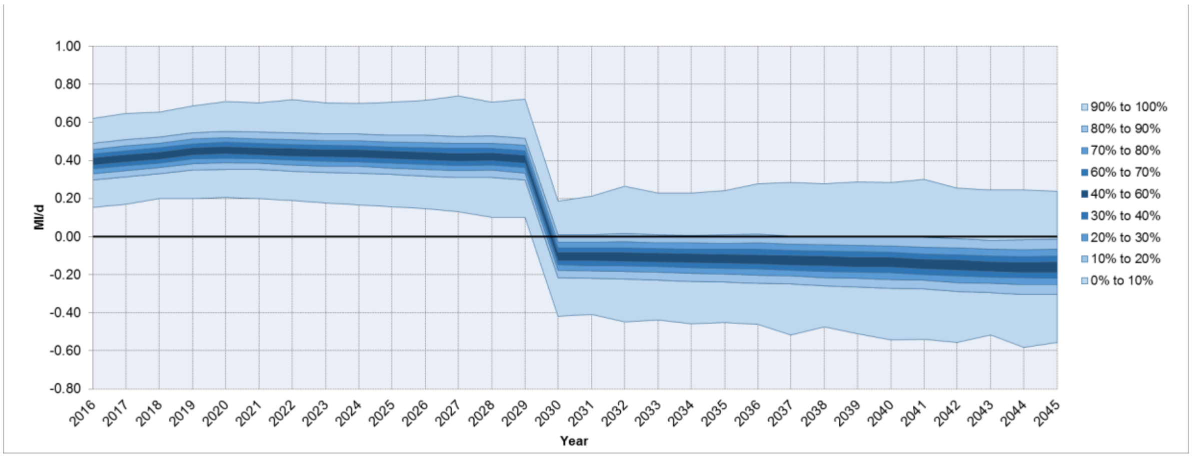


Figure C3.6: Balance of supply for Mardy WRZ

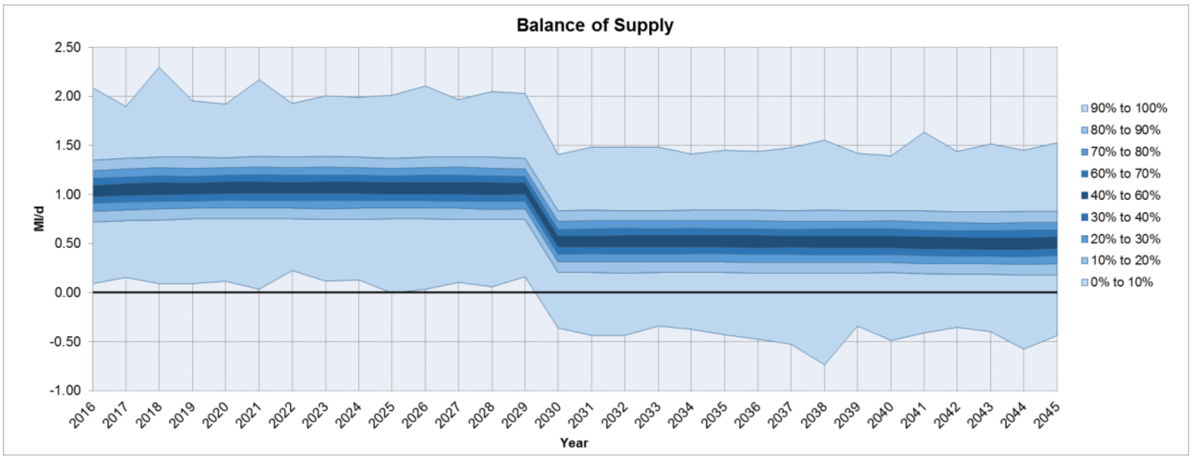


Figure C3.7: Balance of supply for Newark WRZ

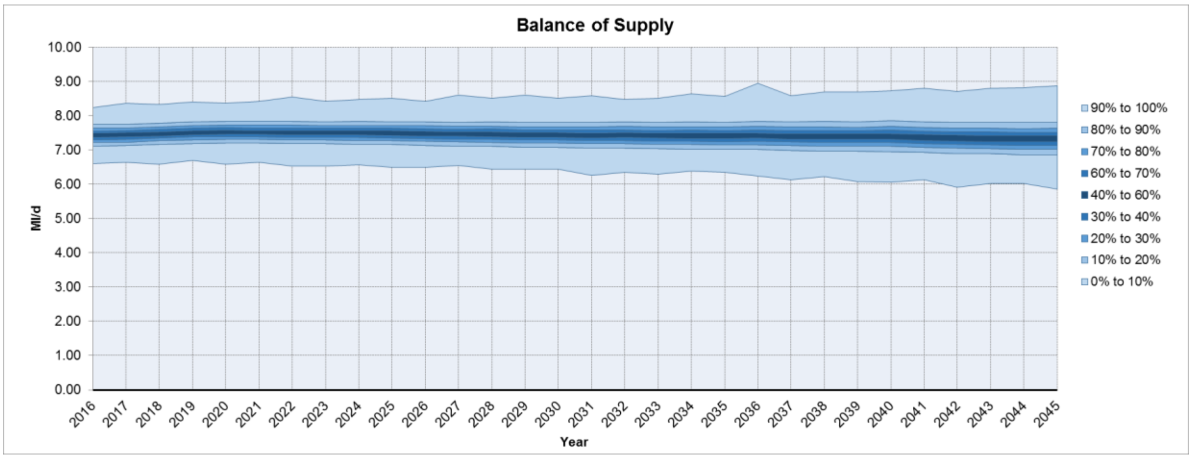


Figure C3.8: Balance of supply for North Staffordshire

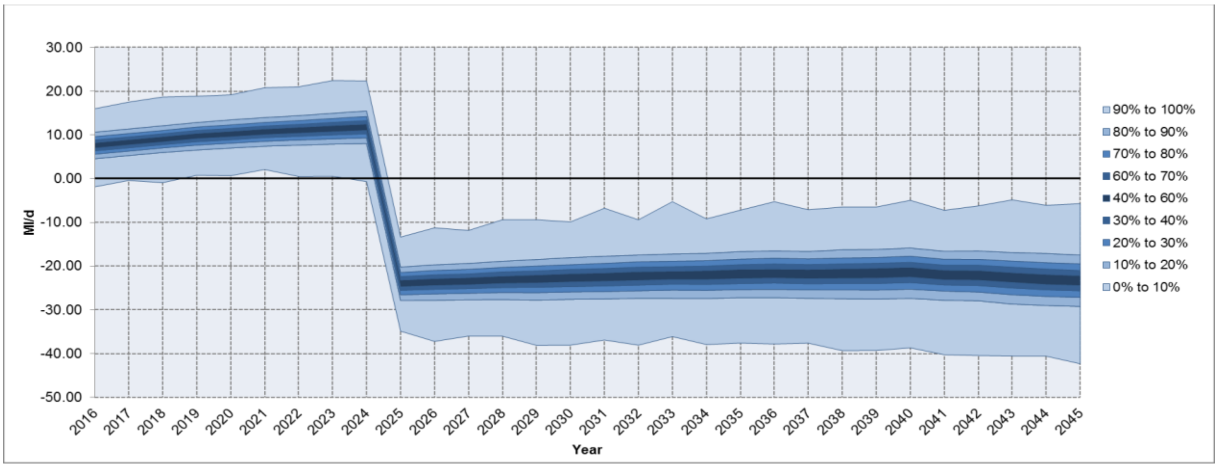


Figure C3.9: Balance of supply for Nottinghamshire WRZ

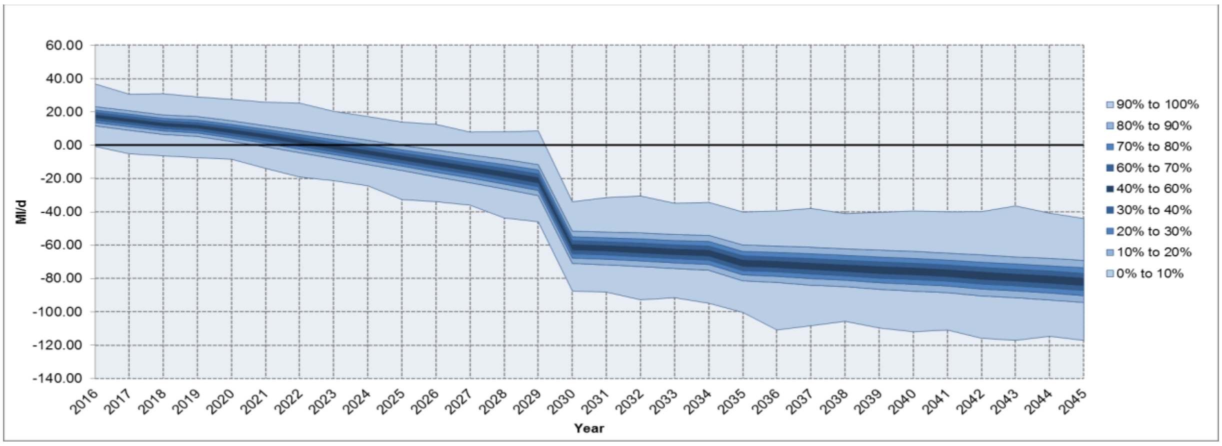


Figure C3.10: Balance of supply for Rutland WRZ

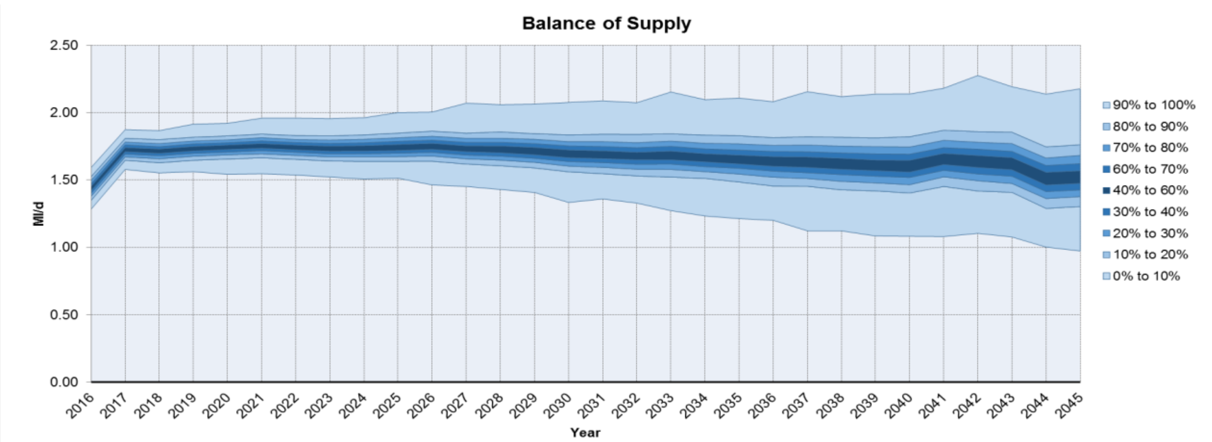


Figure C3.11: Balance of supply for Ruyton WRZ

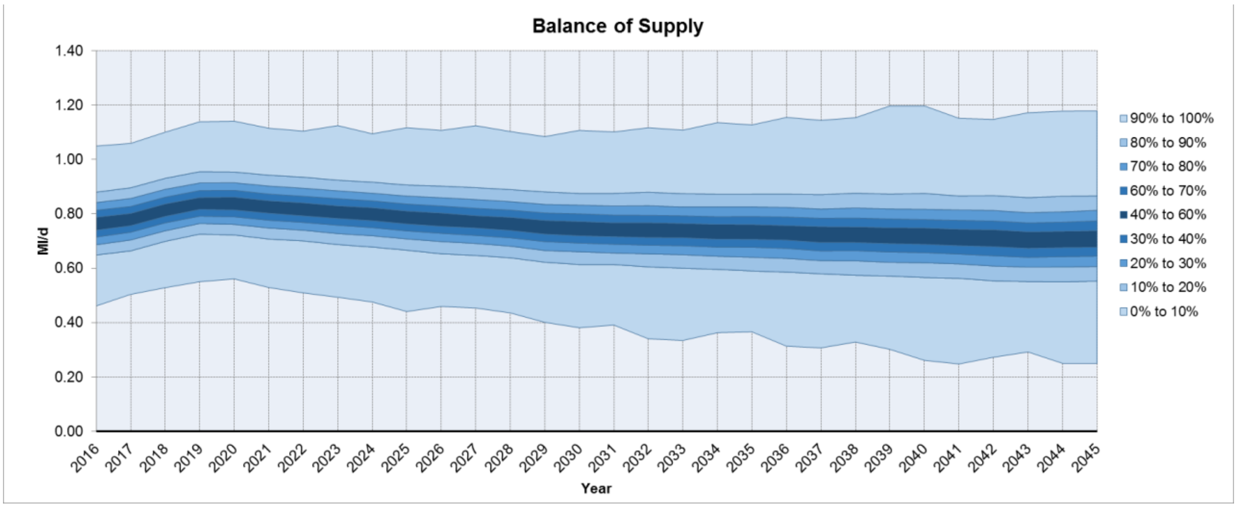


Figure C3.12: Balance of supply for Shelton WRZ

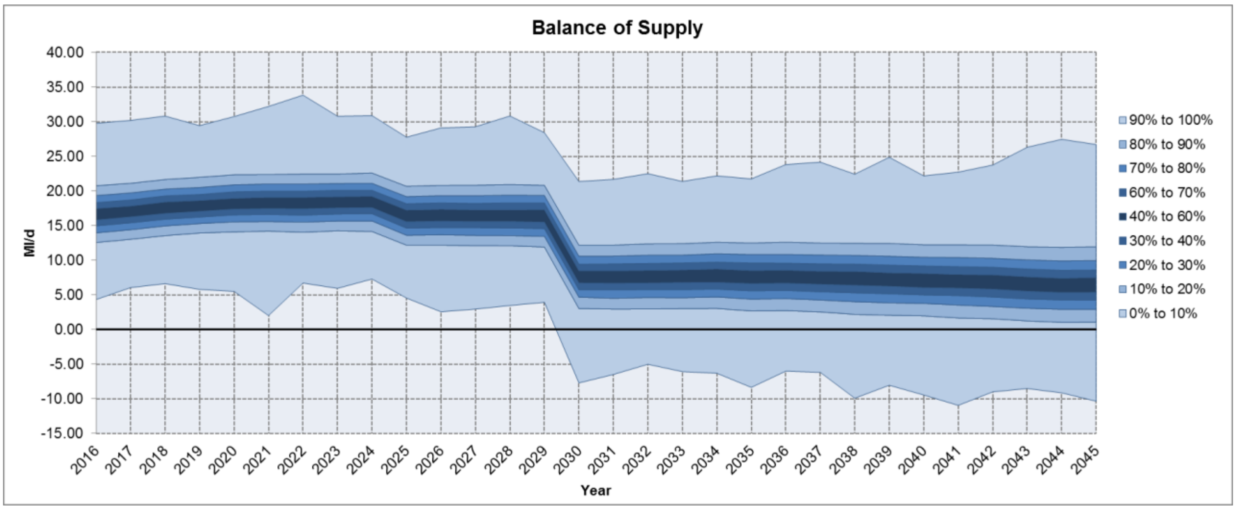


Figure C3.13: Balance of supply for Stafford WRZ

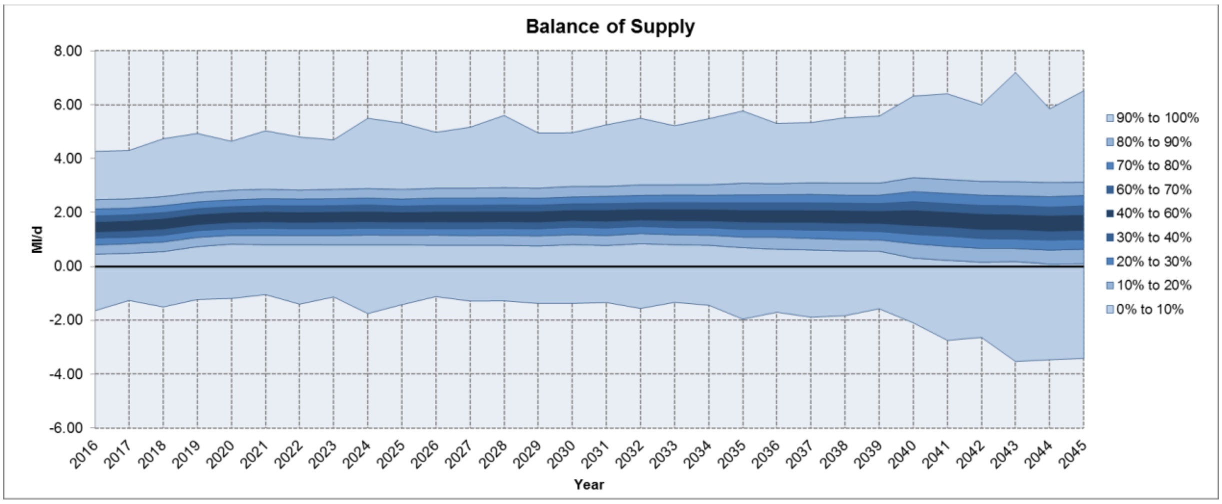


Figure C3.14: Balance of supply for Strategic Grid WRZ

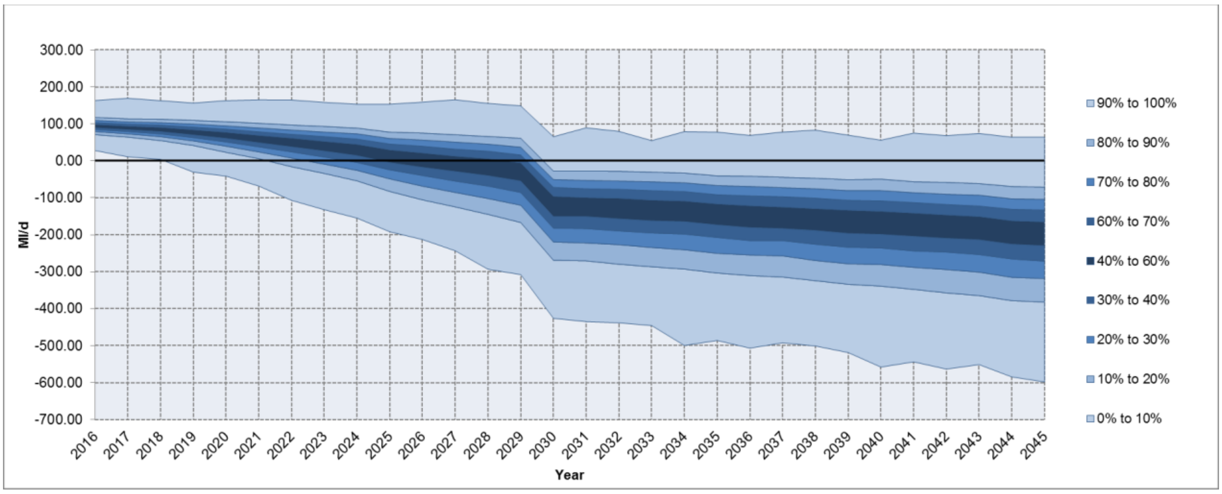


Figure C3.15: Balance of supply for Whitchurch and Wem WRZ

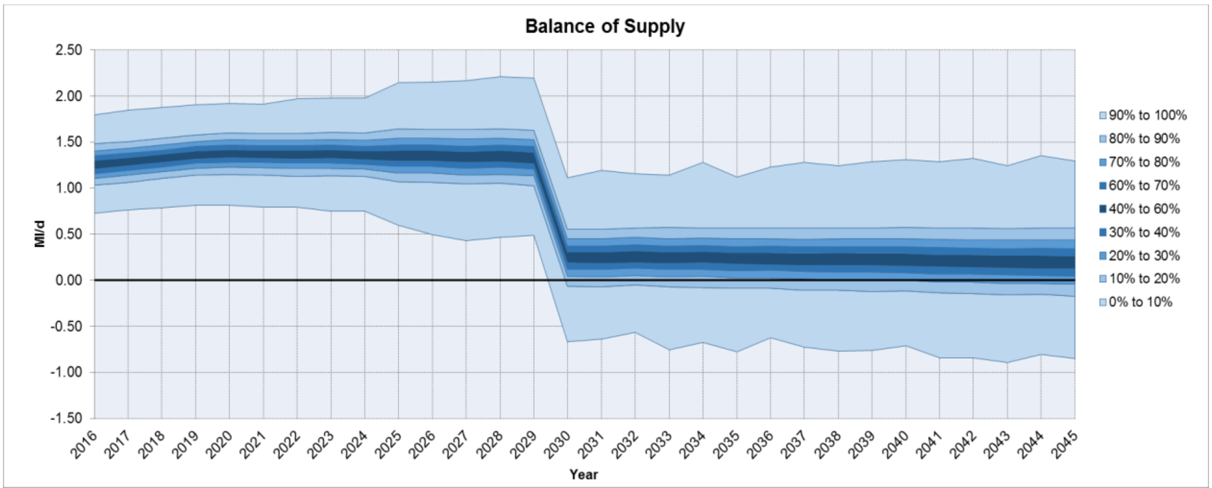
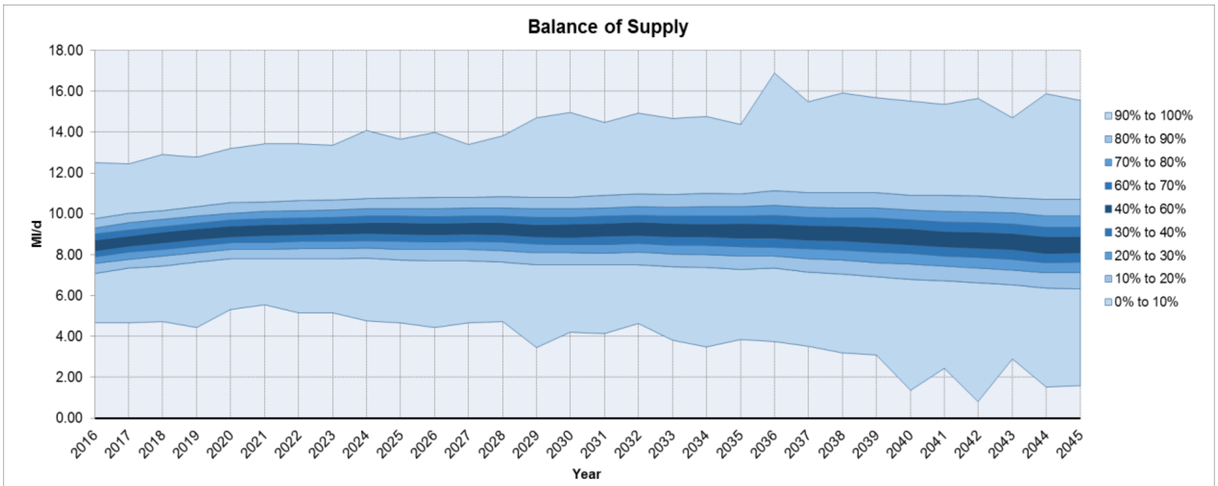


Figure C3.16: Balance of supply for Wolverhampton WRZ



C3.3 Final plan supply demand balance results for individual WRZs

Figures C3.17 to C3.30 in this section illustrate how the measures we are proposing in our final WRMP will maintain the supply demand balance and show the likelihood of our available supplies being sufficient to meet expected demand. The graphs demonstrate that for those zones shown in section C3.2 to have supply demand deficits, the supply and demand investment measures we are proposing will give us high confidence that we can meet customers' demand for water over the next 25 years.

Figure C3.17: Final Plan Balance of supply for Bishops Castle WRZ

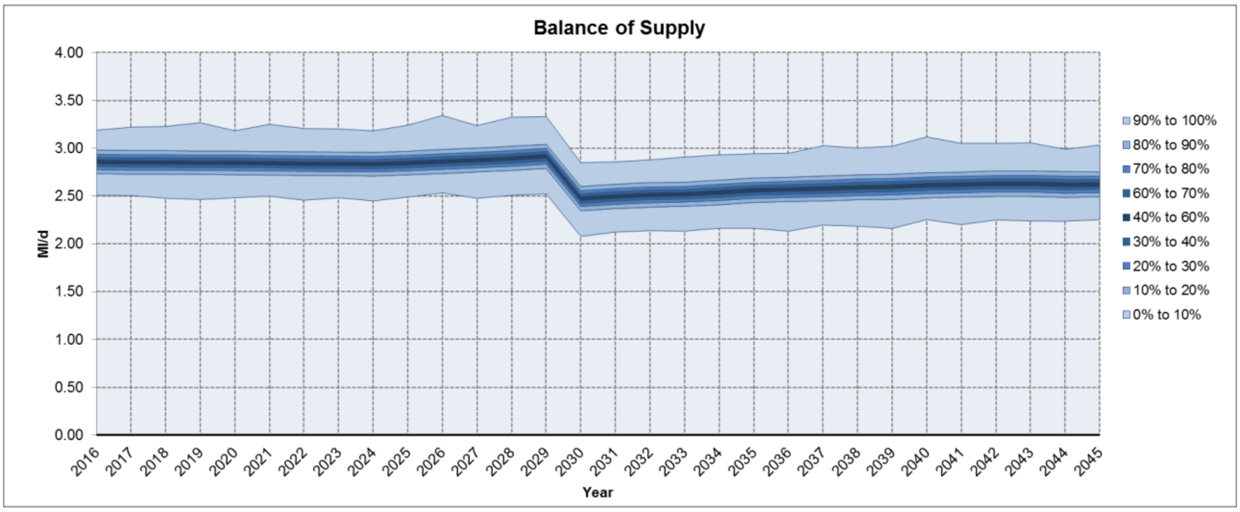


Figure C3.18: Final Plan Balance of supply for Forest and Stroud WRZ

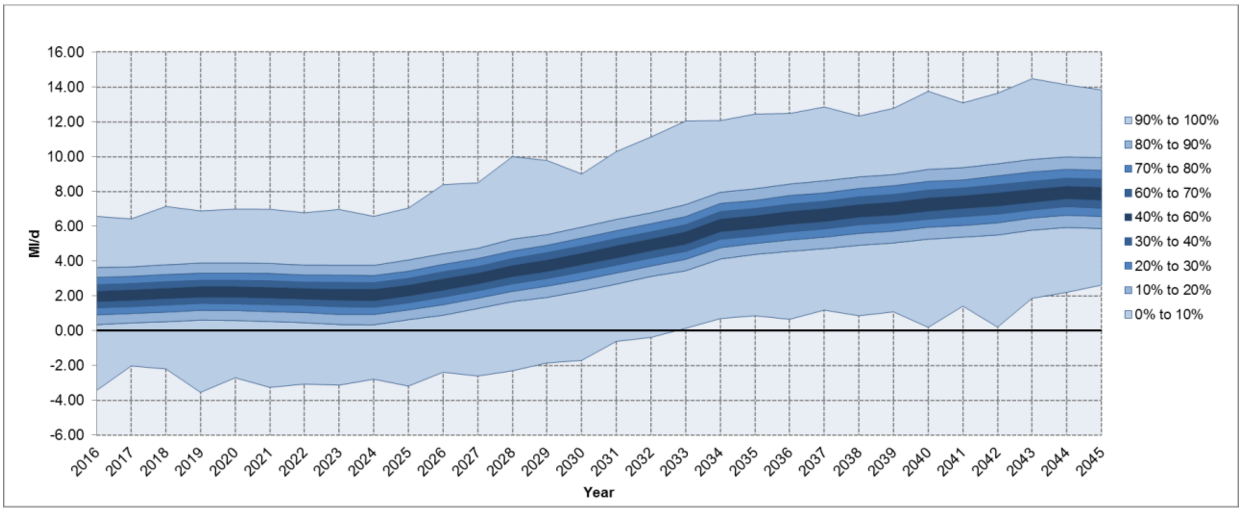


Figure C3.19: Final Plan Balance of supply for Kinsall WRZ

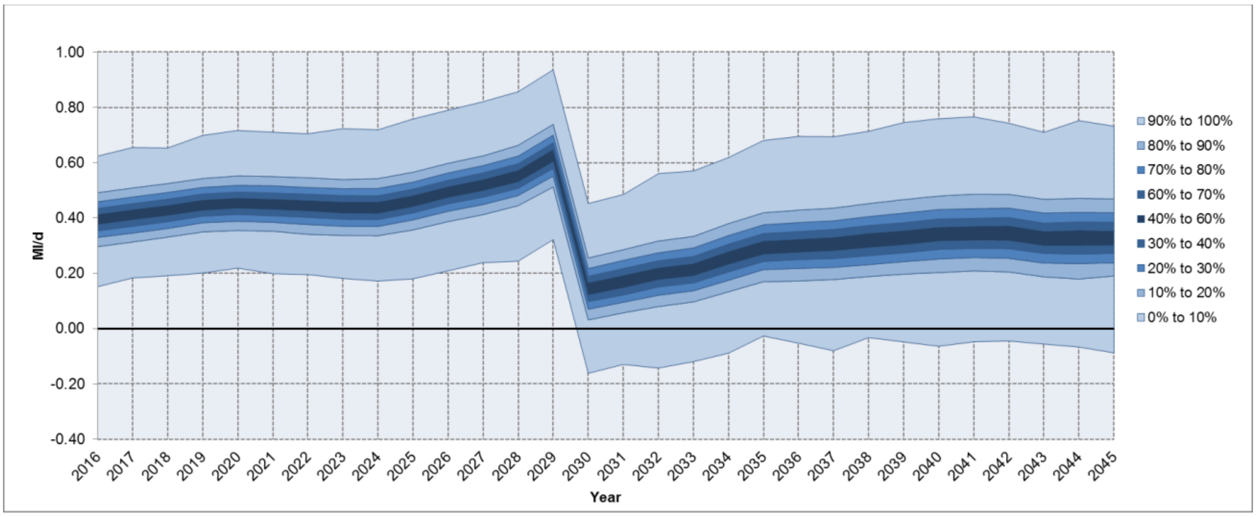


Figure C3.20: Final Plan Balance of supply for Mardy WRZ

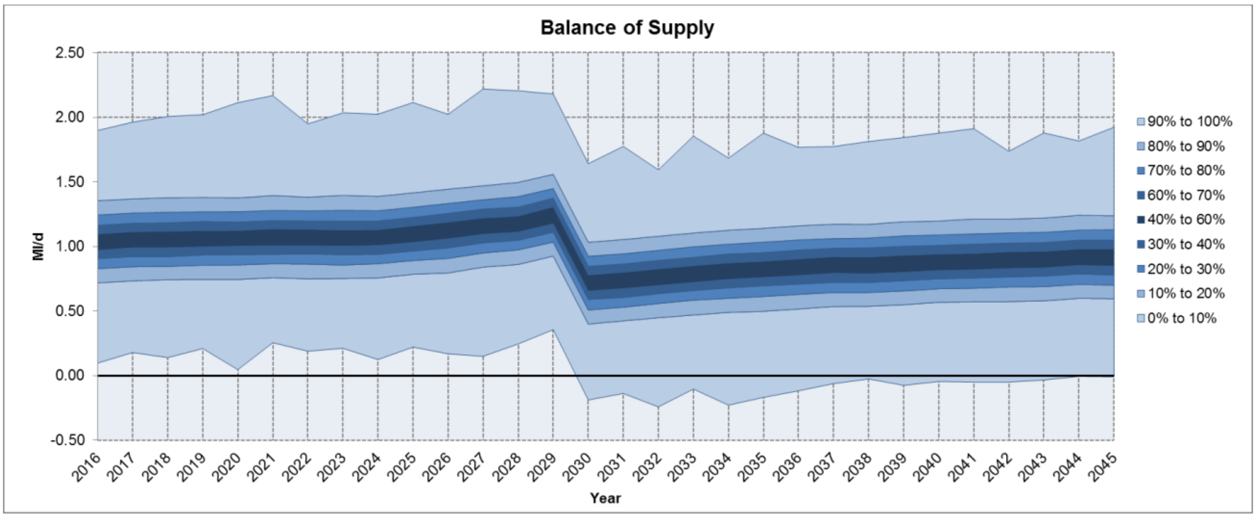


Figure C3.21: Final Plan Balance of supply for Newark WRZ

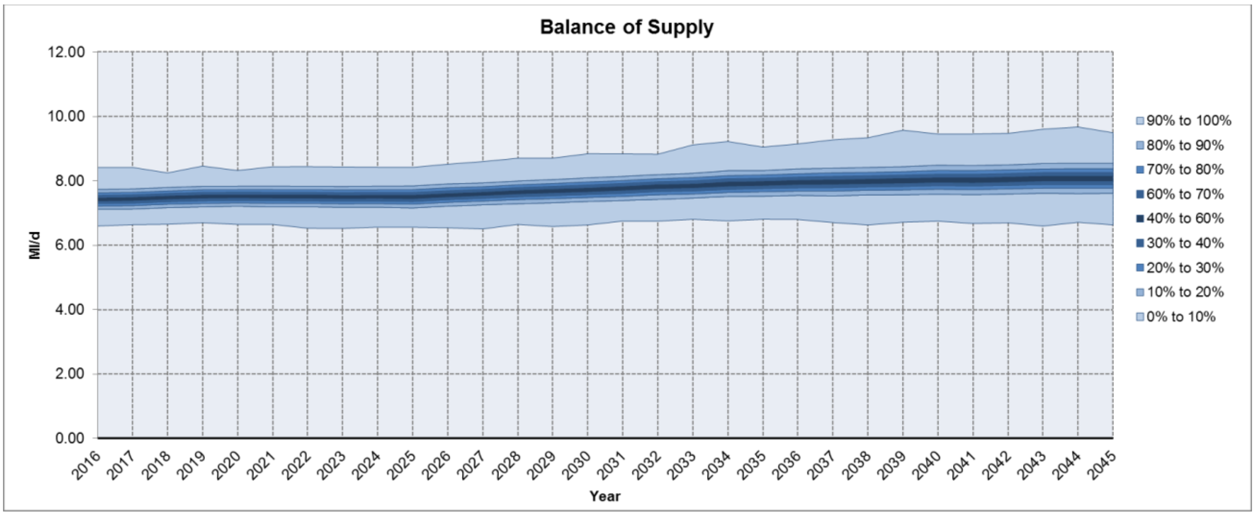


Figure C3.22: Final Plan Balance of supply for North Staffordshire

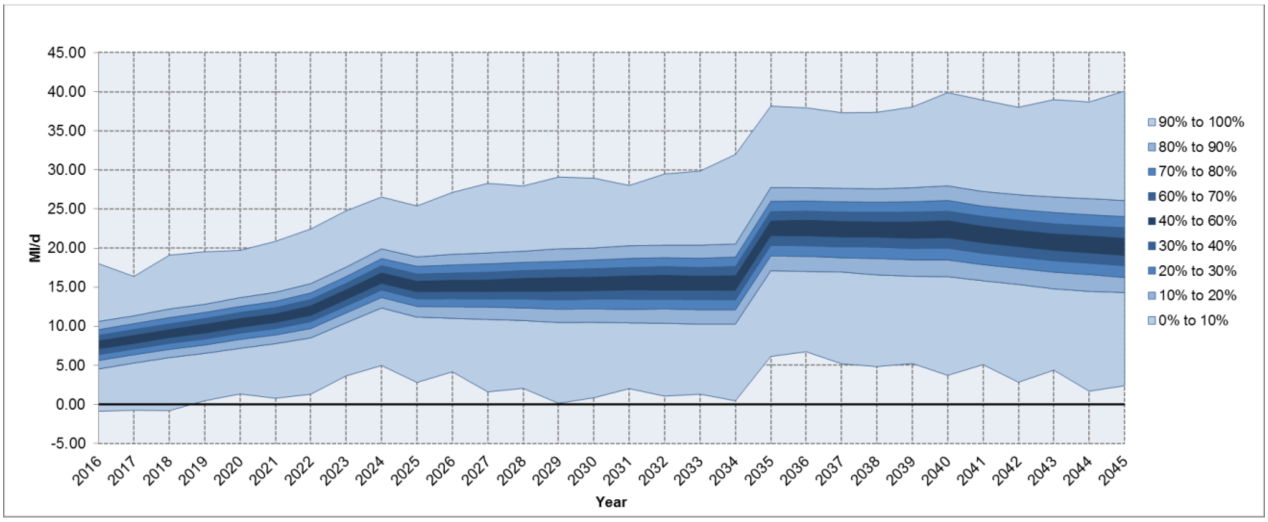


Figure C3.23: Final Plan Balance of supply for Nottinghamshire WRZ

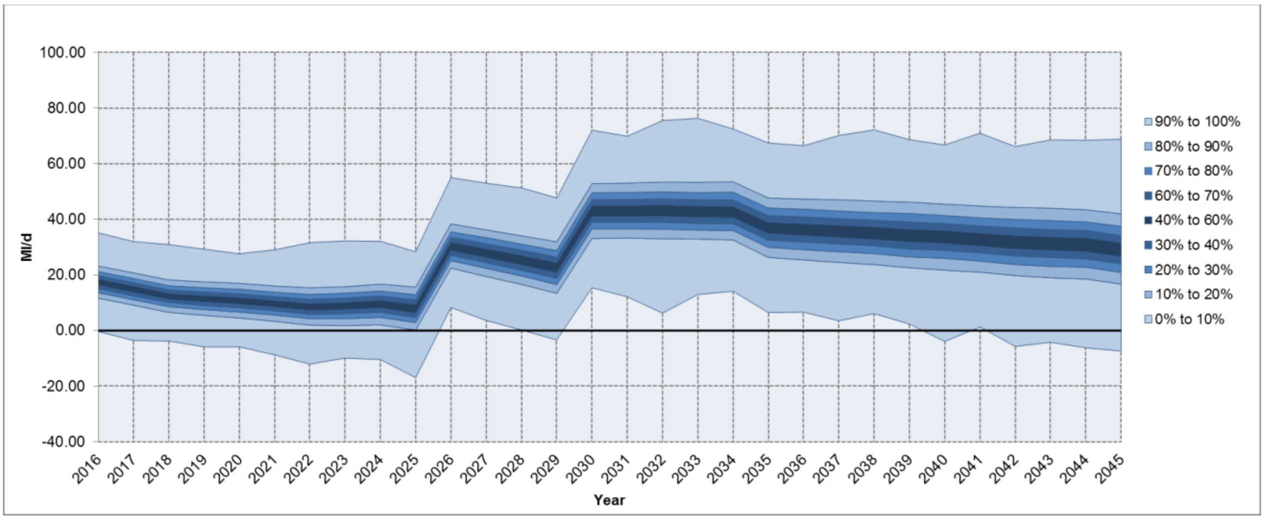


Figure C3.24: Final Plan Balance of supply for Rutland WRZ

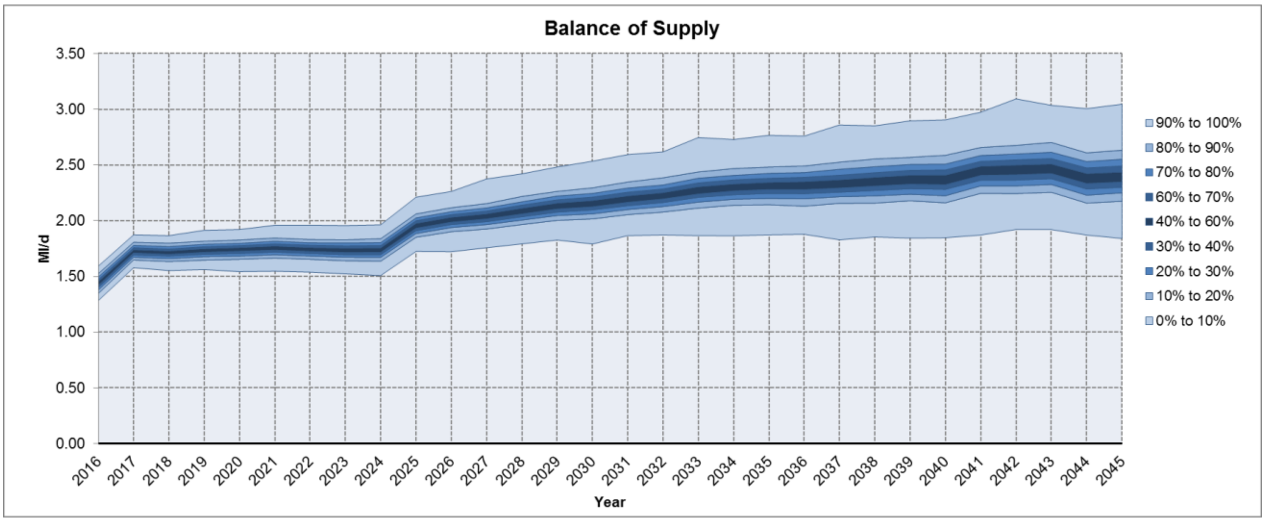


Figure C3.25: Final Plan Balance of supply for Ruyton WRZ

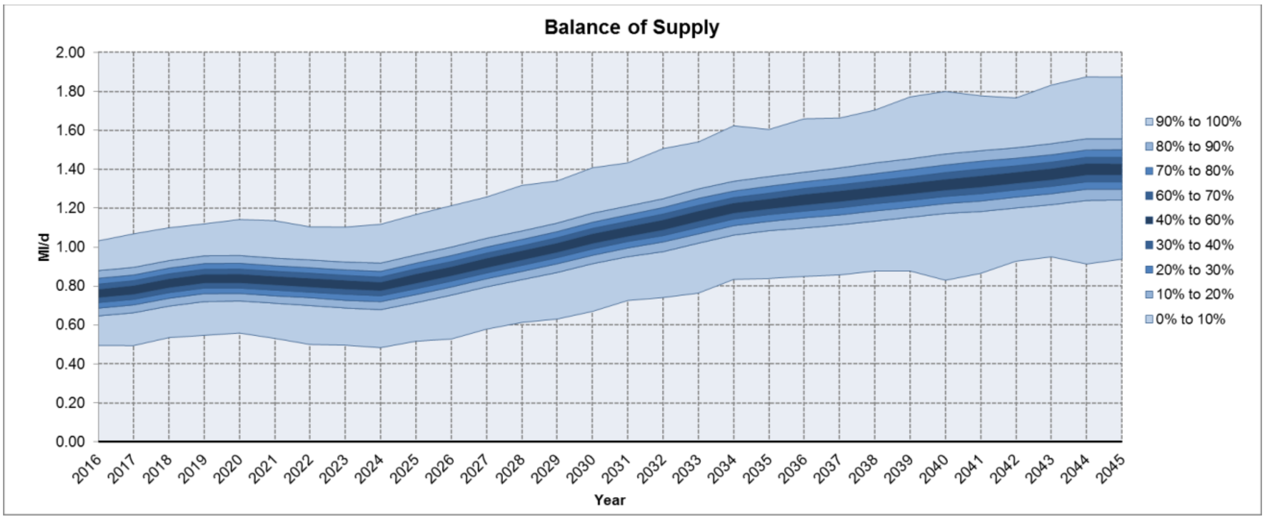


Figure C3.26: Final Plan Balance of supply for Shelton WRZ

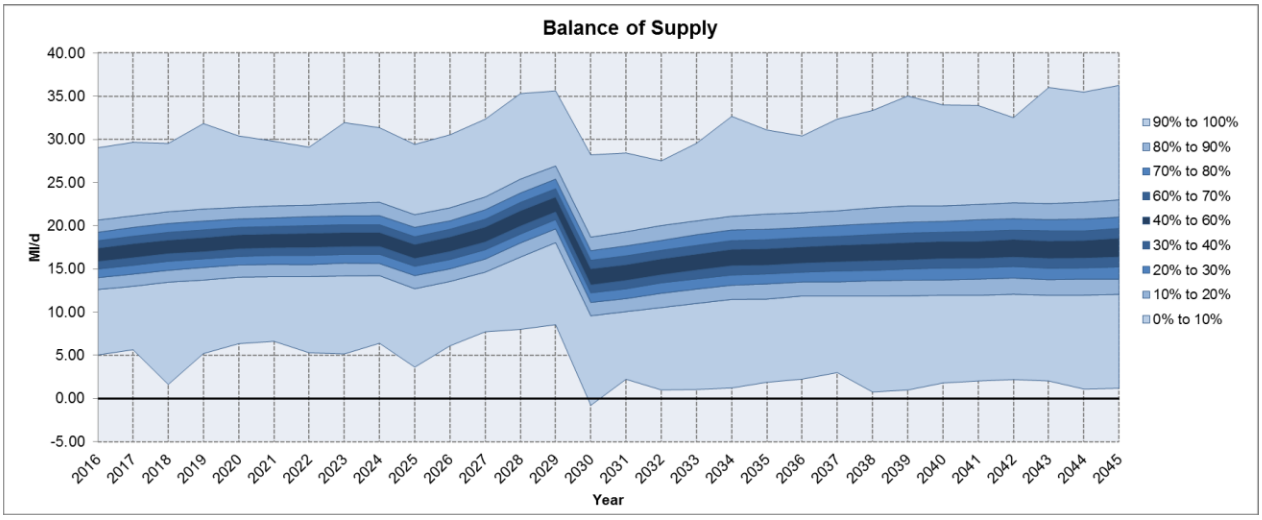


Figure C3.27: Final Plan Balance of supply for Stafford WRZ

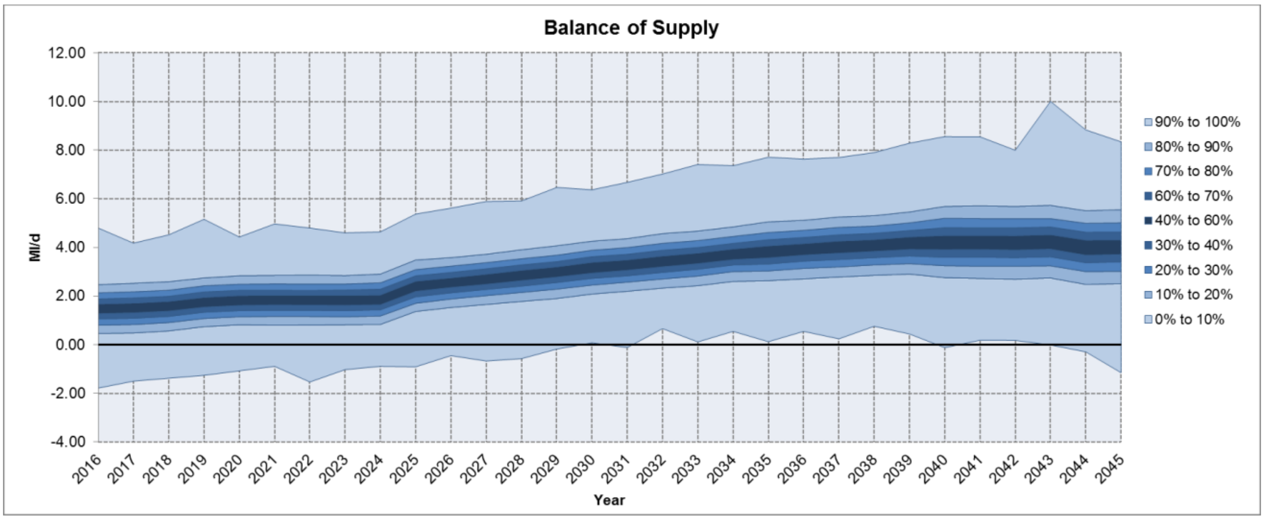


Figure C3.28: Final Plan Balance of supply for Strategic Grid WRZ

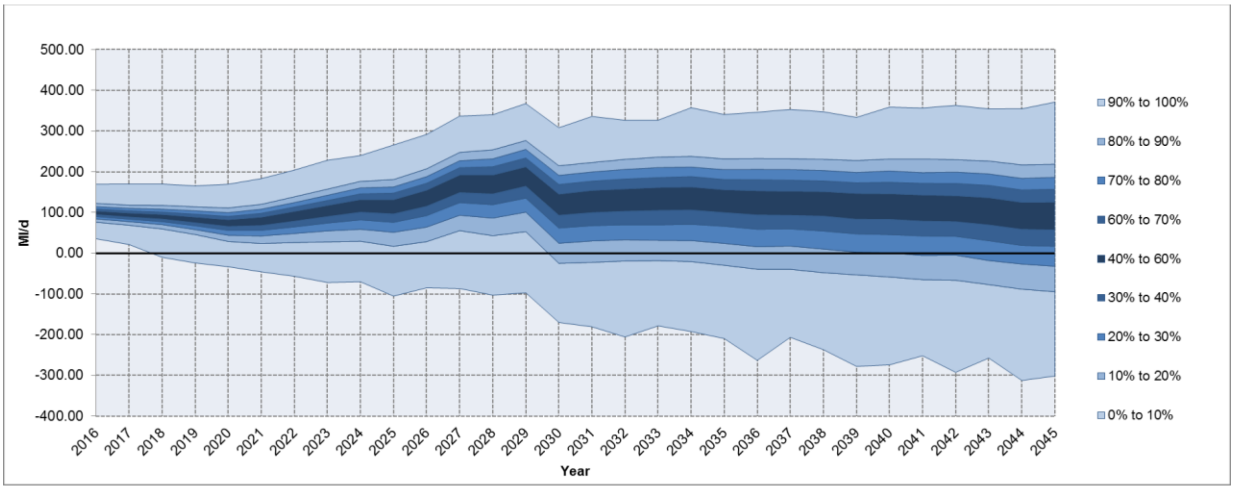


Figure C3.29: Final Plan Balance of supply for Whitchurch and Wem WRZ

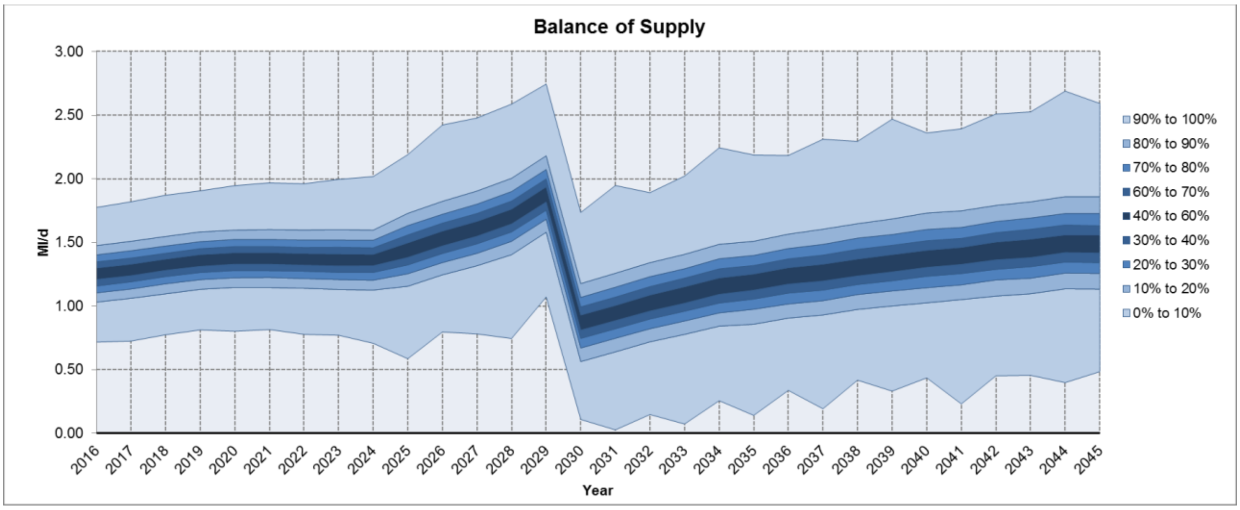


Figure C3.30: Final Plan Balance of supply for Wolverhampton WRZ