Thames Water

Final Water Resources Management Plan 2019

Technical Appendices

Appendix H: Dry year and critical period forecasting

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Dry year and critical period forecasting

A. Scenario forecasting

H.1 Demand for water in any given year is a function of the prevailing weather conditions in that year; cold winters drive up leakage and hot, dry summers increase usage. We can use models of weather-dependent demand coupled with long histories of weather data to derive the range of possible demand scenarios that may have been observed had the weather conditions been different. Understanding the range of demand in these scenarios allows us to produce distribution input (DI) forecasts for Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP) scenarios as required by Section 3.5 of the Water Resource Planning Guidelines[1]

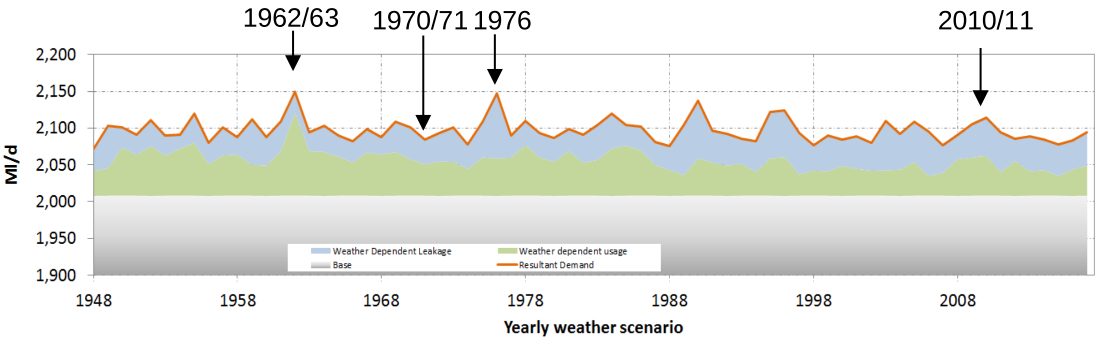
H.2 This section describes how the above may be estimated using the weather-dependent characteristics of demand and its sub-components of leakage and water delivered.

Modelling variability in demand due to the weather

H.3 The prevailing weather conditions for any given year affect the out-turned levels of leakage and usage and hence overall demand. Mechanisms have been developed (using weather-dependent models) that allow the observed demand, usage and leakage for any given year to be placed in the context of a range of other (historically observed) weather conditions.

H.4 Figure H-1 shows the range of DI estimates of the level of demand that was observed in previous years.

Figure H-1: Illustrative demand scenarios (London) generated based on historic weather patterns



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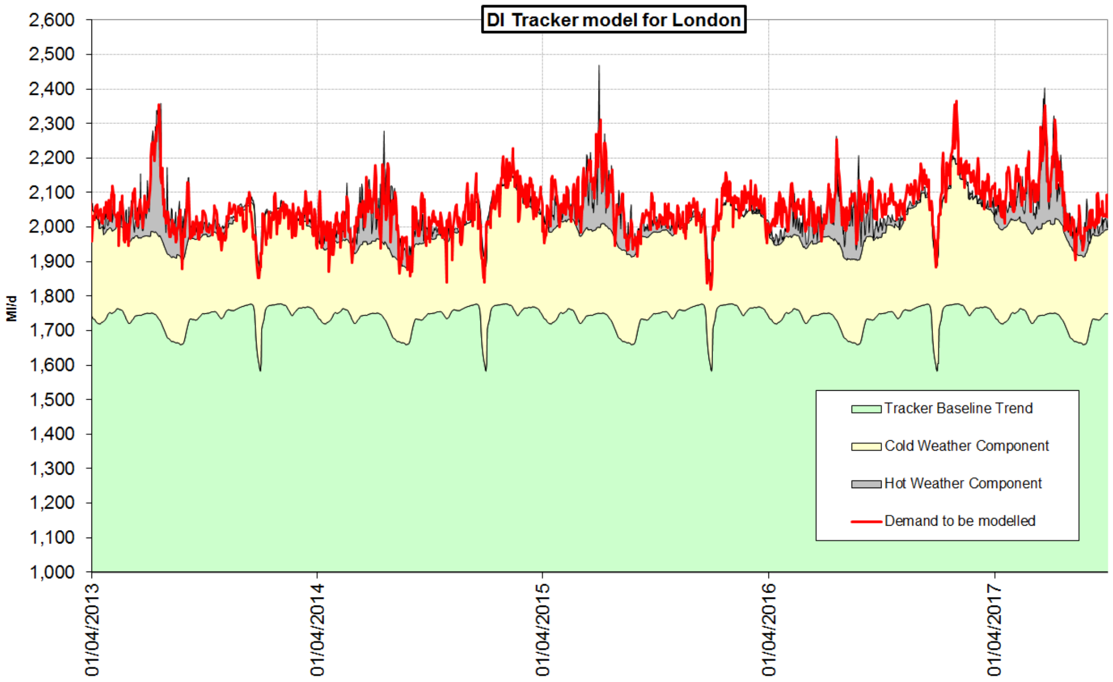
[1] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update April 2017

H.5 The annual average (AA) figures plotted in Figure H-1 have been aggregated up from a weather dependent model with daily resolution as shown in Figure H-2 below. The daily model explains over 90% of the variability in summer demand and accurately tracks both the timing and amplitude of the peaks in demand. This model is used in the quantification of both dry-year AA demand and that of the critical period maximum rolling seven day demand.

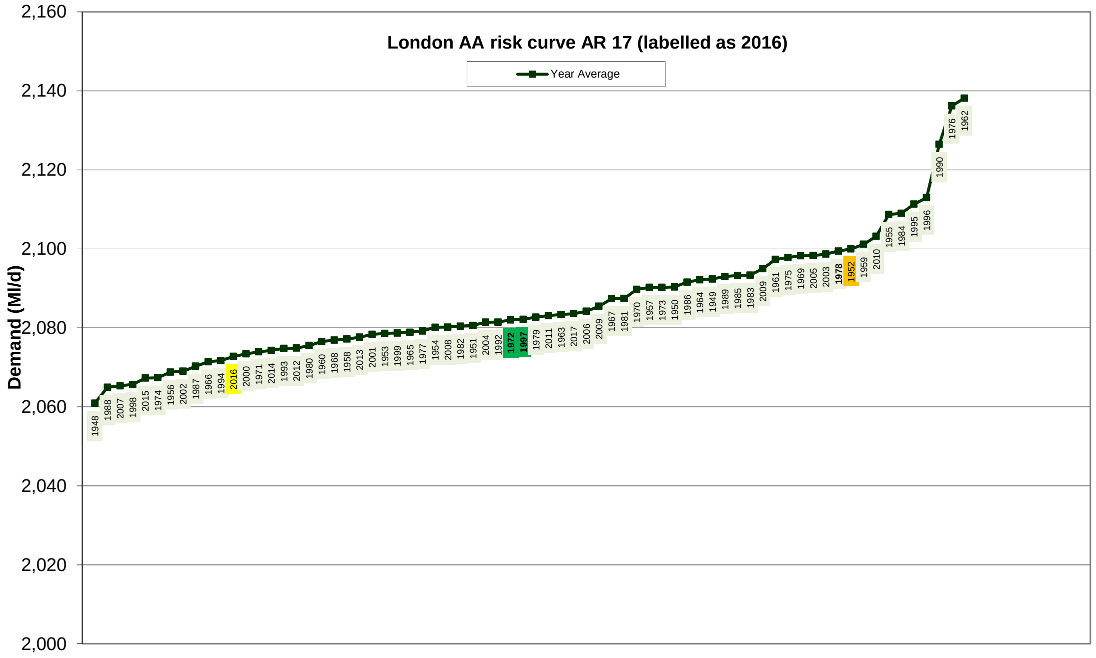
Figure H-2: Observed daily demand plotted with a daily weather-dependent model #



H.6 In Figure H-1 it can be seen that DI in 2016/17 was higher than it could have been under some “milder” conditions (e.g. around 1970), but lower than it could have been under more extreme conditions (e.g. in 1963 or in 1976). As discussed, total demand is composed of usage and leakage, both of which are affected by the extremity of the weather conditions; AA usage is dependent on summer weather conditions whilst leakage is dominated by the severity of the winter. If the high demand as modelled from 1976 was predominately driven by an extremely hot and dry summer that would have driven high summer usage, whilst the high demand in 1962/63 was due to the prolonged extremely cold winter, driving high levels of leakage.

H.7 When ranked in ascending order according to overall demand, the resultant curve (as shown in Figure H-3) can be used to help understand the likelihood of experiencing certain levels of demand.

Figure H-3: AA demand scenarios (London, post MLE) ranked in ascending order (Cumulative Density Function)



H.8 For illustrative purposes, taken at face value, the yearly average curve shown in Figure H-3 suggests:

- Demand in London can range between 2,060 and 2,138 Ml/d as a function of weather[2]. Most scenarios show demand below 2,100 Ml/d
- Between the two extremes, the probability of demand not exceeding a given level can be read from the position along the x-axis, and vice-versa. Moving from left to right on the curve, there is a 0% probability that demand will be below 2,060 Ml/d, there is a 100% probability that demand will be below 2,138 Ml/d
- Normal (1 in 2) Year: The demand at the mid-point (50th percentile, or median) is the most likely level of demand that may be observed in any one year
- 1 in 10 Year: The demand at the 90th percentile is taken to represent the largest value that demand may rise to with a 1 in 10 year return period[3]

H.9 We use curves such as that shown in Figure H-3 to derive levels of usage, leakage and demand that would be expected under normal and dry conditions. The dry-year[2] demand is reported as the combined impact of the joint contribution of 1 in 5 year levels of leakage and usage.

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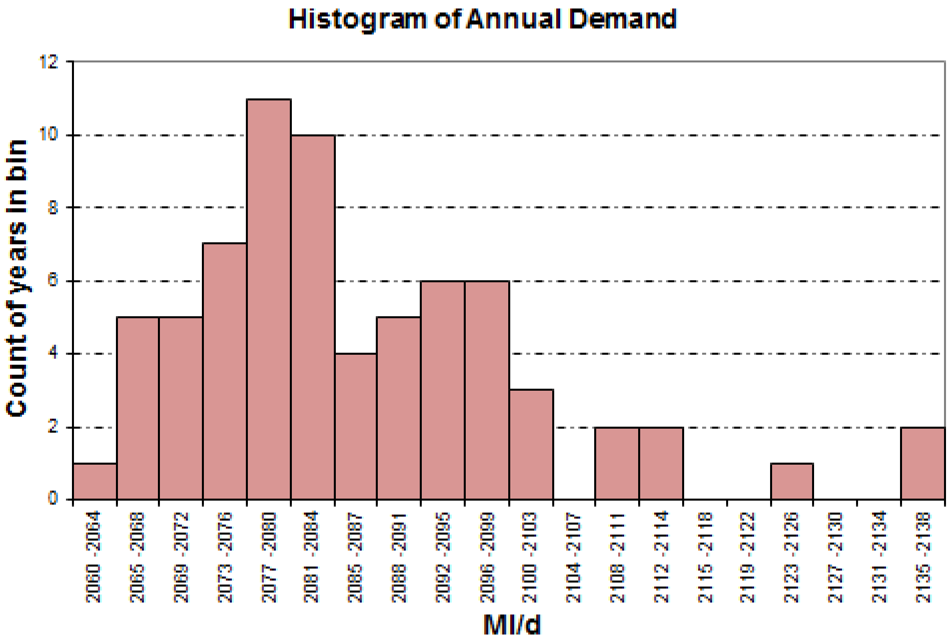
[2] The minimum demand of 2,060 Ml/d is under mild summer and winter conditions, the higher scenarios are a mixture of either extreme winters or extreme summers, rarely both together.

[3] Until AR12 we used the 1 in 10 levels of demand to represent the demand during the "dry-year". In 2012 we moved towards a more refined definition of dry-year that considered the return periods of the leakage and usage components of demand independently.

Characterising variability in demand due to the weather

H.10 The data in Figure H-3 can be re-presented as a probability density function as shown in Figure H-4 below showing the relative likelihood of various demand scenarios more clearly.

Figure H-4: Empirical PDF[4] showing likelihood of various ranges of demand in London



H.11 During droughts, we can intervene to deploy specific measures (such as Temporary Use Bans). Under these conditions, demand becomes artificially constrained and the unconstrained model is no longer valid. In reality, during the weather conditions that would drive the highest demand (at return periods of about 1 in 20), interventions would be brought to bear to manage demand down. In this analysis we assume that demand would effectively be “clipped” at levels observed at the 90th percentile, resulting in demands greater than 2,111 Ml/d being moved into that bin. The adjusted probability distribution would look something like the one shown in Figure H-5.

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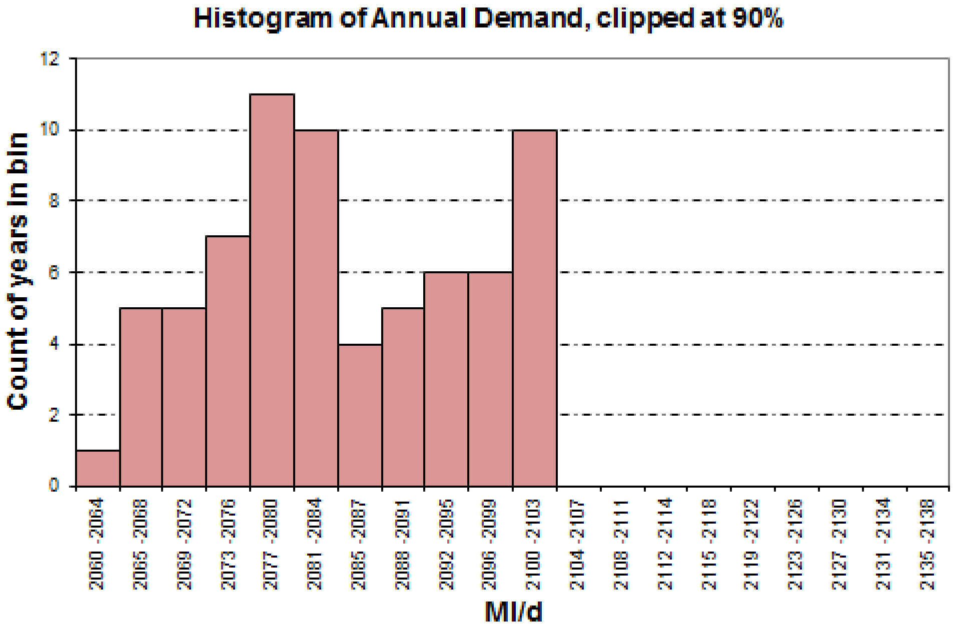
[4] Probability distribution functions

Figure H-5: Empirical PDF of demand in London with extreme high values clipped to 1-in-10



H.12 The distribution of weather-dependent demand shown in Figure H-5 is positively skewed and is biased towards high values and has a broader than normal peak. These properties make the median and average of the curve different, and have implications when estimating the long-run average demand. Key statistics can be calculated from Figure H-5 for London and for the equivalent data from the Thames Valley water resource zones (WRZs) as shown in Table H-1 below.

Table H-1: Key statistics from AA demand risk

WRZ	Dry year (1in5 +1in5) AA (Ml/d)	Normal year (1in2) AA (Ml/d)
London AA	2105.3	2082.2
SWA AA	144.0	142.8
HEN AA	12.5	12.3
GUI AA	45.4	44.8
KEN AA	101.5	100.3
SWOX AA	271.2	268.9

In the context of the Water Resource Planning Guidelines

H.13 WRPG section 2.6 outlines which planning scenarios a water company should calculate and publish. The various scenarios are relevant to differing aspects of resource management. They are listed in Table H-2.

Table H-2: Planning scenarios set out in the WRPG

Scenario	Purpose	Description	Thames Water's implementation
DYAA	Water resource management planning	The level of demand, which is just equal to the maximum AA, which can be met at any time without introducing demand restrictions. This should be based on continuation of current demand management policies. The DYAA should be expressed as the total demand divided by the number of days in the year (Ml/d).	Until AR12, we reported the demand likely at a return period of 1 in 10 (90th percentile of cumulative risk curve (Figure H-3). When the demand is clipped at this level it represents the maximum demand on the system. In AR12 we moved to an alternative representation with an equivalent AA by disaggregating demand into reporting demand, usage and leakage as the joint impact of 1 in 5 usage and 1 in 5 leakage.
DYCP	Water resource management planning	Companies might consider critical period scenarios where a water resource zone is supplied only by ground water or run of river abstractions and limited storage, or where the water resource zone supply demand balances are judged to be particularly sensitive to peak demand and where resource management rather than operational measures are required. Alternatively, the critical period might be determined by the period during which the supply demand balance is at its lowest, for example when deployable output is at its minimum	As per the AA figure, but based on the peak rolling week of demand in the summer. Note: the methodology for estimating the critical period has been set out as part of the AR and is not revisited in this paper.

B. Dry year figures

H.14 As described in Section H.A, one can articulate the variability in demand in terms of overall demand, or in terms of usage and leakage independently. By disaggregating demand into usage and leakage we can refine the estimates of dry years and report them as an appropriate combination of probable figures for usage and leakage[5].

Table H-3: DYAA uplift

WRZ	Uplift from AR17 to Dry-year (1in5 +1in5) AA (Ml/d)	Dry year (1in5 +1in5) AA (Ml/d)
London AA	32.50	2,105.3
SWA AA	1.13	144.0
HEN AA	0.23	12.5
GUI AA	0.65	45.4
KEN AA	1.63	101.5
SWOX AA	2.50	271.2

H.15 For more information on the sensitivity of usage and leakage to weather, please refer to sections 'Analysis of weather-dependent usage' and 'Analysis of weather-dependent leakage' below. Section 'Critical period peaking factors' (below) investigates the weighting that would be required to estimate long run average values based on a weighted combination of the 1 in 2 year and 1 in 10 year figures reported in our Annual Returns.

Analysis of weather-dependent usage

H.16 Section H.A described how scenarios driven from a number of historic weather scenarios can be used to estimate 1 in 2 year, 1 in 10 year and average figures for demand. The same process can be applied to the weather-dependent[6] usage and leakage. The analysis of usage can be used to estimate the variability in consumption. As revenue is specifically a function of usage, it is useful to understand how much of the overall variability in demand can be attributed to it. Figure H-6 shows PDFs for unconstrained weather-dependent usage and the equivalent PDF if usage is clipped to a maximum value of 1 in 10.

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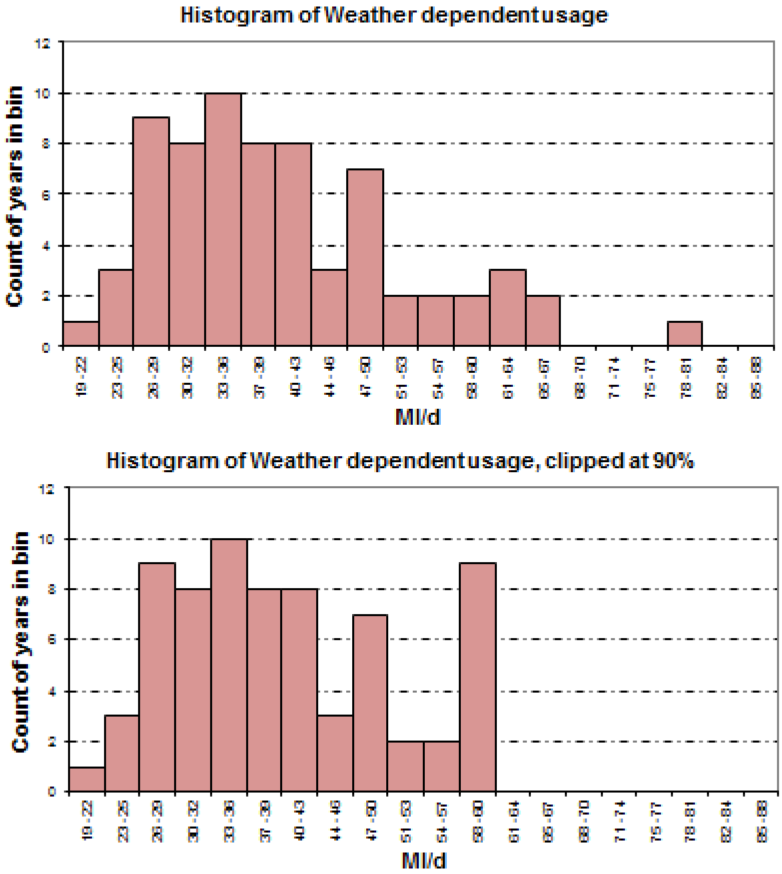
[5] In line with paragraph 1 on page 29 of the planning guidelines.

[6] Note: in this section and in section H2.2, only the weather-dependent components are considered. It is not required to consider the underlying 'base' components for this analysis.

Figure H-6: Unclipped and clipped PDF of variability in usage in London (high values clipped to 1-in-10)



H.17 Key reportable characteristics of clipped weather-dependent usage are shown in Table H-4.

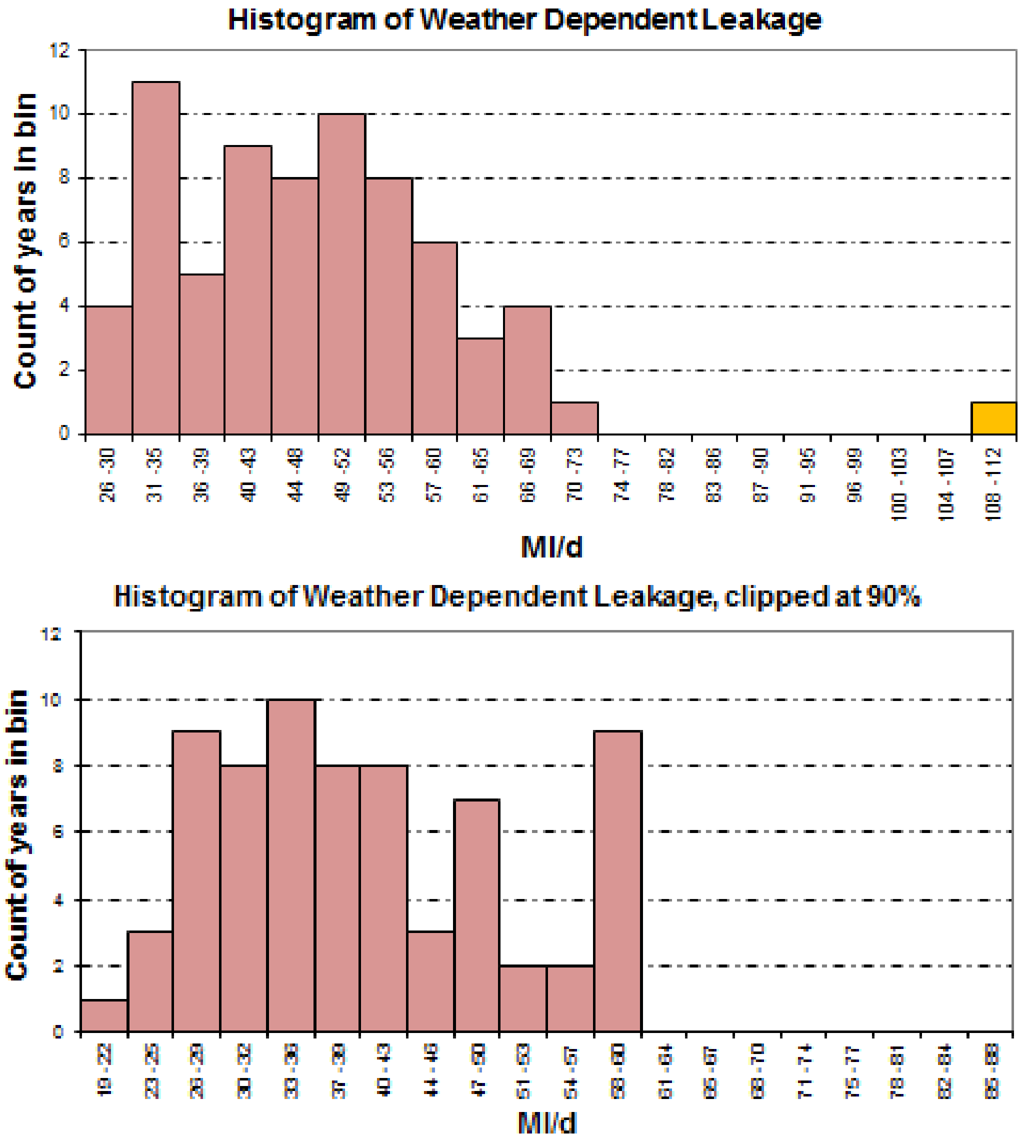
Table H-4: Key statistics from AA weather-dependent usage risk curve

Weather dependent usage (Ml/d)	1in2	1in5
London AA	-1.29	9.18
SWA AA	-0.09	0.85
HEN AA	-0.03	0.14
GUI AA	0.00	0.51
KEN AA	-0.06	0.60
SWOX AA	-0.23	1.61

Analysis of weather-dependent leakage

H.18 The analysis of leakage can be used to estimate the variability in demand that is independent of consumption. Figure H-7 shows PDFs for unconstrained weather-dependent leakage and the equivalent PDF if usage is clipped to exclude the extreme value generated based on the prolonged cold conditions observed in winter 1962/63.

Figure H-7: Unclipped and clipped PDF of leakage in London (highest value removed)



H.19 Key reportable characteristics of clipped weather-dependent leakage are shown in Table H-5.

Table H-5: Key statistics from AA weather-dependent leakage risk curve (clipped)

Weather dependent leakage (Ml/d)	1in2	1in5
London AA	10.72	23.32
SWA AA	0.16	0.28
HEN AA	0.04	0.08
GUI AA	0.07	0.14
KEN AA	0.61	1.03
SWOX AA	0.47	0.89

Critical period peaking factors

H.20 The weather-dependent component of dry-year critical period is estimated using the same uplift mechanisms as described for the AA figures but using the curves generated from the summer critical-period values as shown in Figure H-3.

Commercial peak

H.21 The peak model only considers peak values due to domestic usage. Analysis was undertaken by RPS as part of a UKWIR project[7] which investigated the effects of climate change on non-household demand. The results of the analysis showed little evidence of commercial consumption being affected by weather. Therefore no peak factors are applied to uplift commercial consumption. Commercial consumption in peak periods is calculated as the difference between the peaked DI volume and the sum of the peaked domestic consumption.

Forecasts of future demand

H.22 Changes in demographics and domestic water use are built into our Per Capita Consumption (PCC) model. Additional peak volumes are forecast forward using forecasts of PCC and population for each property type and each WRZ along with a corresponding correction factor for each WRZ.

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[7] Impact of Climate Change on Demand UKWIR CL04B 2013

C. Peaking factors

H.23 Peaking factors are used to uplift or reduce out-turn DI in any year to the DYAA and ADPW planning scenarios. They are calculated using a model called OMSPred which uses historic weather conditions and the current year's base demand to recreate how current demand would vary in different weather conditions. The model uses the peaking factors to uplift or reduce base year demand to the desired level of service, and then calculates uplift volumes that are applied to the base year demand (DI) figures.

H.24 Comparing London AA demand for 2016/17 with the modelled demand using weather data from the last 65 years, the levels in 2016/17 were above that of a normal year, but below that of a dry year, being ranked 40th of the 65 available years. Thames Valley's demand for 2011/12 is ranked 31st of 44 available years.

H.25 The peak week in 2011/12 occurred very early in May and was below both the 1 in 10 and in the 1 in 2 year peak week coming in 12th of the 44 available years.

H.26 Demand is made up of usage and leakage. Due to the mild conditions in the base year of 2011/12 we refined our uplift process so that we are now able to uplift water usage and leakage separately.

H.27 The uplift volumes are shown in Table H-6.

Table H-6: DI uplift volumes (Ml/d)

WRZ	DYAA uplift			ADPW uplift		
	Usage	Leakage	Total	Usage	Leakage	Total
London	9.18	23.32	32.50	n/a	n/a	n/a
SWOX	1.61	0.89	2.50	58.70	n/a	58.70
SWA	0.85	0.28	1.13	32.50	n/a	32.50
Kennet Valley	0.60	1.03	1.63	21.48	n/a	21.48
Guildford	0.51	0.14	0.65	16.96	n/a	16.96
Henley	0.14	0.08	0.23	6.55	n/a	6.55