Headroom Assessment

SES Water dWRMP19

SES Water

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1. Introduction

1.1 Background

SES Water is required to calculate the company's target headroom every five years as part of its Water Resources Management Plan (WRMP) submission. A water company's target headroom is defined as 'a buffer for uncertainty between supply and demand designed to cater for specified uncertainties' (Environment Agency, Water Resources Planning Guideline (WRPG), October 2012). The purpose of including a headroom allowance within the supply/demand balance is to include a margin between supply and demand to allow for the risk of variations in the forecast supply/demand balance due to uncertainty in the various components.

SES Water carried out an assessment of supply/demand uncertainties and calculated a suitable headroom allowance to incorporate within the supply/demand balance for their Final WRMP14. A summary of the results is given in Table 1-1.

Table 1-1: SES Water WRMP14 Target Headroom (Ml/d)

Annual average baseline target headroom (DYAA)	Sutton		East Surrey		Company	
	2011/12	2039/40	2011/12	2039/40	2011/12	2039/40
Risk Percentile (%)	95th	85th	95th	85th	95th	85th
Target Headroom (Ml/d)	4.39	7.90	11.47	11.93	15.86	19.82
% WAFU	6	11	9	9	8	10
% DI	6	9	12	11	9	10
Critical period baseline target headroom (DYCP)	**Sutton**		**East Surrey**		**Company**	
	2011/12	**2039/40**	**2011/12**	**2039/40**	**2011/12**	**2039/40**
Risk Percentile (%)	95th	85th	95th	85th	95th	85th
Target Headroom (Ml/d)	6.22	9.75	14.47	18.37	20.69	28.12
% WAFU	6	9	8	11	7	10
% DI	6	8	10	12	8	10

Source: SES Water (2014) Final Water Resource Management Plan

The values in Table 1-1 were based on a Monte Carlo simulation to combine probability distributions for a number of key uncertainty factors, including accuracy of supply and demand data, demand forecast variation and impact of climate change on deployable output (DO). Company headroom allowance values were selected from each distribution at a reducing profile of risk across the 25-year planning horizon. The most appropriate level of headroom uncertainty was considered to be the 95th percentile for the beginning of the planning period, declining to the 85th percentile by 2039/2040.

AECOM have been commissioned by SES Water to undertake a review of its headroom assessment. For the Final WRMP 2014, SES Water completed a supply/ demand balance analysis for two Water Resource Zones[1] (WRZs), namely Sutton WRZ and East Surrey WRZ. These zones have been combined for the WRMP 2019 submission. This analysis of headroom allowance will therefore be carried out for a single company-wide WRZ. This report presents the methodology and assumptions adopted for the assessment, together with the results of the analysis.

1.2 The current report

The aim of the headroom assessment is to calculate headroom allowance distributions, for each period in the planning horizon until 2084, and for each planning scenario, to cover the various uncertainties inherent within the future supply/demand balance. Headroom allowance values can then be determined from the distribution for each period at an appropriate level of risk.

[1] A Water Resource Zone is the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall

The key objectives of this analysis can be summarised as follows:

- Assess the risks and uncertainties which apply to the components of SES Water's supply/demand balance, through consideration of relevant information;
- Develop suitable probability distributions to represent each relevant uncertainty factor;
- Combine the individual probability distributions into a single distribution representing SES Water's headroom uncertainty for each year in the planning horizon; and
- Determine headroom allowance profiles, by selecting values from the combined headroom uncertainty distributions at appropriate levels of risk across the planning horizon.

2. Headroom assessment methodology

There are two methods available for the calculation of target headroom, developed by UKWIR in 1998 and 2003 respectively, and recommended by the Environment Agency WRPG (October 2012):

- 'A Practical Method for Converting Uncertainty into Headroom' (UKWIR, 1998): a relatively simple, pragmatic approach which attempts to quantify uncertainty by a judgement-based proforma system; and
- 'An Improved Methodology for Assessing Headroom' (UKWIR, 2002): a more detailed, analytical approach to the determination of uncertainty through probabilistic simulation.

For their WRMP14, SES Water has adopted the more rigorous, probabilistic approach of the 2002 methodology. In this approach, a probability distribution is assigned to each individual risk or uncertainty factor within the supply/demand balance, based on known data and other relevant information. These probability distributions are then combined using the statistical technique of Monte Carlo simulation, which iteratively takes random samples from each distribution and sums them according to specified rules. The summed result of each iteration then forms a point on the curve of the combined distribution; by sampling the distributions over a large number of iterations it is then possible to build up a probability distribution to represent the overall risk or uncertainty of all factors taken together.

The Monte Carlo simulation software @RISK was used for the analysis, which operates in conjunction with the Microsoft Excel spreadsheet package. Due to the random nature of the Monte Carlo simulation technique, it is not possible to guarantee that identical results will be generated each time the same simulation is run. However, by selecting a suitably large number of iterations for the simulation, to give an acceptable mean standard error for the simulation results, it should be possible to obtain repeatable results to an acceptable level of accuracy. This study found that consistent results were obtained using 10000 iterations. For the WRMP14, SES Water evaluated the supply/demand balance analysis separately in each WRZ.

For the draft WRMP19, AECOM has undertaken the analysis in a single WRZ at the source works level. Two planning scenarios have been considered in this headroom assessment, as follows:

- Dry Year Annual Average – based on Dry Year Minimum Resource Level (DYMR) and Minimum Resource Deployable Output (MDO). The assessment of Minimum Deployable Output (MDO) is linked to the critical period (minimum groundwater level and river flow) scenario. Groundwater source 'ADO' assessments (improved methodology) were based on monthly operational data for those months when groundwater levels were at or near their annual minima for the worst drought to have affected the area of the source (UKWIR, 2000). However, the use of data associated with minimum groundwater levels means that the assessments now fall under the category of MDO. MDO is the *"DO for the period in which groundwater levels are at their lowest, usually late autumn"* (UKWIR, 2014)*;*
- Dry Year Critical Period – based on dry year Average Demand in Peak Week (ADPW) and Peak Deployable Output (PDO). Water companies *"may also choose to explain how you will deal with a period of peak strain known as the critical period"* (Environment Agency, 2017). The assessment of PDO is associated with the 'dry year critical period' (DYCP) planning scenario and also the design drought, where the resource zone supply-demand balance is sensitive to peak demand. PDO is the "*deployable output for the period in which there is highest demand*" (UKWIR, 2014).

Key areas of future risk and uncertainty relevant to SES Water's future supply/demand balance were identified through discussion and correspondence with SES Water (Personal Communication with Alison Murphy, 14/08/2017). A review of relevant data, including DO assessments, demand forecasts, water quality data and other relevant information, was also carried out. A brief note of the key assumptions and proposed probability distributions was then drawn up and agreed as the basis for the headroom analysis. The types of uncertainty, relating to both supply and demand factors, as specified in the UKWIR methodology *An Improved Methodology* *for Assessing Headroom* (UKWIR, 2002) are shown in Table 2-1. These uncertainties, along with the assumptions adopted for SWW headroom calculation, are discussed further in Section 3.

Table 2-1: Headroom Uncertainty Factors

Factor	Name
S1	Vulnerable Surface water licences
S2	Vulnerable Groundwater licences
S3	Time Limited Licences
S4	Bulk Imports
S5	Gradual Pollution
S6	Accuracy of Supply-Side Data
S8	Impact of Climate Change on Deployable Output
S9	New Sources
D1	Accuracy of Sub-component Demand Data
D2	Demand Forecast Variation
D3	Impact of Climate Change on Demand
D4	Demand Management Measures

3. Headroom assumptions

3.1 Headroom assumptions

The assumptions used to inform this headroom analysis along with assumptions made for the WRMP14 headroom analysis are summarised in Table 2-1 and are discussed further in the following sections. The deployable output values for the worst drought on historic record (WDHR) were used (for both scenarios) in the supply side headroom assessment; therefore the tables detailing uncertainty probability distributions in the following sections pertain to this drought event.

The target headroom was also assessed for the 1:200 year event, using the same methodology as described in Section 2, and the same assumptions as stated in Section 3. For conciseness, the tables detailing the uncertainty probability distributions for this event as provided in Appendix B.

Table 3-1: Summary of assumptions informing the headroom analysis - WRMP14 and WRMP19

Component	WRMP14	WRMP19
Supply related		
S1 - Vulnerable surface water licences	No vulnerable surface water licences identified.	No change.
S2 - Vulnerable groundwater licences	No vulnerable groundwater licences identified.	No change.
S3 - Time limited licences	Environment Agency guidelines preclude these from the headroom analysis.	No change.
S4 - Bulk imports	No bulk imports therefore not included in the analysis.	No change.
S5 - Gradual pollution causing a reduction in abstraction	Unconfined Chalk - Triangular distribution with a maximum of 3% probability of zonal loss of DO per AMP period, best estimate of 2% and minimum of 0%.	No change.
	Greensands – Triangular distribution with a maximum loss of 20% of the aquifer group DO per AMP period, minimum loss of 0% and best estimate of 4% ADO and 5% PDO per AMP period.	Greensands – Triangular distribution with a maximum loss of 5% of the aquifer group DO per AMP period, minimum loss of 0% and best estimate of 3% ADO per AMP period.
	Surface water – 2.5% zonal loss of DO as maximum per AMP, best estimate is 1.5% of zonal DO and minimum of 0%.	No change.
	Not included	Confined Chalk - Triangular distribution with a maximum of 1% probability of zonal loss of DO per AMP period, best estimate of 0.5% and minimum of 0%.
S6 - Accuracy of supply-side data		
S6/1 - Uncertainty for yields constrained by pump capacity	Not included	No change.
S6/2 - Meter uncertainty for licence critical sources	Standard deviation of ± 2% of the total DO	95% probability that the reading is within ± 5%
S6/3 - Uncertainty for aquifer constrained groundwater sources	Standard deviation of ± 2% of the total DO	95% probability that the reading is within ± 5%
S6/4 - Uncertainty for climate and catchment characteristics affecting surface waters	Not included	95% probability that the value is within ± 10%
S8 - Uncertainty of impact of climate change on source yield	Triangular distribution with upper and lower bounds of the impact of climate on supply, and the best estimate is the difference between the two.	No change however new methodology to determine the upper and lower bounds used.
S9 - Uncertain output from new resource developments	Total combined volumetric uncertainty of options as defined in the investment model which provides each feasible option with a ± uncertainty range is used to define the bounds of the triangular distribution.	No change. These are only included after EBSD, for any identified options
Demand related		
D1 - Accuracy of sub-component data	Normal distribution of ± 2%.	95% probability that the reading is within ± 3%
D2 - Demand forecast variation	Triangular distribution starting with 0 variation in first year, leading linearly to ±10% at the end of the planning period – household population growth Triangular distribution starting with 2% variation in first year, leading linearly to ±10% at the end of the planning period – per capita consumption	Triangular distribution using the central demand forecast, lower demand forecast and higher demand forecast to determine the min, most likely and max uncertainty range
D3 - Uncertainty of impact of climate change on demand	The difference between the maximum potential impact and the best estimate impact was applied to changing demand (PCC and population) over time to provide the volumetric estimate of uncertainty of climate change impacts on demand.	Triangular distribution using the 50th percentile climate change scenario (most likely), 10th percentile climate change scenario (low climate change) and the 90th percentile climate change projections (high climate change) to determine the min, most likely and max uncertainty range.
D4 - Uncertain outcome from demand management measures	As in S9	No change. These are only included after EBSD, for any identified options.

3.1.1 S1 Vulnerable Surface water licences

No vulnerable surface water licences have been identified; therefore risk/uncertainty allowance for this factor was excluded from this assessment.

3.1.2 S2 Vulnerable Groundwater licences

No vulnerable groundwater licences have been identified; therefore risk/uncertainty allowance for this factor was excluded from this assessment.

3.1.3 S3 Time Limited Licences

The Environment Agency's updated WRPG (April 2017)[2] states that an allowance for uncertainty relating to the non-renewal of time limited licences should be considered. Any allowance for uncertainty related to sustainability changes to permanent licences should not be included, "as the Environment Agency or Natural Resources Wales will work with the company to ensure that these do not impact security of supply". This factor was therefore excluded from the headroom analysis.

3.1.4 S4 Bulk imports

SES Water only has a bulk supply agreement with Scottish and Southern Energy. There are no bulk imports; therefore this factor was excluded from the analysis.

3.1.5 S5 Gradual pollution

This category of the assessment considers the vulnerability of sources to gradual pollution. Some of the factors considered were whether the aquifer was confined or unconfined, as unconfined aquifers are vulnerable to pollution, whether there were any sources of either point or diffuse pollution near the abstraction sites and the treatment capability for these potential sources of pollution, whether there has been historic loss of DO due to a pollution/contamination event at the sites, and whether there are observed water quality trends. Three areas were identified as risk of gradual pollution:

1. The sources in the unconfined chalk are at risk from cryptosporidium and nitrate pollution. Although there is some treatment in place to remove pollutants, there is a suspicion that the water quality is likely to deteriorate further in the near future. To represent this uncertainty, a triangular distribution has been used with a maximum of 3% probability of zonal loss of DO per AMP period, best estimate of 2% and minimum of 0%.
2. Lower Greensand sources are vulnerable to pollution from local landfill sites and have a history of contamination. In order to represent uncertainty associate with these sources, a triangular distribution has been used with a maximum loss of 5% of the aquifer group DO per AMP period, minimum loss of 0% and best estimate of 3% per AMP period.
3. There is concern that the water quality in Bough Beach Reservoir is likely to deteriorate as a result of increased use of pesticides, and potential cryptosporidium contamination. Although treatment is in place to deal with this, pesticides are not always effectively removed therefore some risk still remains. This is represented by a triangular distribution assuming a maximum zonal loss of 2.5% per AMP, a best estimate of 1.5% loss of zonal DO and a minimum loss of 0%.
4. The confined chalk is considered to be at a low risk of contamination therefore a triangular distribution with a maximum loss of 1% of the aquifer group DO per AMP period, minimum loss of 0% and best estimate of 0.5% per AMP period, has been used to represent the uncertainty.

The uncertainties used for this category are summarised in Table 3-2 below.

[2] Environment Agency, Final Water Resources Planning Guideline, May 2016

Table 3-2: S5 headroom uncertainty probability distribution summary data

	Uncertainty range (DYAA)			Uncertainty range (DYCP)		
	Maximum	Best	Minimum	Maximum	Best	Minimum
Unconfined Chalk	4.33	2.89	0.00	6.22	4.14	0.00
Lower Greensand sources	1.84	1.10	0.00	2.23	1.34	0.00
Bough Beech	0.65	0.39	0.00	0.79	0.47	0.00
Confined Chalk	0.08	0.04	0.00	0.17	0.09	0.00

3.1.6 S6 Accuracy of supply side data

S6/1: Uncertainty for yields constrained by pump capacity

SES Water groundwater DO assessments use actual pumping rates rather than nominal pumping capacities; hence this component does not apply.

S6/2 Meter uncertainty for licence critical sources

It is assumed that all sources are subject to meter uncertainty. A ± 5% uncertainty allowance has therefore been included in this analysis with a 95% probability that the value is within this range. A normal probability distribution has been adopted to represent the range of uncertainty, around a mean of 0 Ml/d as shown in Table 3-3.

S6/3 Uncertainty for aquifer constrained groundwater sources

A ± 5% uncertainty allowance has been included in this analysis with a 95% probability that the value is within this range. A normal probability distribution has been adopted to represent the range of uncertainty, around a mean of 0 Ml/d as shown in Table 3-3.

S6/4Uncertainty for climate and catchment characteristics affecting surface waters

Uncertainty around the accuracy of river flow measurements associated with Bough Beach has been included in this assessment. The UKWIR, 2002 guidance suggests that an accuracy of ± 10% should be assumed for catchments/sources with long records and/or where the catchments are large. A ± 10% uncertainty allowance has therefore been chosen for Bough Beach, with a 95% probability that the value is within this range. A normal probability distribution has been adopted to represent the range of uncertainty, around a mean of 0 Ml/d. This is shown in Table 3-3.

Table 3-3: S6/2 headroom uncertainty probability distribution summary data

	Uncertainty range (DYAA)				Uncertainty range (DYCP)			
Source name	**MDO (Ml/d)**	**Min**	**Max**	**STDEV**	**PDO (Ml/d)**	**Min**	**Max**	**STDEV**
Cheam	8.9	-0.45	0.45	0.23	12	-0.60	0.60	0.31
Cheam Park	1.19	-0.06	0.06	0.03	1.3	-0.07	0.07	0.03
Nonsuch Park	5	-0.25	0.25	0.13	12	-0.60	0.60	0.31
Sutton	9.5	-0.48	0.48	0.24	17.2	-0.86	0.86	0.44
Sutton Ct Rd	0.8	-0.04	0.04	0.02	1.45	-0.07	0.07	0.04
Hackbridge & Goatbridge	8.47	-0.42	0.42	0.22	17.2	-0.86	0.86	0.44
Oaks	4.5	-0.23	0.23	0.11	9.92	-0.50	0.50	0.25
Holly Lane	6.13	-0.31	0.31	0.16	6.5	-0.33	0.33	0.17
Woodmansterne	15	-0.75	0.75	0.38	16.5	-0.83	0.83	0.42
Smitham	5.68	-0.28	0.28	0.14	5.68	-0.28	0.28	0.14
Kenley	17.74	-0.89	0.89	0.45	22.08	-1.10	1.10	0.56
Purley	5.05	-0.25	0.25	0.13	19.2	-0.96	0.96	0.49
Fetcham Boreholes	0.94	-0.05	0.05	0.02	0.96	-0.05	0.05	0.02
Elmer & Young St	14.25	-0.71	0.71	0.36	17.05	-0.85	0.85	0.43
Leatherhead	27.92	-1.40	1.40	0.71	40.91	-2.05	2.05	1.04
Dorking	11.82	-0.59	0.59	0.30	11.82	-0.59	0.59	0.30
Clifton's Lane	0.87	-0.04	0.04	0.02	1.3	-0.07	0.07	0.03
Warwick Wold	3.25	-0.16	0.16	0.08	3.9	-0.20	0.20	0.10
Brewer Street	2.45	-0.12	0.12	0.06	2.55	-0.13	0.13	0.07
Bletchingley	2.05	-0.10	0.10	0.05	3.5	-0.18	0.18	0.09
North Park	3.5	-0.18	0.18	0.09	4.46	-0.22	0.22	0.11
Godstone	2.48	-0.12	0.12	0.06	2.6	-0.13	0.13	0.07
Flower Lane A&B	2	-0.10	0.10	0.05	2.05	-0.10	0.10	0.05
Flower Lane C	0	0.00	0.00	0.00	1.32	-0.07	0.07	0.03
South Green	2.18	-0.11	0.11	0.06	2.18	-0.11	0.11	0.06
Westwood	2.7	-0.14	0.14	0.07	5.61	-0.28	0.28	0.14
Bough Beech	26.1	-2.61	2.61	0.65	26.1	-3.16	3.16	0.79

3.1.7 S8 Impact of Climate Change on Deployable Output

The minimum, mean and maximum climate change impacts on DO for the 2080s were calculated from eleven Future Flows Climate scenarios (AECOM, 2017). These values were then used in this assessment to determine the uncertainties using a triangular distribution to represent the potential variation from the most likely impacts if either the low or high impacts were to apply. The parameters of each triangular distribution were therefore calculated as follows:

Minimum = Low – most likely in Ml/d (a negative value)

Most Likely = 0 (i.e. zero uncertainty)

Maximum = High – most likely forecast in Ml/d (a positive value)

This approach is consistent with WRMP14. The minimum and maximum values are shown in Table 3-4; however the most likely is not shown as it is zero for both scenarios across all the years.

Table 3-4: S8 headroom uncertainty probability distribution summary data

AMP	Uncertainty range DYAA (Ml/d)		Uncertainty range DYCP (Ml/d)	
	Min	Max	Min	Max
2015/16	-1.68	1.68	-4.50	2.63
2019/20	-1.84	1.85	-4.95	2.89
2024/25	-2.05	2.06	-5.51	3.22
2029/30	-2.26	2.27	-6.08	3.55
2034/35	-2.47	2.48	-6.64	3.88
2039/40	-2.68	2.69	-7.20	4.21
2044/45	-2.89	2.90	-7.76	4.53
2049/50	-3.10	3.11	-8.33	4.86
2054/55	-3.31	3.32	-8.89	5.19
2059/60	-3.52	3.53	-9.45	5.52
2064/65	-3.73	3.74	-10.01	5.85
2069/70	-3.94	3.95	-10.58	6.18
2074/75	-4.15	4.16	-11.14	6.51
2079/80	-4.36	4.37	-11.70	6.83

3.1.8 S9 New Sources

This has not been included at this stage. Should the Economics of Balancing Supply and Demand (EBSD) modelling identify that new supply schemes are required, a second headroom assessment will be undertaken after the selected options are included in the Water Available For Use (WAFU) estimates.

3.1.9 D1 Accuracy of sub-component demand data

An allowance of ± 3% has been included to represent the uncertainty in the accuracy of distribution input (DI) meters, with a 95% probability that the value is within this range. A normal probability distribution has been adopted to represent the range of uncertainty, around a mean of 0 Ml/d as shown in Table 3-5. It should be noted that these meters are typically located at the point of distribution and are not the same as those used to measure abstraction, so this avoids double-counting with factor S6/2 (see Section 3.1.6).

Table 3-5: D1 headroom uncertainty probability distribution summary data

AMP	Uncertainty range DYAA (Ml/d)				Uncertainty range DYCP (Ml/d)			
	Average Demand	Min	Max	STDEV	Peak Demand	Min	Max	STDEV
2015/16	137.22	-4.12	4.12	2.10	177.92	-5.33	5.33	2.72
2019/20	137.66	-4.13	4.13	2.11	178.9	-5.32	5.32	2.72
2024/25	139.68	-4.19	4.19	2.14	181.99	-5.37	5.37	2.74
2029/30	142.87	-4.29	4.29	2.19	186.82	-5.48	5.48	2.79
2034/35	144.86	-4.35	4.35	2.22	190.01	-5.53	5.53	2.82
2039/40	147.37	-4.42	4.42	2.26	193.92	-5.6	5.6	2.86
2044/45	151.27	-4.54	4.54	2.32	199.81	-5.73	5.73	2.92
2049/50	155.11	-4.65	4.65	2.37	205.62	-5.86	5.86	2.99
2054/55	158.59	-4.76	4.76	2.43	210.95	-5.97	5.97	3.05
2059/60	161.82	-4.85	4.85	2.48	215.97	-6.07	6.07	3.10
2064/65	164.82	-4.94	4.94	2.52	220.68	-6.15	6.15	3.14
2069/70	167.58	-5.03	5.03	2.57	225.06	-6.22	6.22	3.17
2074/75	170.10	-5.1	5.1	2.60	229.13	-6.27	6.27	3.20
2079/80	172.38	-5.17	5.17	2.64	232.87	-6.31	6.31	3.22

3.1.10 D2 Demand forecast variation

A triangular distribution has been used to express the probability distribution, starting with zero forecast variation in 2015/16 and leading linearly to an assumed error of ±10% at the end of the planning period. The Min and Max values are shown in Table 3-6; however the most likely is not shown as it is zero for both scenarios across all the years. This approach is consistent with WRMP14.

Table 3-6: D2 headroom uncertainty probability distribution summary data

AMP	Uncertainty range DYAA (Ml/d)			Uncertainty range DYCP (Ml/d)		
	Average Demand	Min	Max	Peak Demand	Min	Max
2015/16	137.22	-0.20	0.20	177.92	-0.28	0.28
2019/20	137.66	-1.10	1.09	178.90	-1.41	1.39
2024/25	139.68	-2.35	1.92	181.99	-2.93	2.50
2029/30	142.87	-3.42	3.04	186.82	-4.27	3.89
2034/35	144.86	-4.47	4.16	190.01	-5.63	5.33
2039/40	147.37	-5.68	5.46	193.92	-7.24	7.02
2044/45	151.27	-6.81	6.66	199.81	-8.75	8.59
2049/50	155.11	-7.90	7.75	205.62	-10.29	10.14
2054/55	158.59	-9.03	8.88	210.95	-11.89	11.74
2059/60	161.82	-10.27	10.12	215.97	-13.69	13.54
2064/65	164.82	-11.66	11.50	220.68	-15.67	15.51
2069/70	167.58	-13.18	13.03	225.06	-17.81	17.67
2074/75	170.10	-14.75	14.60	229.13	-20.17	20.02
2079/80	172.38	-16.51	16.36	232.87	-22.64	22.49

3.1.11 D3 Impact of climate change on demand

In order to incorporate the demand forecast scenarios into factor D3 of the headroom allowance, a triangular distribution has been adopted to represent the potential variation from the 'most likely' climate change demand forecast (50th percentile scenario) if either the 'No Climate Change' or 'High Climate Change' scenario (90th percentile) were to apply.

The parameters of each triangular distribution were therefore calculated as follows:

Minimum = No Climate Change – Most Likely forecast in Ml/d (a negative value)

Most Likely = 0 (i.e. zero uncertainty)

Maximum = High – Most Likely forecast in Ml/d (a positive value)

The triangular distributions for both scenarios considered in this analysis across the planning horizon to 2079/80 are shown in Table 3-7. The most likely values are not shown as they are zero for both scenarios across all the years.

Table 3-7: D3 headroom uncertainty probability distribution summary data

AMP	Uncertainty range DYAA (Ml/d)		Uncertainty range DYCP (Ml/d)	
	Min	Max	Min	Max
2015/16	0.00	0.00	0.00	0.00
2019/20	-0.04	0.04	-0.11	0.12
2024/25	-0.13	0.16	-0.38	0.43
2029/30	-0.22	0.27	-0.65	0.73
2034/35	-0.30	0.39	-0.93	1.03
2039/40	-0.39	0.50	-1.20	1.33
2044/45	-0.48	0.62	-1.47	1.63
2049/50	-0.57	0.73	-1.75	1.92
2054/55	-0.65	0.84	-2.02	2.22
2059/60	-0.74	0.95	-2.29	2.52
2064/65	-0.83	1.07	-2.57	2.82
2069/70	-0.92	1.18	-2.84	3.12
2074/75	-1.01	1.29	-3.11	3.42
2079/80	-1.10	1.41	-3.39	3.72

3.1.12 D4 Demand Management Measures

This has not been included at this stage. Should the Economics of Balancing Supply and Demand (EBSD) model identifies that new demand management schemes are required, a second headroom assessment will be undertaken after the selected options are included in the demand estimates.

3.2 Relationship between headroom components

Interdependencies between uncertainty factors have been incorporated within the Monte Carlo analysis. Interdependency is where the sampled value of one probability distribution is not completely independent of the value of another, i.e. there is some relationship between the two variables. The only interdependency identified in this assessment is between the impact of climate change on deployable output and on demand, i.e. the greater the increase in demand due to climate change, the greater the reduction in deployable output (both of which impacts have a positive effect on the calculated headroom allowance). This has been modelled by setting a positive correlation between the probability distribution functions for factor S8 and factor D3 respectively, in each year across the planning horizon.

3.3 Summary of key changes from WRMP14

Uncertainties associated with both abstraction and DI meter readings have been increased to ±3% (S6/2 and D1), and the uncertainty associated with aquifer constrained sources has been increased to ±5% following discussion with SES Water (Personal Communication with Alison Murphy, 14/08/2017).

Previous demand forecast variation included a 2% uncertainty in the beginning of the planning period leading linearly to an assumed error of ±10% at the end of the planning period for the non-household demand. Following discussions with Artesia, this assessment has used the upper, central and lower demand forecasts to determine the uncertainty associated with the demand forecast.

There has been a change in the methodology for estimating the impact of climate change on WAFU (including uncertainty) (S8) since WRMP14. Previously, UKCP09 monthly flow factors were used to obtain "dry" and "wet" predictions, which were used to give an estimate of uncertainty to include in the headroom. The new guidance specifies that where a WRZ is classified as Low Vulnerability and rainfall-runoff models are available, a "Tier 2" analysis should be undertaken as a minimum (Environment Agency, June 2016). This involves the use of the Future Flows Climate scenarios under a medium emissions scenario for the 2080s

4. Results

4.1 Worst drought on historic record

The results of the probabilistic assessment for the WDHR at the end of the planning period are summarised in Table 4-1 below (the full results from @RISK spreadsheet is contained in Appendix A).

Table 4-1: Target headroom (Ml/d) at the end of the planning period (2079/80)

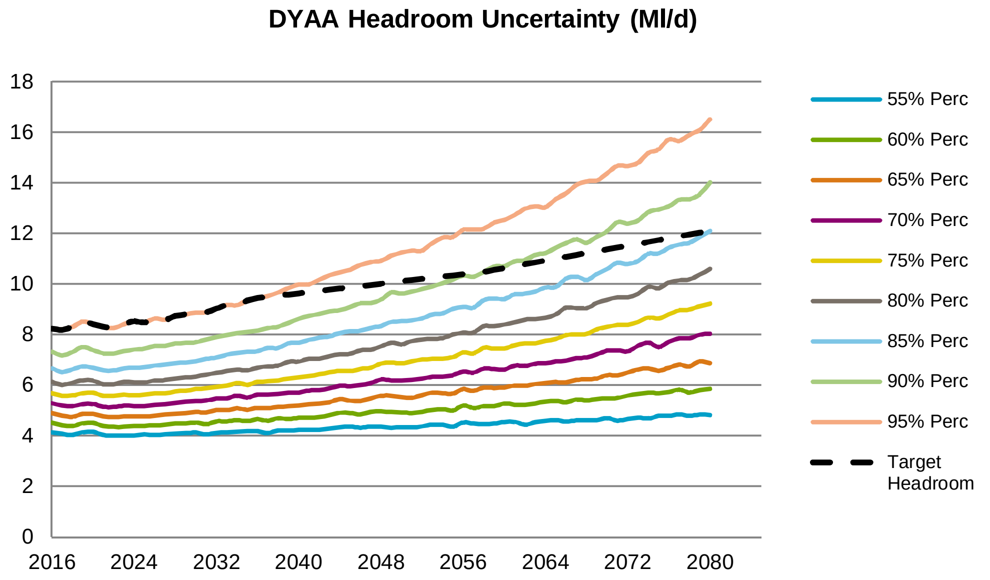
Planning scenario	Probability								
	55%	60%	65%	70%	75%	80%	85%*	90%	95%**
DYAA (Ml/d)	4.82	5.86	6.87	8.04	9.23	10.60	**12.11**	14.02	**16.50**
DYCP (Ml/d)	5.02	6.51	7.95	9.51	11.33	13.07	**15.19**	17.82	**21.35**

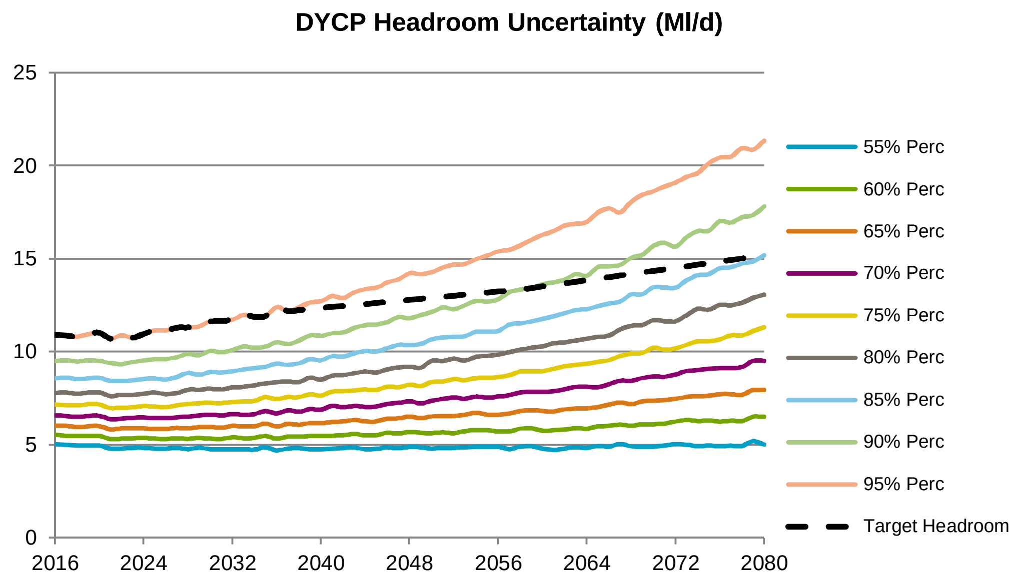
** Risk Percentile to be used at the end of the planning period*
*** Risk Percentile to be used at the start of the planning period*

The level of acceptable risk was determined to be 95% in the beginning of the planning period, falling to 85% at the end of the planning period. This was considered to be most appropriate in order to ensure the headroom is not so large that it drives unnecessary expenditure, and not too small that it leaves the possibility that the planned level of service cannot be met. A higher level of risk is more acceptable in the future than in the early years (first 5 years) because as time progresses, the uncertainties for which headroom allows reduce and there is more time to adapt to any changes. This is in line with the Environment Agency's updated WRPG (April 2017) which promotes the use of a glide path approach.

Figure 4-1 below summarises how the headroom uncertainty varies over time in each planning scenario as well as the target headroom based on the acceptable level of risk over the planning period. It can be seen that generally the uncertainty increases with time; however the glide path reflects the changing risk profile over time. A lower level of risk is acceptable in the early years (hence using the 95th percentile value) as there is little time to react and implement mitigation measures, while in the longer term there is more time to implement appropriate measures and so a higher level of risk is acceptable (85th percentile).

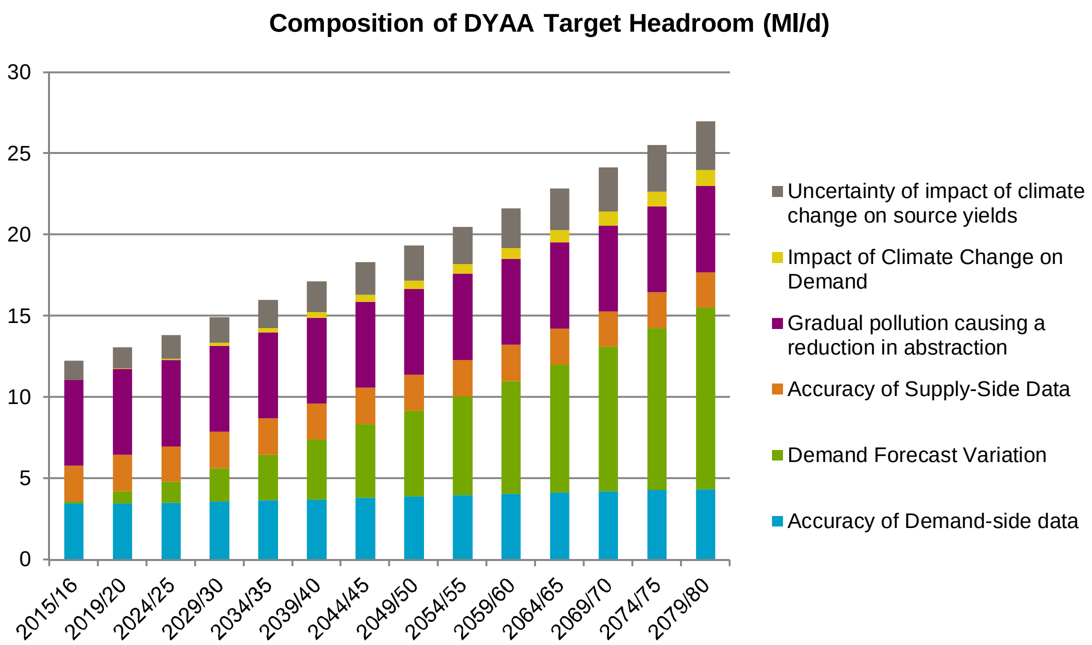
Figure 4-1: Headroom uncertainty and varying risk percentiles and Target Headroom - WDHR

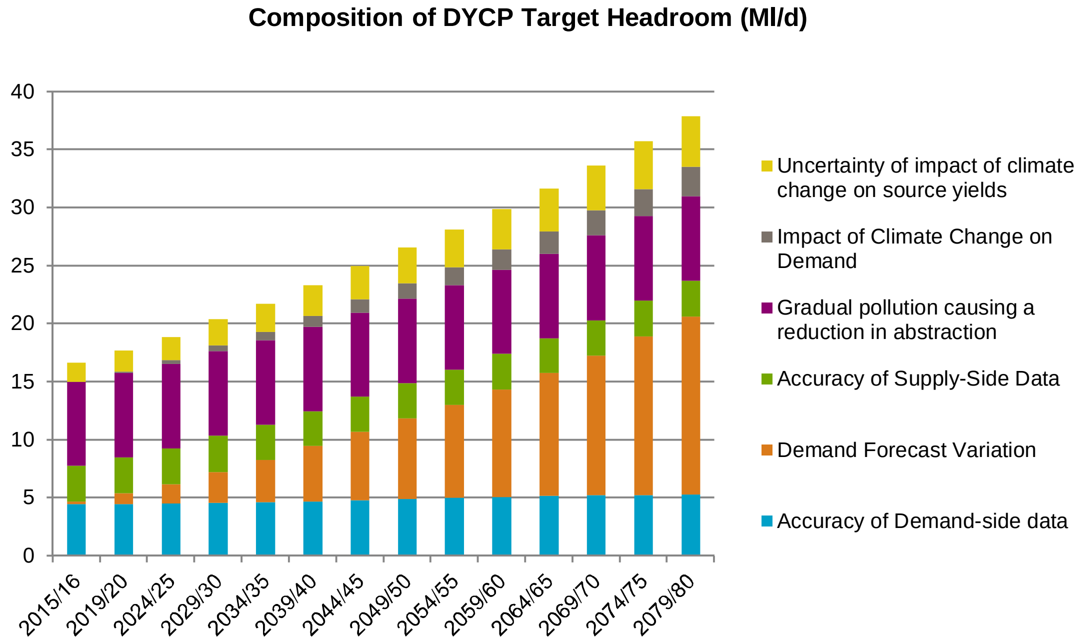




The relative contribution of the different components of the target headroom assessment is shown in Figure 4-2 below. It should be noted that the sum of the different categories in Figure 4-2 do not match the target headroom as shown in Figure 4-1. This is because the sum of the individual categories does not provide a statistically correct percentile impact for the overall target headroom. The sum of all these components' results is greater than the overall target headroom result, because statistically, the probability of all components experiencing the same percentile impact simultaneously is much smaller than a single headroom component experiencing a particular percentile impact. By using @Risk to sum all the categories within the model runs, the sums are done during each iteration of the model and therefore the target headroom allowance is lower than the sum of the individual categories.

Figure 4-2: Relative contribution of the different categories to the target headroom for both scenarios - WDHR





The contribution of “accuracy of demand and supply side data” and “gradual pollution of sources” is constant throughout the planning period. The uncertainties associated with the impact of climate change on source yields and demand, as well the demand forecast variation increase across the planning period, with the latter contributing the most to uncertainty by the end of the planning period.

4.2 Comparison with WRMP 14

The previous assessment produced a higher headroom allowance than this assessment, as can be seen in Table 4-2. This is because the total headroom allowance in WRMP14 was calculated by summing the uncertainty associated with the individual categories; while this assessment used @Risk to sum all the categories within the model runs which has resulted in a lower headroom allowance (see Section 4).

Table 4-2: SES Water Target Headroom Allowance comparison between WRMP14 and WRMP19

	Company headroom allowance DYAA WRMP14		Company headroom allowance DYCP WRMP14		Company headroom allowance DYAA WRMP19		Company headroom allowance DYCP WRMP19	
	2011/12	2039/40	2011/12	2039/40	2015/16	2079/80	2015/16	2079/80
Risk Percentile (%)	95th	85th	95th	85th	95th	85th	95th	85th
Target Headroom (Ml/d)	15.86	19.82	20.69	28.12	8.23	12.11	10.93	15.19
% WAFU	8	10	7	10	3.8	5.6	3.6	5.1

The WRMP19 assessment also predicts uncertainty over a longer planning period up to 2079/80 according to the new guidance (Environment Agency, June 2016).

4.3 1 in 200 year drought event

The target headroom was also assessed for the 1:200 year event scenario, using the same methodology described in Section 2 and the same assumptions as stated in Section 3. The main difference in this assessment was the impact of climate change on source yields, as determined in the *Deployable Output and Climate Change Impact Assessment Report* (AECOM 2017). The results of the probabilistic assessment at the end of the planning period are summarised in Table 4-3 below (the full results from @RISK spreadsheet is contained in Appendix B).

Table 4-3: Target headroom (Ml/d) at the end of the planning period (2079/80) – 1:200 year event

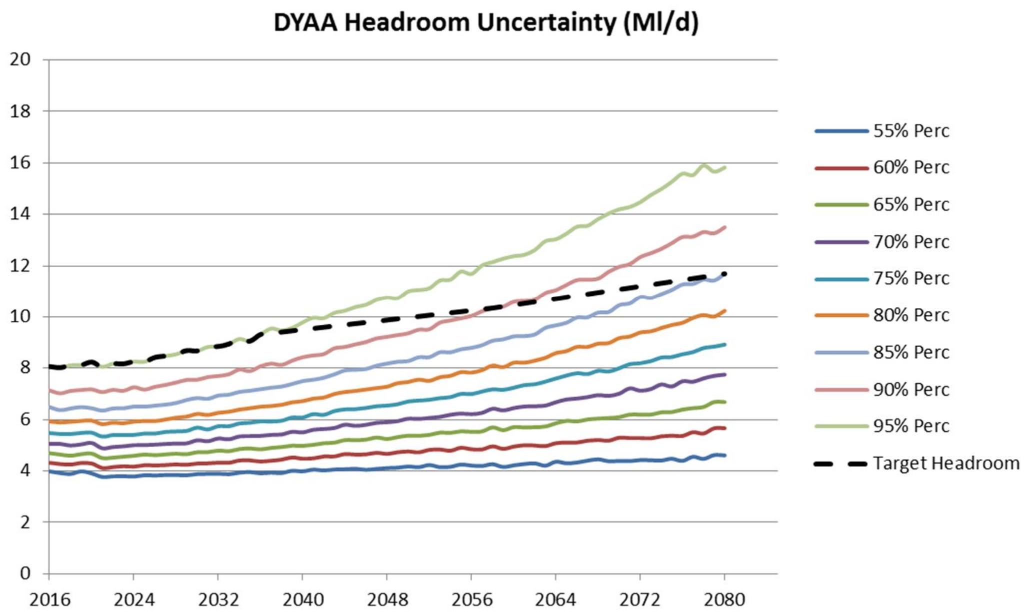
Planning scenario	Probability								
	55%	60%	65%	70%	75%	80%	85%*	90%	95%**
DYAA (Ml/d)	4.60	5.66	6.68	7.75	8.92	10.23	**11.69**	13.50	**15.82**
DYCP (Ml/d)	6.47	7.91	9.37	11.01	12.72	14.50	**16.61**	19.09	**22.77**

** Risk Percentile to be used at the end of the planning period*

*** Risk Percentile to be used at the start of the planning period*

Figure 4-3 below summarises how the headroom uncertainty varies over time in each planning scenario as well as the target headroom based on the acceptable level of risk over the planning period. It can be seen that generally the uncertainty increases with time; however the glide path reflects the changing risk profile over time. A lower level of risk is acceptable in the early years (hence using the 95th percentile value) as there is little time to react and implement mitigation measures, while in the longer term there is more time to implement appropriate measures and so a higher level of risk is acceptable (85th percentile).

Figure 4-3: Headroom uncertainty and varying risk percentiles and Target Headroom – 1:200 year event



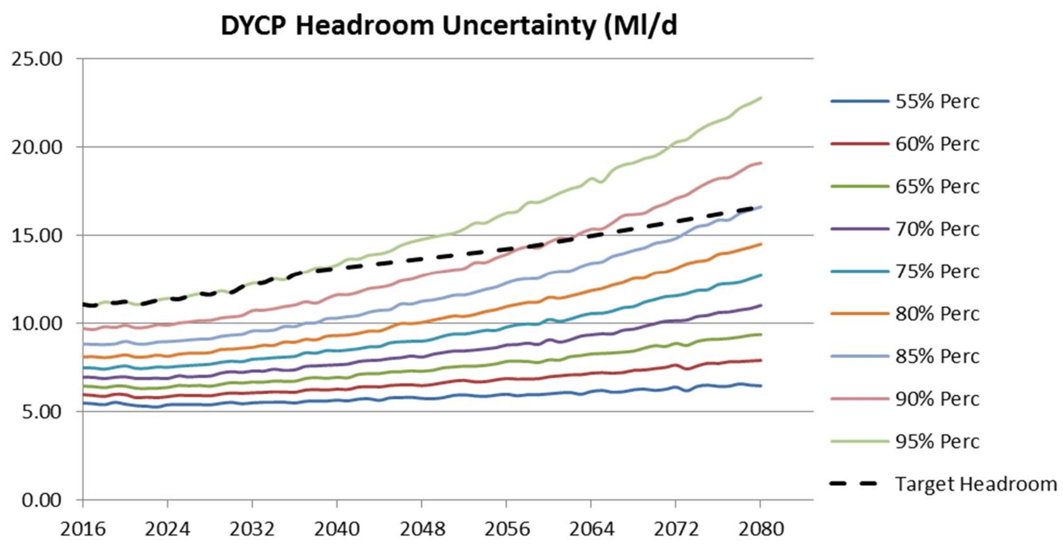
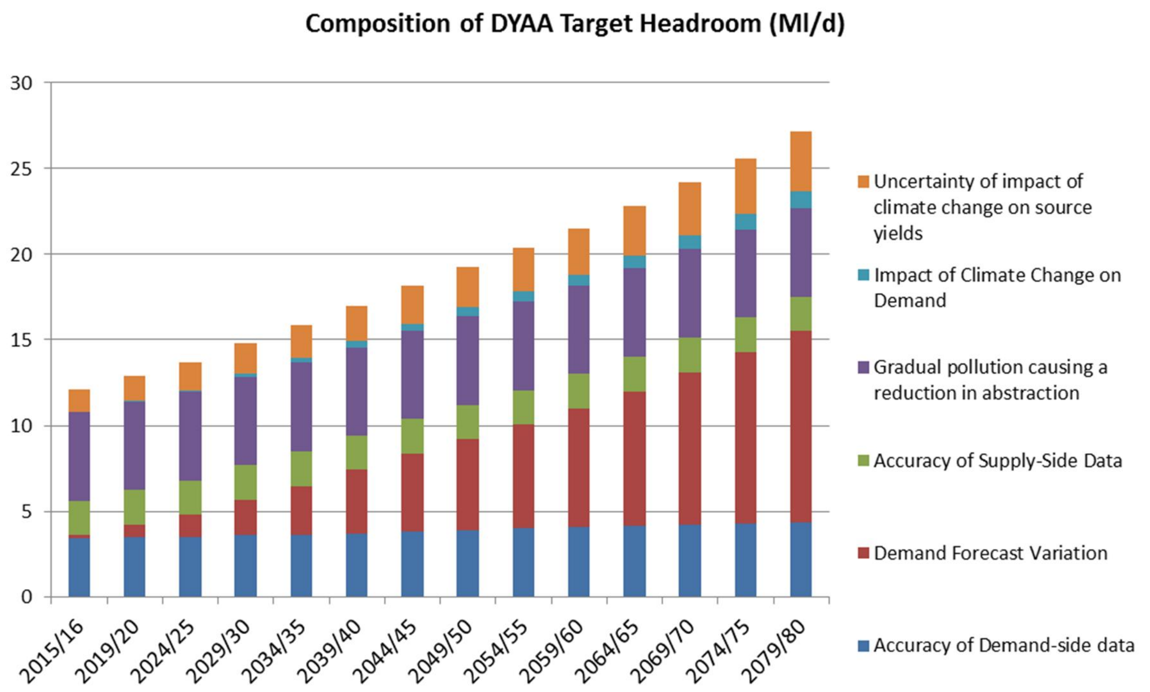
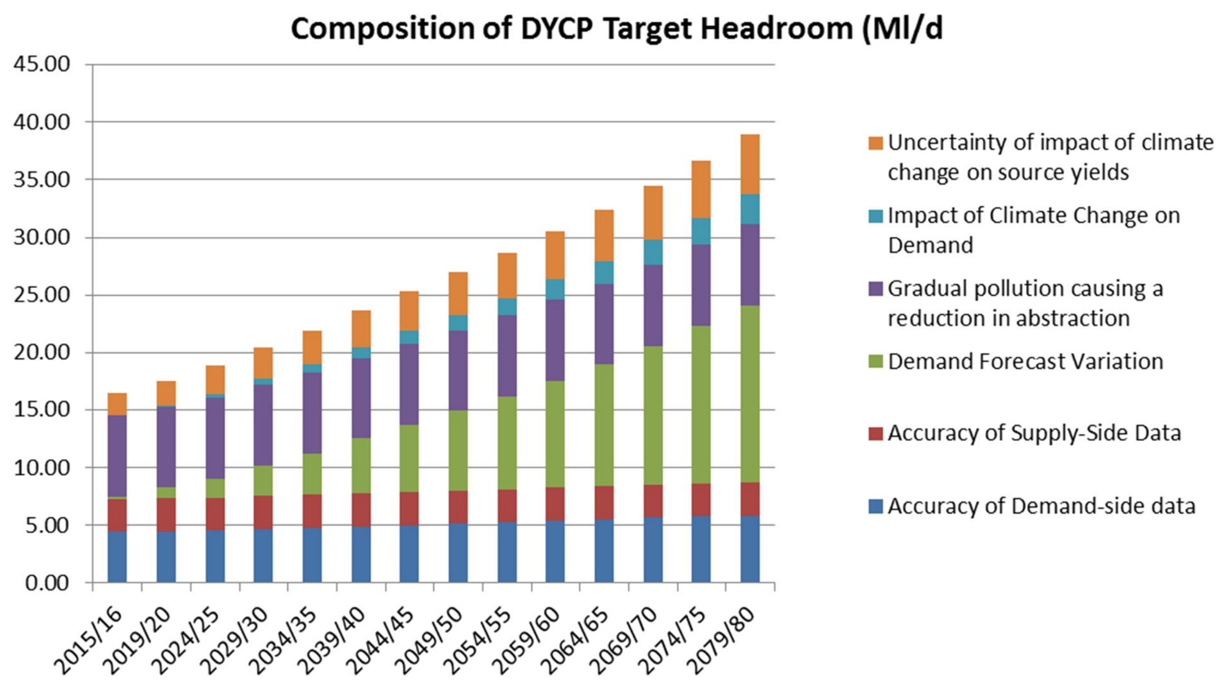


Figure 4-4: Relative contribution of the different categories to the target headroom for both scenarios – 1:200 year event





5. Conclusions

A headroom assessment for SES Water's dWRMP19 submission has been prepared. The assessment runs through to 2079/80, and has adopted the latest guidance provided by the Environment Agency.

In general, the assumptions made for WRMP14 have been followed through with this assessment. A slight change has taken place for category S8 (the impact of climate change on deployable output), D3 (the impact of climate change on demand) due to the new methodology for assessing the impact of climate change and to S6 and D1 (uncertainties associated with both abstraction and DI meter readings, and uncertainty associated with aquifer constrained sources), following discussions with SES Water. Following discussions with Artesia, the uncertainty associated with D2 has also been adapted to use the upper, central and lower forecast to determine the uncertainty rather than using a set variation at the end of the planning period.

A glide path approach has been adopted, whereby the level of acceptable risk is maintained at 95% for the next AMP period, reducing to 85% at the end of the planning period. This is in line with the latest Environment Agency guidance.

The results of the headroom assessment for the worst drought on historic record are 8.23 Ml/d for 2015/16 under the DYAA scenario and 10.93 Ml/d under the DYCP scenario; and 12.11 Ml/d for 2079/80 under the DYAA scenario and 15.19 Ml/d under the DYCP scenario. These figures are less than those produced and used in the WRMP14 due to a change in methodology for the summing of uncertainty associated with the individual categories.

The results of the headroom assessment for the 1 in 200 year event are 8.07 Ml/d for 2015/16 under the DYAA scenario and 11.07 Ml/d under the DYCP scenario; and 11.69 Ml/d for 2079/80 under the DYAA scenario and 16.61 Ml/d under the DYCP scenario. There were no figures produced and used in the WRMP14 for this event; therefore no comparison with previous results is possible.

6. Recommendations

- The dWRMP19 headroom assessment will need to be updated once the final supply and demand options are agreed.
- Stakeholder comments that arise from the dWRMP19 report should be taken on board for the final WRMP19.
- A final headroom assessment should be completed should EBSD (Economics of Balancing Supply and. Demand) modelling indicates the need for new supply/demand management options.

7. References

AECOM 2017. Water Supply – Deployable Output Assessment Report.

Environment Agency, April 2017. Water Resources Planning Guideline: Interim update (WRPG).

Environment Agency, June 2016. Estimating impacts of climate change on water supply.

Environment Agency, October 2012. Water Resources Planning Guideline (WRPG).

SES Water, 2014. Final Water Resource Management Plan.

UKWIR, 2014. Handbook of source yield methodologies.

UKWIR, 2002. An Improved Methodology for Assessing Headroom.

UKWIR, 2000. Unified Methodology for the Determination of Deployable Output.

UKWIR, 1998. A Practical Method for Converting Uncertainty into Headroom.

Appendix A - @Risk Spreadsheet Outputs for WDHR

A.1 DYAA Headroom Allowance by Probability

	55%	60%	65%	70%	75%	80%	85%	90%	95%
2015/16	4.13	4.53	4.91	5.29	5.69	6.14	6.67	7.33	8.23
2019/20	4.17	4.51	4.87	5.27	5.71	6.18	6.69	7.40	8.42
2024/25	4.05	4.40	4.76	5.18	5.64	6.11	6.72	7.45	8.48
2029/30	4.13	4.53	4.95	5.38	5.85	6.35	6.95	7.70	8.87
2034/35	4.18	4.59	5.04	5.52	6.02	6.59	7.33	8.11	9.35
2039/40	4.24	4.71	5.20	5.71	6.32	6.94	7.68	8.63	9.98
2044/45	4.37	4.91	5.39	5.96	6.56	7.25	8.13	9.10	10.57
2049/50	4.35	4.94	5.54	6.19	6.86	7.62	8.53	9.63	11.24
2054/55	4.37	5.00	5.67	6.40	7.11	8.01	9.02	10.19	11.86
2059/60	4.55	5.29	5.92	6.63	7.46	8.40	9.41	10.71	12.54
2064/65	4.63	5.39	6.13	6.94	7.84	8.81	9.89	11.43	13.36
2069/70	4.71	5.49	6.40	7.37	8.31	9.39	10.60	12.09	14.38
2074/75	4.79	5.69	6.58	7.51	8.65	9.84	11.21	12.95	15.33
2079/80	4.82	5.86	6.87	8.04	9.23	10.60	12.11	14.02	16.50

A.2 DYCP Headroom Allowance by Probability

	55%	60%	65%	70%	75%	80%	85%	90%	95%
2015/16	5.02	5.54	6.03	6.58	7.15	7.80	8.59	9.51	10.93
2019/20	4.95	5.48	6.01	6.56	7.17	7.81	8.59	9.52	11.03
2024/25	4.80	5.33	5.85	6.44	7.05	7.81	8.57	9.60	11.16
2029/30	4.76	5.34	5.98	6.62	7.26	8.02	8.91	10.06	11.63
2034/35	4.87	5.47	6.14	6.81	7.57	8.30	9.21	10.29	11.93
2039/40	4.77	5.48	6.16	6.90	7.65	8.51	9.55	10.86	12.72
2044/45	4.78	5.53	6.26	7.07	7.95	8.90	10.02	11.47	13.46
2049/50	4.81	5.63	6.53	7.38	8.38	9.52	10.68	12.14	14.27
2054/55	4.89	5.79	6.63	7.53	8.60	9.79	11.09	12.71	15.18
2059/60	4.79	5.77	6.81	7.85	8.97	10.30	11.78	13.63	16.30
2064/65	4.93	5.98	7.03	8.11	9.46	10.80	12.46	14.56	17.50
2069/70	4.90	6.10	7.37	8.68	10.22	11.71	13.48	15.70	18.63
2074/75	4.97	6.30	7.65	9.08	10.56	12.27	14.18	16.52	20.14
2079/80	5.02	6.51	7.95	9.51	11.33	13.07	15.19	17.82	21.35

Appendix B - @Risk Spreadsheet Outputs for 1:200 year event

B.1 DYAA Headroom Allowance by Probability

	55%	60%	65%	70%	75%	80%	85%	90%	95%
2015/16	3.98	4.32	4.69	5.06	5.47	5.93	6.49	7.13	8.07
2019/20	3.90	4.29	4.67	5.09	5.49	5.96	6.44	7.17	8.24
2024/25	3.83	4.22	4.64	5.00	5.46	5.94	6.50	7.17	8.25
2029/30	3.88	4.29	4.73	5.19	5.69	6.22	6.84	7.55	8.67
2034/35	3.96	4.41	4.87	5.35	5.88	6.44	7.12	7.88	9.05
2039/40	3.99	4.47	4.98	5.50	6.08	6.72	7.50	8.43	9.79
2044/45	4.08	4.64	5.19	5.76	6.41	7.11	7.94	8.93	10.38
2049/50	4.17	4.76	5.37	6.03	6.70	7.46	8.28	9.36	11.00
2054/55	4.25	4.90	5.54	6.23	7.00	7.84	8.73	9.95	11.78
2059/60	4.22	4.95	5.70	6.44	7.24	8.21	9.24	10.59	12.38
2064/65	4.30	5.11	5.95	6.78	7.71	8.66	9.77	11.26	13.25
2069/70	4.39	5.29	6.09	7.01	8.00	9.17	10.46	11.96	14.20
2074/75	4.47	5.37	6.29	7.29	8.43	9.68	11.06	12.88	15.27
2079/80	4.60	5.66	6.68	7.75	8.92	10.23	11.69	13.50	15.82

B.2 DYCP Headroom Allowance by Probability

	55%	60%	65%	70%	75%	80%	85%	90%	95%
2015/16	5.50	5.97	6.45	6.96	7.48	8.10	8.83	9.71	11.07
2019/20	5.43	5.96	6.45	6.98	7.59	8.22	8.98	9.89	11.22
2024/25	5.41	5.93	6.49	7.03	7.58	8.26	9.01	10.01	11.37
2029/30	5.53	6.07	6.65	7.27	7.86	8.53	9.33	10.36	11.75
2034/35	5.54	6.12	6.72	7.34	8.09	8.94	9.82	10.95	12.48
2039/40	5.66	6.28	6.95	7.65	8.44	9.31	10.29	11.62	13.32
2044/45	5.79	6.49	7.25	8.01	8.90	9.78	10.78	12.16	14.11
2049/50	5.80	6.64	7.49	8.35	9.28	10.30	11.44	12.95	15.02
2054/55	5.94	6.81	7.71	8.63	9.60	10.77	12.06	13.72	16.01
2059/60	6.02	6.98	7.94	9.07	10.22	11.47	12.84	14.61	17.10
2064/65	6.21	7.21	8.29	9.41	10.57	11.97	13.49	15.36	18.03
2069/70	6.21	7.44	8.73	9.98	11.35	12.86	14.54	16.58	19.49
2074/75	6.50	7.75	9.08	10.45	11.90	13.61	15.60	17.98	21.23
2079/80	6.47	7.91	9.37	11.01	12.72	14.50	16.61	19.09	22.77