Section 3

Current and future demand for water

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Current and future demand for water

In this section we explain how we calculate current and forecast future demand for water. This is one of the foundations of our plan as it provides the information that enables us to define the supply-demand balance we need to manage in the future.

'Demand' is composed of five elements:

- Household water use
- Non-household water use (water used by businesses)
- Operational use (water used in maintaining the network)
- Water taken unbilled (water used legally or illegally without charge)
- Leakage (from our pipes and also those belonging to our customers').

We estimate that in our 'base year' (2016/17), we supplied water to nearly 3.7 million households and 215,000 businesses. The average current household demand is 145.3 litres per person per day. The average current metered non-household demand is 478 litres per day.

The base year presents our current level of demand and is reported as part of our Annual Return. Part of this reporting is accounting for the weather conditions of the base year. We do this through the use of scenarios and we produce forecasts for 'Dry Year Annual Average' (DYAA) and 'Average Day Peak Week' (ADPW) scenarios.

We are required to plan for the property growth projected by the 95 local authorities in our area. Based on their plans, we estimate that the number of customers in our area will grow by more than two million people to 11.8 million by 2045.

Because local authority plans only plan 15-20 years into the future, we have worked with demographic experts to develop our own projections to the end of the century. We forecast that the number of people in our area could reach up to 15.4 million by 2100.

Finally we forecast demand for each of the five water balance components for each of our six water resource zones (WRZs). The uncertainty regarding the demand forecasts is then estimated in Section 5: Allowing for risk and uncertainty, before the supply-demand balance is calculated in Section 6: Baseline water supply demand position.

A. Introduction

3.2 We are responsible for the supply of wholesome water to more than 9.8 million customers in over 3.9 million properties. Over the past ten years the population we serve has been growing at average rate of more than 100,000 people a year. This is the equivalent of the population of Birmingham, more than 1 million people, moving into our supply area in the last decade.

3.3 To ensure we are able to provide a safe and secure supply of water to all our customers, we produce forecasts of what the likely demand for water will be.

3.4 'Demand' is the term we use to describe the water that is supplied through our network to households, workplaces and schools; water taken illegally and legally unbilled; water used by industry; water used in maintaining the water network; and water that is lost through the distribution systems.

3.5 Demand forecasting is the method by which we estimate future demand for water. We use mathematical models which use information such as population and property projections, water use data and trends, and a range of other information to forecast how the components of demand for water are likely to vary over the next 80 years.

3.6 Over the planning period we face continued growth in demand. Upward pressures include:

- Population increase
- Decreasing household size (occupancy), as occupancy decreases per person water use increases
- Climate change

3.7 These upward pressures are partially offset by downward pressures from:

- The improving efficiency of water fixtures and fittings such as toilets, dish washers, washing machines, etc.
- Water efficient new housing resulting from design requirements of building regulations
- Customers opting for a meter to better manage their consumption
- Customers being more efficient in their use of water

3.8 For the draft Water Resource Management 2019 (draft WRMP19), we have developed a new forecasting model using the methods identified from the UKWIR project "WRMP19 Methods – Household Consumption Forecasting"[1]. Using this model, we estimate an increase in household demand of more than 241 Ml/d by 2045 and a total increase of approximately 429 Ml/d by 2100.

3.9 Non-household water use is forecast to decline by approximately 3% over the planning period to 2045 and continues to decline by 5% in 2100, although it should be noted there are differing trends across our six WRZs. Generally, increases in water use from service industries (e.g. offices, call centres) are being offset by reductions in demand from non-service industries (e.g. industrial sites, breweries).

[1] UKWIR 2015 WRMP19 Methods – Household Consumption Forecasting 15/WR/02/9

3.10 The baseline demand forecast is the starting position for the future supply demand balance without any planned interventions from 2020. It includes demand reductions from the promotion of water efficiency, leakage reduction and metering activities assumed in price limits up to 2019/20, i.e. the demand management practices in place at the beginning of the new planning period.

3.11 Water taken unbilled, operational use and leakage are forecast to remain at current levels in the baseline forecast.

3.12 Overall, the total baseline demand forecast (before intervention) is expected to increase by 241 Ml/d in the period of 2017-2045 and by 429 Ml/d by 2100. This represents a significant challenge, particularly in the face of reductions in our supply capability (Section 4: Current and future water supply). As part of our plan we have looked at the potential to reduce demand and show how different levels of demand management affect the cost and performance of future plans and strategy. This is in accordance with the 2018 Water Resources Planning Guideline[2] (WRPG) which states that the plan should address government policy including reducing the demand for water.

3.13 The remainder of this section is structured as follows:

- An introduction to what is 'demand'
- Guiding principles and drivers of demand
- Annual water balance – reporting the components of the water balance relevant to the base year, 2016/17
- Demand forecasting – how we forecast demand to 2045 and then to 2100

[2]Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018

What is 'demand'?

3.14 'Demand' is the term we use to describe the water that we use that is supplied through Thames Water's network.

3.15 When reporting demand for water it is split in to the following categories:

- Household Use - water used in the home and garden
- Non-household Use - water used by businesses
- Operational Use - water used maintaining the network
- Water Taken Unbilled - water used without charge either legally (e.g. fire hydrant use), or illegally (e.g. usage in a property declared as void (empty)).
- Leakage - water lost from the distribution system

3.16 We calculate and report these components on an annual basis in a process known as the 'water balance'.

3.17 Demand forecasting is the method by which water companies estimate future demand for water. We use mathematical models which use information such as population and property projections, water use data and trends, and a range of other information to forecast how the components of demand for water are likely to vary over the next 80 years. We produce updated forecasts every five years, with an annual review in the intervening period. We follow industry guidelines supplemented with our own detailed analysis.

Guiding principles

3.18 The WRPG sets a clear framework for developing a demand forecast. We have followed the latest UKWIR guidance[3] in developing our forecasts.

3.19 For the baseline forecasts it is assumed that beyond 2019/20 water efficiency activity will continue at approximately 3 Ml/d of activity per year. We have also assumed that meters will only be fitted where customers request a meter and in new properties, and that there will be no additional leakage reduction, although activity to maintain leakage at current levels continues.

3.20 AMP6 activity includes the progressive household metering programme in London to 2020, where we will fit meters to properties including those that have not requested a meter. Our progressive metering programme assumes that after a two year adjustment period the customer will be switched over to a measured tariff. This will deliver benefits through demand reduction and leakage detection and repair, as well as delivering long term efficiencies for network maintenance in metered areas.

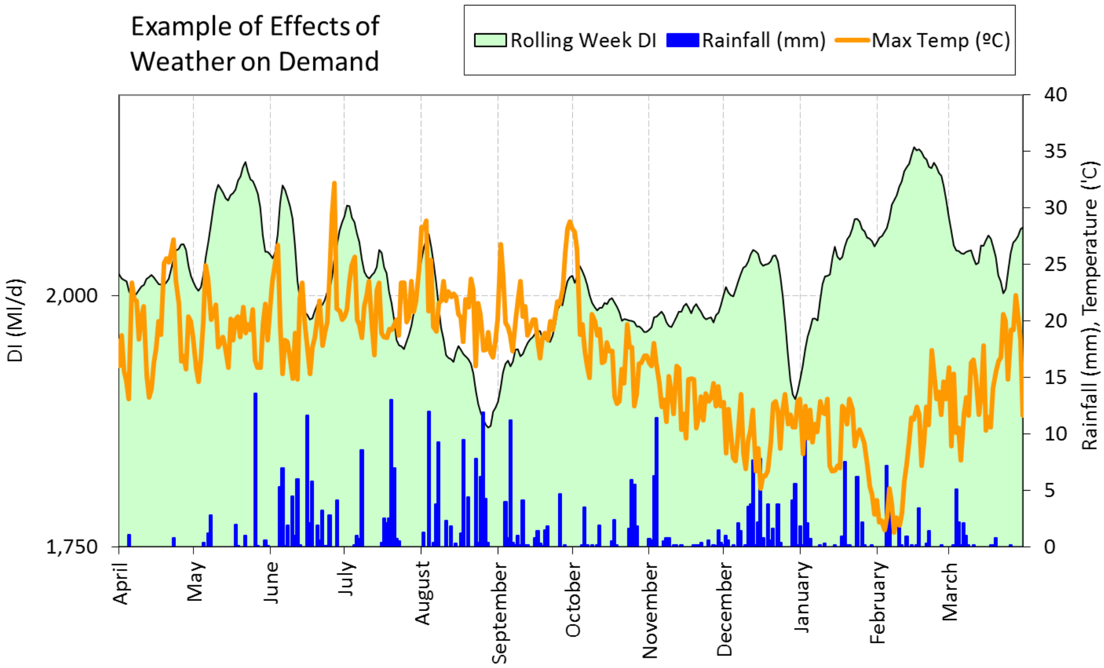
3.21 Once all the steps in the water resource planning process have been completed, a range of demand reduction options will be included in the demand forecast, such as further leakage reduction, progressive household metering and additional water efficiency measures (Section 8: Appraisal of demand options, Section 10: Programme appraisal and Section 11: Preferred programme). We call this final demand forecast the 'Final Plan' forecast to differentiate it from the 'Baseline' forecast described above.

[3] UKWIR, WRMP19 Methods – Household Consumption Forecasting, 15/WR/02/9, 2015

Demand drivers

3.22 Demand for water varies due to a number of factors. One of the most important of these factors is the weather. In hot dry weather, customer use more water is used for activities such as garden watering or filling paddling pools. On the other hand, in cold weather, leakage will rise, because pipes can contract and leak. The effect of weather on demand is shown in Figure 3-1.

Figure 3-1: Effect of weather on demand (measured by Distribution Input)



3.23 Demand will change over time in response to a range of drivers which also change over the planning period. The main drivers, which are included within demand forecasting models, are:

- Population and property growth, in line with the plans developed by local authorities
- Effects of climate change
- Changes in non-household consumption, including industrial and commercial use
- Trends in household water use linked to behaviour and technological development of water using devices

3.24 Agricultural water use does not feature as a driver for demand due to the relatively small volume of water that is used for this purpose within the Thames Water supply area. Currently it is estimated that approximately 0.7% of all non-household demand within the Thames Water supply area is for agricultural water use.

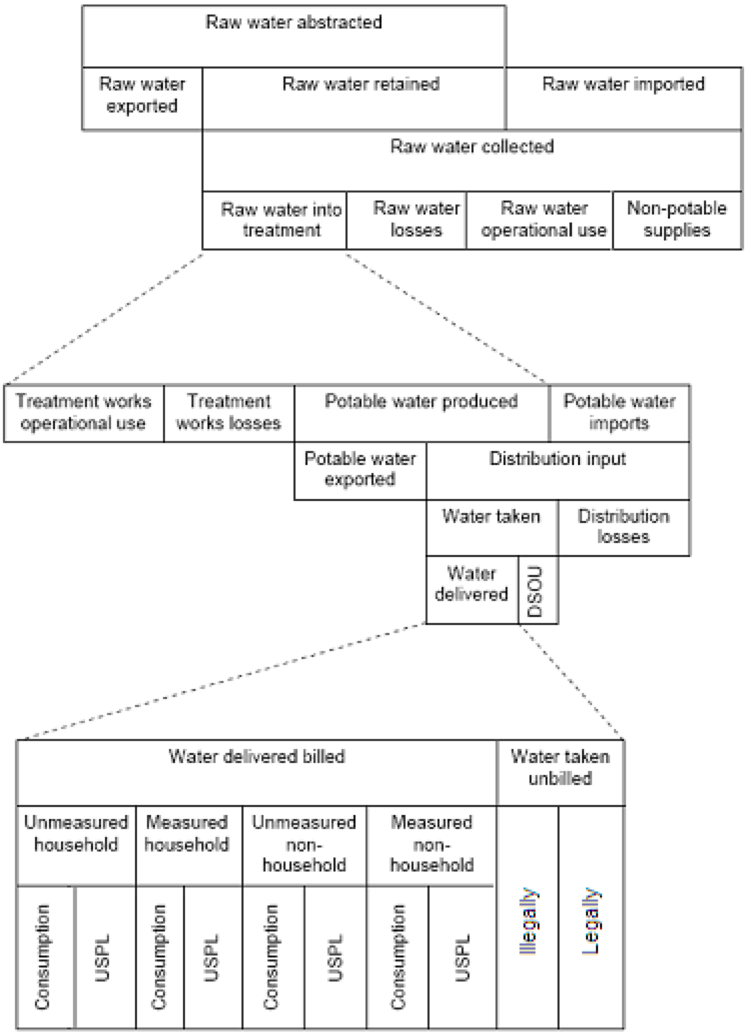
3.25 Leakage is an important element of demand but in our baseline scenario leakage remains constant at its base year value across the entire forecast period.

3.26 These demand drivers are discussed in more detail within the remaining sections of this document and in Appendix E: Populations and property projections, Appendix F: Household water demand modelling, Appendix G: Non-household water demand and Appendix H: Dry year and critical period forecasting.

B. Current demand

The water balance

Figure 3-2: Overview of water balance



DSOU – distribution system operational use
USPL – underground supply pipe losses

Base year properties

3.27 Company level property numbers by type (measured/unmeasured, household/non-household, void[4] household/void non-household) are derived from our Customer Information System (CIS). These include adjustments to the unmeasured and measured household and non-household figures for missing properties. They also take account of properties that have moved to a measured tariff due to optant metering as well as the addition of new properties to the count of measured households.

3.28 The numbers of properties within each WRZ are then calculated using a database called Netbase. Netbase takes property information from CIS and geo-references it, firstly to District Meter Areas (DMAs), a discreet area of the network where water supplied is measured by a district meter, then to Flow Monitoring Zones (FMZs), discreet areas of the network where the water supplied is measured by a zonal meter, and finally to WRZs. The proportions from this exercise are then used to apportion the property numbers from CIS to each WRZ.

3.29 The base year property values are summarised in Table 3-1.

Table 3-1: Base year properties

WRZ	Households			Non-households		
	Unmeasured	Measured	Void	Unmeasured	Measured	Void
London	1,817,250	912,337	76,433	33.635	912,337	15,099
SWOX	152,244	273,437	7,134	1,511	22,805	1,709
SWA	98,954	106,686	3,563	665	9,691	969
Kennet Valley	71,727	87,337	2,686	610	6,941	731
Guildford	29,131	32,506	1,083	342	3,346	325
Henley	7,066	14,226	360	97	1,001	81
Thames Water	**2,176,371**	**1,426,528**	**91.260**	**36.861**	**159.074**	**18.914**

Base year population

3.30 The starting point for estimating base year population is the mid-2015 population estimates published by the Office for National Statistics (ONS). This data was then updated to the base year of 2016/17 using projections from expert consultants, Edge Analytics, and the Greater London Authority (GLA) for areas within London. Edge Analytics have worked with us to develop a more granular distribution of population for the draft WRMP19. This has been done using census output areas giving a better occupancy distribution and population split across WRZs. This work has been incorporated in our plan.

3.31 Not all population is accounted for in official statistics. To take account of "hidden" population, short-term migrants and second addresses we apply an additional allowance, based on a study

[4] Void properties which are households and commercial buildings that are not occupied or being used

by Edge Analytics[5]. This allowance totals an additional population of 517,228, the majority of which are considered to be within London.

3.32 Non-household population is comprised of population residing in communal establishments; based on the Ofwat eligibility criteria released in July 2016.

3.33 The total household population is derived by subtracting the total non-household population from the total population. This year, the number associated with communal establishments has been updated at 103,843. The unmeasured non-household population remains at zero.

3.34 The population split between measured and unmeasured households uses data obtained from occupancy questionnaires which were sent to 49,028 households, both unmeasured and measured, as research to inform our June Return 2010 (JR10) regulatory reporting, of which 11,482 were returned with valid data. All responses could be classified by property type, metering type, ethnicity and region enabling us to scale up responses according to the effective sampling rates of each category. We also adjusted for any occupancy bias in the responses by comparison with profiles of occupancy classes obtained from the Census 2011 for regions covering our London and Thames Valley zones.

3.35 To update population splits between measured and unmeasured households this year we have used the movement in properties, reductions in unmeasured properties as customers opt for a meter, and increases in measured properties associated with the optants, in addition to newly built properties. It is assumed that the occupancy of the additional measured properties is the same as the occupancy of the existing measured properties. This plan also considers the impact of population in bulk billed blocks of flats (subsidiary properties), taking account of the population in the measured unmeasured household split rather than in non-household population. This should provide a more reflective view of the population distribution. The residual movement in population is assumed to be in the unmeasured population base. Base year populations are summarised in Table 3-2. As with any company, large changes in government statistics on population estimates would affect our plan.

Table 3-2: Base year population 2016/17 (000s)

WRZ	Populations	
	Unmeasured	Measured
London	5,226,919	2,368,700
SWOX	436,344	585,481
SWA	301,178	247,666
Kennet Valley	211,881	189,855
Guildford	86,763	73,423
Henley	22,339	28,562
Thames Water	**6,285,422**	**3,493,687**

[5] Clandestine and Hidden Populations Edge Analytics October 2016

Household demand

3.36 Household demand is normally described by the volume of water used per person each day, and is called 'Per Capita Consumption' or PCC. Unmeasured customer PCC is calculated from our Domestic Water Use Survey (DWUS), a panel of approximately 1,600 customers who have, voluntarily, had meters installed but are charged on an unmeasured basis. Measured customer PCC is calculated by totalling the volume recorded by all customer meters, allowances are then applied for supply pipe leakage, which is subtracted, and meter under-registration, which is added. This total volume of water is then divided by the total number of measured customers to give a measured customer PCC.

3.37 For 2016/17 the PCC for measured, unmeasured and average for each WRZ is shown in Table 3-3.

Table 3-3: Per capita consumption (l/person/d)

WRZ	Unmeasured PCC	Measured PCC	Average PCC	% Metered
London	159.46	120.16	147.20	33.42%
SWOX	149.12	129.32	137.77	64.24%
SWA	151.87	125.46	139.95	51.88%
Kennet Valley	143.23	125.73	134.96	54.91%
Guildford	155.90	137.91	147.66	52.74%
Henley	141.66	144.95	143.51	66.81%
Thames Water	**157.72**	**122.95**	**145.30**	**39.59%**

Non-household demand

3.38 The vast majority of the non-household demand is measured. It is primarily water used by commercial, industrial and agricultural premises, though there is a small population whose consumption is included within the non-household category as they live in properties classified as 'mixed' (e.g. a flat above a shop).

3.39 Assessed non-household[6] usage is estimated using a matrix which looks at the size of the property supply and the number of full time employees as well as the business type, calculating an estimated daily consumption. Unmeasured non-household usage is assigned by billing band type and number of billed units supplied by the Central Market Operating System (CMOS).

3.40 Non-household demand was reported as shown in Table 3-4 for 2016/17.

Table 3-4: Non household consumption (Ml/d)

WRZ	Measured	Unmeasured
London	350.99	14.93
SWOX	58.47	0.64

[6] Non-household properties where it is impractical to fit a meter

WRZ	Measured	Unmeasured
SWA	19.79	0.27
Kennet Valley	18.64	0.23
Guildford	7.57	0.16
Henley	1.74	0.04
Thames Water	**457.21**	**16.26**

Leakage

3.41 The reported leakage value for our 2017 Annual Return (AR17) was 667.84 Ml/d. For the revised draft WRMP19 we have used a different value which is consistent with the guidance contained within the 2017 UKWIR report "Consistency of Reporting Performance Measures" (17/RG/04/5). Using this new method results in a Dry Year Annual Average (DYAA) leakage value of 741.16 Ml/d for Thames Water and will form the basis of water industry leakage reporting from 2020 onwards.

3.42 Leakage is split into two categories.

- Distribution losses: these are leaks on our own infrastructure and make up approximately 72% of total leakage
- Supply pipe leakage: this is water leaking from customer supply pipes, which is the responsibility of customers, although we offer a free leakage repair service to household customers who meet the eligibility criteria

3.43 Leakage for each WRZ, as reported within our Appendix A of AR17, is shown in Table 3-5.

Table 3-5: Actual leakage (Ml/d)

WRZ	Total Leakage
London	524.45
SWOX	61.32
SWA	42.81
Kennet Valley	24.10
Guildford	12.16
Henley	3.01
Thames Water	**667.84**

Minor components

3.44 Minor components include the demand taken from the distribution system for our operational use and any water which is taken but unbilled. Operational use includes water used by a company to maintain water quality standards in the distribution system such as mains flushing. Water taken unbilled includes public supplies for which no charge is made (sewer flushing etc.), fire training and fire-fighting supplies; it also includes water taken illegally.

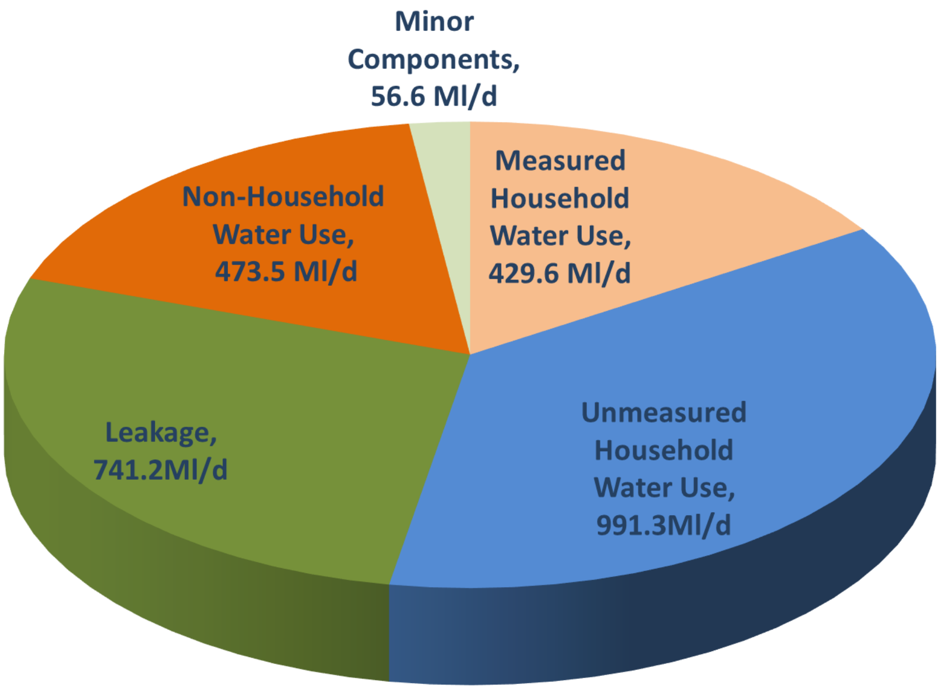
3.45 At the company level, minor components add up to approximately 57 Ml/d.

Summary for 2016/17

3.46 Figure 3-3 shows the breakdown of the total demand reported in the water balance for 2016/17 by component. Overall household water use accounts for 53%, leakage for just over 27% and non-household demand accounting for approximately 18% of total demand. The remaining 2% is accounted for by the minor component of water take unbilled and operational uses.

3.47 This split of total demand and its sub-components forms the base position for the demand forecast.

Figure 3-3: Dry Year Annual Average demand[7]



C. Future demand – the demand forecast

Planning scenarios

3.48 The water balance reflects the conditions experienced in that year. It may have been, looking at the year as a whole, wet, dry, hot, cold or somewhere in the middle. From a planning perspective, we are interested in the demand that would be expected to be met up to the point that the system becomes stressed, as set out in our level of service. Therefore, we need a demand forecast which is reflective of that level of service. We use planning scenarios to recreate anticipated demand levels.

[7] Consistent with 2017 UKWIR report "Consistency of Reporting Performance Measures" (17/RG/04/5)

3.49 Demand forecasts are developed for different conditions which describe demand in an average year and in the Dry Year Critical Period (DYCP). For us the DYCP scenario is defined as the Average Day Peak Week (ADPW) for our Thames Valley zones, i.e. all zones except for London. Table 3-6 summarises the scenarios constructed for each of our WRZs. The table describes two different scenarios:

- The DYAA scenario: this is the forecast for a dry year (a period of low rainfall) where there are no constraints on demand; and
- The ADPW scenario: this describes the average daily demand during the peak week for water demand. The peak week is the critical period of demand which drives the need for water resource management options to be implemented.

Table 3-6: Planning scenarios used in each of our WRZs

WRZ	Baseline		Final Plan	
	DYAA	ADPW	DYAA	ADPW
London	✓	×	✓	×
SWOX	✓	✓	✓	✓
SWA	✓	✓	✓	✓
Kennet Valley	✓	✓	✓	✓
Guildford	✓	✓	✓	✓
Henley	✓	✓	✓	✓

3.50 We do not report on ADPW demand for the London WRZ. This is because peak demands in London can be met through the relatively large volume of surface (raw) water storage (reservoirs) and treated water in the London Ring Main. The ability to meet peak demands is therefore not a resource availability issue at present but dictated by treatment and transmission capabilities.

3.51 All other zones are driven by summer weather-related peak demands and thus the ADPW scenario is the main driver for water resource investment.

3.52 All scenarios are produced by factoring up or down the demand reported in the base year, the approach used is described below.

Peaking factors

3.53 Peaking factors are used to uplift or reduce out-turn demand 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. We have refined our uplift process so that we are now able to uplift water usage and leakage separately. The model uses the peaking factors to uplift or reduce base year leakage and usage to the desired level of service, and then calculates uplift volumes that are applied to base usage and leakage volumes.

3.54 Comparing London's annual average demand for 2016/17 with the modelled demand using weather data from the last 69 years demonstrates that the levels in 2016/17 have been below that of a normal year, and a dry year, being ranked 12th of the 69 available years.

3.55 Thames Valley's annual average demand for 2016/17 is ranked 18th of 49 available years. The peak week in 2016/17 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 49 available years.

3.56 The uplift volumes, for each component, are shown in Table 3-7.

Table 3-7: Distribution input 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

3.57 These uplifts result in the overall demand, measured in terms of distribution input, shown in Table 3-8.

Table 3-8: Overall demand (Distribution Input) post uplift

WRZ	DYAA (Ml/d)	ADPW (Ml/d)
London	2,114.05	N/A
SWOX	272.78	328.79
SWA	144.83	176.07
Kennet Valley	102.15	121.91
Guildford	45.64	61.93
Henley	12.63	18.94
Thames Water	**2,679.99**	**N/A**

3.58 The impact on leakage values for the different forecast scenarios in each WRZ is given in Table 3-9.

Table 3-9: Uplifted leakage 2016/17 (Ml/d)

WRZ	Shadow Leakage DYAA
London	582.76
SWOX	68.04
SWA	46.04
Kennet Valley	27.56
Guildford	13.35
Henley	3.40

WRZ	Shadow Leakage DYAA
Thames Water	**741.16**

3.59 More information can be found on peaking factors in Appendix H: Dry year and critical period forecasting.

Population and property forecasts

Introduction

3.60 Throughout this section, the term ‘forecast’ is used as a generic term to encompass both population projections (trend-based outcomes) and population forecasts (policy-based outcomes, e.g. housing-led forecasts).

3.61 Robust population and property forecasts are a key underpinning of the WRMP19 process. A sustained period of new housing growth, ageing population profiles and an uncertain future for international migration are key considerations for industry planners.

3.62 The WRPG produced by Defra, in conjunction with the Environment Agency, Welsh Government, Natural Resources Wales and Ofwat, include guidance on the key requirements for population, property and occupancy forecasts to support the WRMP19. This guidance has formed the basis for the development of the forecasts presented here.

3.63 Given our requirement for an extended forecast we commissioned two separate components to our forecasting evidence:

1) the *core* forecasts relate to the 2016-2045 planning horizon based on local authority plans; and
2) the *longer-term* outlook considers the extended 2045-2100 planning horizon which used trend-based methods.

3.64 In the draft WRMP19 (published in February 2018), population and property output from the University of Leeds' demographic forecasting model was used as the basis for the long-term growth outlook. Since completion of the draft WRMP19, the ONS has published a new 2016-based, long-term projection, the first release of future population growth estimates since the Brexit referendum in June 2016.

3.65 To ensure alignment with the latest ONS evidence on the likely trajectory of growth during the second half of the 21st century, we commissioned updated population and property forecasts for our WRZs for the extended, 2045-2100 horizon.

3.66 Whilst the core and long-term forecasts have used consistent methodologies, the long-term forecasts have been formulated using trend-based inputs and assumptions that are consistent with the ONS 2016-based NPP; this contrasts to the housing-led approach used in the development of the core, 2016-2045 forecasts.

3.67 All forecasts have been produced for us by Edge Analytics Ltd who are experts in demographic analytics and scenario forecasting. They are contracted by the Local Government Association

(LGA) to support and develop the POPGROUP suite of forecasting models used by planners, analysts and researchers across the UK.

3.68 These core forecasts have been produced in line with the requirements of the WRPG, with ‘plan-based’ population and property growth estimates underpinned by published evidence on local authority housing plans. The longer-term outlook has been underpinned by the latest evidence from the ONS on growth projections to 2100[8].

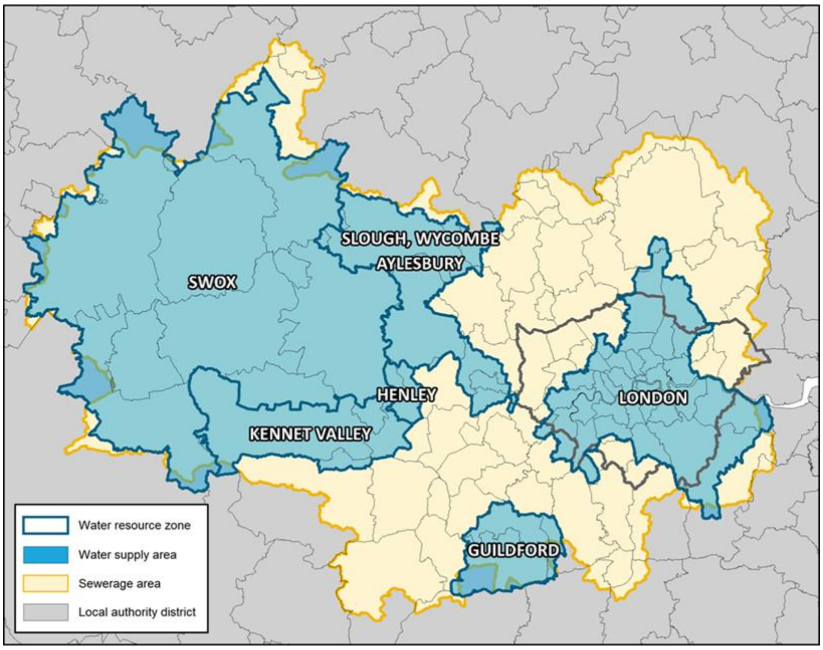
3.69 The remainder of this section provides a summary of the methodology and outcomes of these forecasting approaches. Further detail is provided in Appendix E: Property and population projections.

Area definition

3.70 The Thames Water area of operations in which it provides its water and sewerage services encompasses a total of 95 local authority areas (either in full or in part); a mix of London Boroughs, Unitary Authorities and non-metropolitan districts.

3.71 The six WRZs are covered by a sub-set of these local authority areas, as shown in Figure 3-4, again either in full or in part. This sub-set of local authority areas has provided the basis for the development of our WRMP19 population and property forecasts.

Figure 3-4: Area definition of Thames Water operational areas and local authorities



3.72 Population and property forecasts developed for each local authority area have been scaled to ensure consistency with the WRZ geography. This scaling process has been based upon the proportional distribution of properties, using digital map data and Geographical Information System (GIS) technology to ensure the most accurate process of estimation.

8 ONS 2016-based NPPs https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2016basedstatisticalbulletin#things-you-need-to-know-about-this-release

Regulatory guidance

3.73 In developing population and property forecasts for the draft WRMP19, the WRPG published by Defra *et al* mandates the use of housing growth evidence from Local Plans to inform the core 2016-2045 scenarios:

> *'For companies supplying customers wholly or mainly in England you will need to base your forecast population and property figures on local plans published by the local council or unitary authority.' (p. 21)*[9]

3.74 The WRPG acknowledges that councils may be at different stages of Local Plan development but has required population and property forecasts to be aligned to the best-available evidence. Where plan evidence does not exist, the WRPG advises the use of the ONS and Department for Communities and Local Government (DCLG) official statistics as an alternative.

3.75 To support the WRPG documentation, UKWIR has produced a suite of documents which provide additional guidance on the development of population, property and occupancy forecasting. The UKWIR documentation is in three forms: a Guidance Manual; a Worked Example; and a Supplementary Report that includes a review of stakeholder engagement and a technical review of forecasting approaches.

3.76 The UKWIR Guidance Manual is not prescriptive in terms of methodological recommendations for forecast development but it does identify six key 'tasks' required to complete the process:

1) Assess needs and make choices
2) Assess Local Development Plans
3) Calculate population and household forecasts
4) Calculate occupancy forecasts
5) Analyse uncertainty
6) Review and finalise population, household and occupancy forecasts

3.77 Whilst the core (2016-2045) and long-term (2045-2100) forecasts use different data inputs and assumptions, their underpinning demographic modelling methodology and principles are the same and align with methods employed by the ONS and the GLA. The following sub-sections first provide a short summary of generic demographic methods, and then describe the particular approaches adopted for the development of the core and long-term forecasts.

Demographic forecasting methodologies

3.78 Population forecasts have been developed using a cohort-component methodology, the universal standard for demographic analysis. The cohort-component method models the annual growth in the size and age-sex structure of a population over time, taking account of fertility, mortality and migration, as follows:

$$Pop_{(a,s,t+n)} = Pop_{(a,s,t)} + B_{(s)} - D_{(a,s)} + InUK_{(a,s)} - OutUK_{(a,s)} + InOV_{(a,s)} - OutOV_{(a,s)}$$

where:

Pop(a,s,t) = the population at time (t), by age (a) and sex (s)

[9] Final Water Resources Planning Guideline 2018 Environment Agency, Natural Resources Wales, Defra, Ofwat

B(s) and D(a,s) = number of births and deaths occurring between t and t+n.

InUK(a,s) and OutUK(a,s) = domestic in- and out-migration during the period t to t+n.

InOV(a,s) and OutOV(a,s) = immigration and emigration during the period t to t+n.

3.79 Household forecasts have been developed using a 'household representative rate' (also known as 'household headship rate') model that is consistent with approaches applied by the ONS, GLA and the Welsh, Scottish and Northern Ireland national statistical agencies. The annual growth in the number and profile of households over time is calculated as follows:

$$H_{(a,s,d,t)} = HPop_{(a,s,t)} * R_{(a,s,d,t)}$$

where:

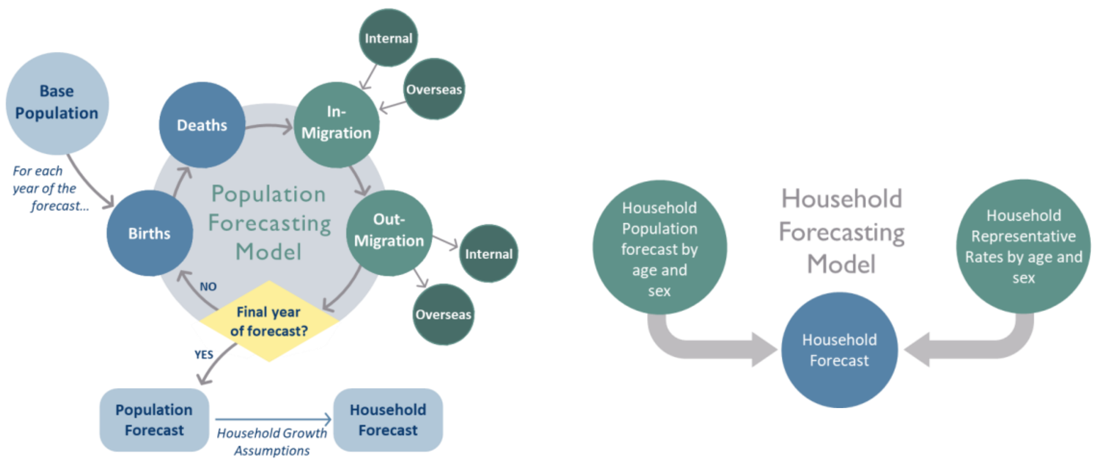
$H_{(a,s,d,t)}$ = Households at time (t), by age (a), sex (s) and household type (d)

$HPop_{(a,s,t)}$ = Household Population at time t by age and sex

$R_{(a,s,d,t)}$ = Household Representative Rate at time t by age, sex and household type

3.80 The population and household models can work independently or in tandem. When operating together, the models can be used to evaluate 'housing-led' growth scenarios, whereby population change is determined by a forecast growth in the number of new homes. This functionality has been key to the development of the 'plan-based' forecasts for our 2016-45 planning horizon and is summarised in Figure 3-5.

Figure 3-5: Population and household forecasting methodologies



Core forecasts (2016-2045) – Plan-based

3.81 Using a combination of its demographic modelling expertise in conjunction with an extensive Local Plan data collection and validation exercise, Edge Analytics has derived a 'plan-based' forecast of population and property growth for our WRZs to 2045. In achieving this objective, Edge Analytics has sought to ensure that the draft WRMP19 requirements detailed by Defra *et al* in its WRPG documentation have been met and that the technical approach has aligned with UKWIR's recommendations for the development of population and property forecasts.

Appendix E: Population and property projections, provides a full technical report provided in support of the delivery of the plan-based forecasts.

3.82 Key to the development of the plan-based forecast was the collection of Local Plan housing evidence from all local authorities within our area of operations. Edge Analytics liaised directly with local authorities to collect both 'macro' and 'micro-level' detail on planned new housing developments. The macro-level information has provided the overall housing growth trajectory for each local authority's chosen plan period. Where available, the micro-level information has provided the detail on the geographical distribution of planned new homes. The combination of macro- and micro-level information has enabled the development and alignment of 'top-down' and 'bottom-up' forecasts to inform the draft WRMP19.

3.83 Edge Analytics used a combination of its POPGROUP and VICUS technology to develop the plan-based forecasts. POPGROUP is the industry-standard, cohort-component and headship rate model that is managed by Edge Analytics on behalf of the LGA and used by planners across the UK. VICUS is Edge Analytics' micro-forecasting model, enabling the population impact of the most geographically-detailed housing growth plans to be derived. The VICUS micro-level detail aligns directly to the local authority-level forecasts derived from the POPGROUP model.

3.84 The base-year of the plan-based forecasts was 2016, with base-year property numbers aligning to those in the Royal Mail's Address Based Premium dataset. The forecast horizon was 2045, with underpinning demographic assumptions on fertility, mortality, domestic and international migration drawn from published ONS statistics. Household representative rate statistics and estimates of non-household populations were derived from DCLG evidence. Vacancy rates, enabling the calculation of property numbers from household totals were derived from the 2011 Census.

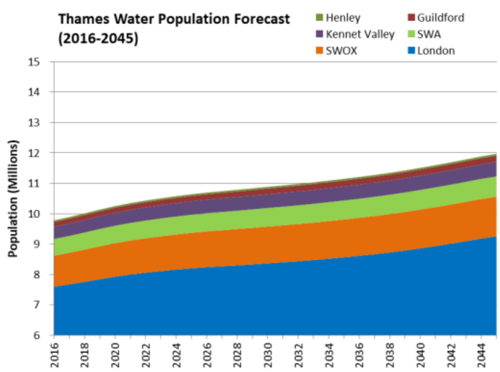
3.85 For each local authority, planned housing growth was used as the key determinant of future population change, with net-migration used to balance the relationship between population size and property numbers. Using the cohort-component functionality, the forecasting model considered not only the planned housing growth but also the changing age-sex profile of the population and the forecast changes in household headship representative rates by age and sex.

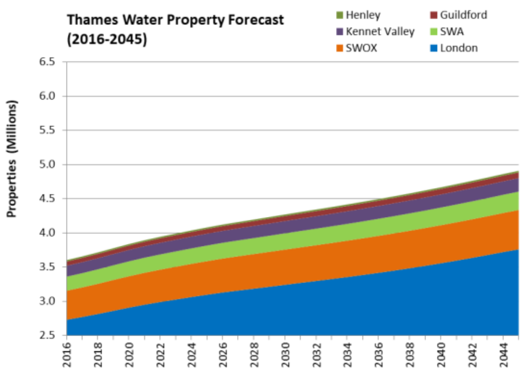
3.86 Local Plans typically have a 15-20 year horizon, with most housing growth trajectories ending in 2030-35. The plan-based forecasts have assumed that, at the end of the Local Plan period, housing growth makes a gradual return to the trend evident in the ONS 2014-based projections, achieving the average annual trend growth by 2045.

3.87 Aligning with base-year totals, we have used the plan-based output to derive population and property forecasts by WRZ, illustrated below. The rate of population change is relatively high in the short-term (approximately 2016-2025), consistent with higher housing growth in Local Plans, reducing towards the end of the Local Plan periods (2030-2035). Population growth is higher thereafter as housing growth totals return to the trend evident in the ONS 2014-based projection.

3.88 For the six WRZs in combination, the plan-based forecast estimates a population growth of 2.1 million (21.5%) for the 2016-2045 plan period. In terms of properties, the plan-based forecast estimates a growth of 1.26 million (34.9%) over the same time-period. The growth across this period is shown in Figure 3-6.

Figure 3-6: Growth in population and properties, 2016-2045





3.89 The population and property growth forecasts are presented for each individual WRZ. The population of the London WRZ is forecast to increase by 1.58 million (20.9%) by 2045, with a total property growth of 0.99 million (36.3%).

3.90 The lowest percentage change in population is forecast for the smallest WRZ, Henley at 11.6%, with an associated property growth of 14.1%. The highest percentage growth is evident in the Guildford and Swindon and Oxfordshire (SWOX) WRZs at 27.5% and 27.4% respectively, with associated property growth of 33.6% and 34.3%. This growth is summarised in Table 3-10.

Table 3-10: Growth in population and properties for each WRZ, 2016-2045

WRZ	Total Population	Change in Population from Base Year				% Change in Population from Base Year to 2044/45
	2016/17	2019/20	2024/25	2029/30	2044/45	
London	7,595,624	246,205	562,497	733,487	1,584,089	20.9%
SWOX	1,021,824	62,121	134,637	182,091	279,508	27.4%
SWA	548,844	21,152	42,819	58,582	114,509	20.9%
Kennet Valley	401,735	16,666	37,731	49,905	76,506	19.0%
Guildford	160,186	4,909	14,426	24,605	44,019	27.5%
Henley	50,901	2,237	3,698	4,132	5,895	11.6%
Total	**9,779,115**	**353,289**	**795,807**	**1,052,801**	**2,104,527**	**21.5%**

WRZ	Total Properties	Change in Properties from Base Year				% Change in Properties from Base Year to 2044/45
	2016/17	2019/20	2024/25	2029/30	2044/45	
London	2,729,586	131,218	332,222	482,909	989,749	36.3%
SWOX	425,681	25,148	59,520	84,705	145,951	34.3%
SWA	205,640	9,339	20,717	30,318	61,080	29.7%
Kennet Valley	159,064	4,855	13,083	19,096	37,080	23.3%
Guildford	61,637	2,081	6,045	10,455	20,709	33.6%
Henley	21,292	508	875	1,290	3,011	14.1%
Total	**3,602,900**	**173,148**	**432,463**	**628,774**	**1,257,580**	**34.9%**

3.91 The evaluation of the level of uncertainty associated with these plan-based forecasts is a key component of the draft WRMP19 process. Section 5: Allowing for risk and uncertainty, considers this uncertainty, using UKWIR's technical guidance to inform the calculation of a Target Headroom allowance.

Long-term forecasts (2045-2100) – Trend-based

3.92 The plan-based forecasts provide a growth perspective to 2045. A second key component of our demand forecasting process has been the consideration of longer-term forecasts of population and property growth, with a horizon that stretches to 2100.

3.93 In the draft WRMP19, published in February 2018, population and property output from the University of Leeds' demographic forecasting model was used as the basis for the long-term growth outlook. Since completion of the draft WRMP19 the ONS has published a new 2016-based, long-term projection, the first release of future population growth estimates since the Brexit referendum in June 2016.

3.94 To ensure alignment with the latest ONS evidence on the likely trajectory of growth during the second half of the 21st century, updated population and property forecasts for the WRZs have been formulated.

3.95 Whilst the core and long-term forecasts have used consistent methodologies, the long-term forecasts have been formulated using trend-based inputs and assumptions that are consistent with the ONS' 2016-based NPP; this contrasts to the housing-led approach used in the development of the core, 2016-2045 forecasts.

3.96 A summary of the long-term forecasting approach and analysis is provided here, with further detail and analysis provided in Appendix E: Population and property projections.

3.97 At the end of 2017, the ONS published a 2016-based 'national' population projection for the UK and its constituent countries. The Principal projection for the UK, estimates substantially lower population growth than each of its 2010-based, 2012-based and 2014-based predecessors. The UK's population is projected to increase to 83 million by 2100 under the 2016-based growth trajectory, compared to 91 million under the previous, 2014-based scenario. The lower rate of growth in the 2016-based scenario is driven by a combination of: lower international migration; lower fertility rates; and a slower rate of increase in life expectancy.

3.98 In addition to its 2016-based Principal projection, the ONS also published a number of variant UK national projections which consider alternative assumptions for future fertility, mortality and migration. A selection of the UK growth variants illustrates the impact of higher or lower levels of international migration. These international migration variants have provided the basis for the long-term scenario analysis for each of our WRZs. These scenarios have included the 2016-based fertility and mortality differentials applied to all local authority areas and assumptions on the long-term effect of domestic migration to and from London.

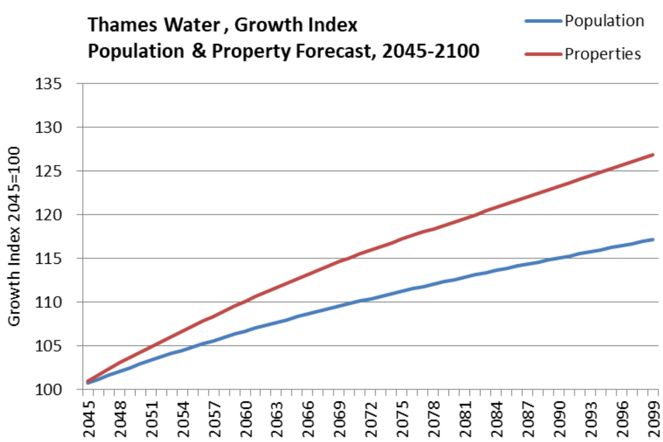
3.99 A total of seven variants of higher/lower international migration were presented, with a 'Principal-2016' scenario recommended for inclusion in the WRMP. Post-2045 this is driven by a UK net international migration total of approximately +165,000 per year, plus a domestic net migration outflow from London that reverts to pre-2007 levels over the course of the forecast period.

3.100 The UK's planned exit from the EU points towards lower rather than higher international migration, so the high-migration variants represent a less likely outcome for our WRZs over the long-term horizon. However, whilst lower international migration is a likely consequence of exit from the EU, the UK's economy will require a constant and ready supply of labour both from the UK and overseas.

3.101 For WRMP purposes, the 'Principal-2016' scenario presents an appropriate balance between the higher-growth scenario and the low migration options presented by the ONS.

3.102 A summary of the long-term population and property forecasts is presented below, in Figure 3-7, for the six WRZs in total, illustrating an *index* of growth over the 2045-2100 plan period.

Figure 3-7: Growth index, population and properties, 2045-2100



3.103 Population is forecast to grow by 2.04 million to 2100, a 17.1% rate of growth from 2045. Associated property numbers are forecast to grow by 1.3 million, a 26.8% growth rate from 2045.

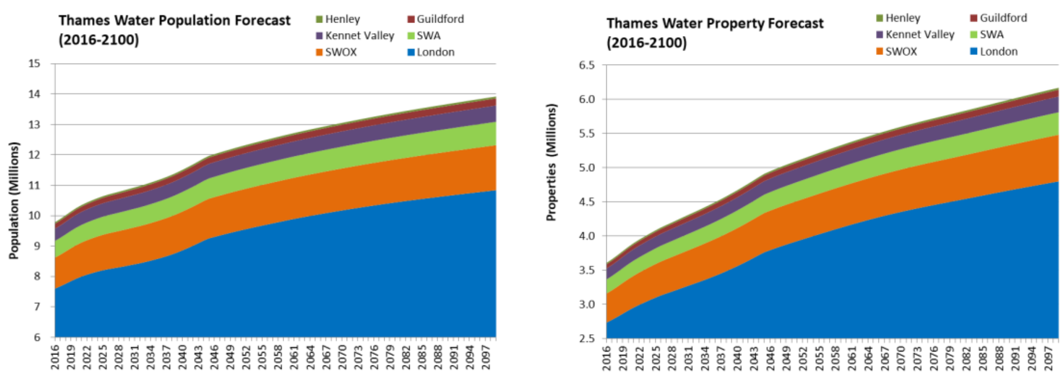
Final forecast

3.104 Evidence from the plan-based and long-term population and property forecasts have been used to inform our *final* forecast. The final forecast used to produce our baseline household demand forecast was calculated as follows:

- Both the plan-based forecast and the long-term trend forecast were converted to growth profiles
- The plan-based growth profile for the period from 2016 to 2045 was applied to our base year values for population and properties
- This has produced a forecast for populations and properties to 2045 which is based on the plan-based analysis completed by Edge Analytics
- Beyond 2045 the Principal-2016 projection, underpinned by key ONS long-term assumptions on growth, has been utilised
- The growth between 2045 and 2100 from Edge Analytics' Principal-2016 projection has been applied from the end of the plan-based forecast
- This extends the population and property forecasts to 2100.

3.105 A summary of the combined plan-based and long-term population and property forecasts is presented below, in Figure 3-8. For the six WRZs in combination, the forecast estimates a population growth of 4.14 million (42.3%) for the 2016-2100 plan period. In terms of properties, the forecast estimates growth of 2.56 million (71.1%) over the same time-period.

Figure 3-8: Growth in population and properties, 2016-2100



3.106 Growth by WRZ is illustrated in Table 3-11, providing an indication of population and property growth for the initial, plan-based horizon and for the longer-term, trend-based outlook to 2100.

Table 3-11: Growth in population and properties for each WRZ, 2016-2100

WRZ	Total Population	Change in Population from Base Year			% Change in Population from Base Year to:	
	2016/17	2044/45	2069/70	2099/100	2044/45	2099/2100
London	7,595,624	1,584,089	2,545,741	3,241,288	20.9%	42.7%
SWOX	1,021,824	279,508	357,072	460,410	27.4%	45.1%
SWA	548,844	114,509	167,337	220,443	20.9%	40.2%
Kennet Valley	401,735	76,506	99,949	132,995	19.0%	33.1%
Guildford	160,186	44,019	57,398	72,616	27.5%	45.3%
Henley	50,901	5,895	8,824	12,791	11.6%	25.1%
Total	**9,779,115**	**2,104,527**	**3,236,321**	**4,140,543**	**21.5%**	**42.3%**

WRZ	Total Properties	Change in Properties from Base Year			% Change in Properties from Base Year to:	
	2016/17	2044/45	2069/70	2099/100	2044/45	2099/2100
London	2,729,586	989,749	1,601,449	2,066,895	36.3%	75.7%
SWOX	425,681	145,951	192,349	256,414	34.3%	60.2%
SWA	205,640	61,080	91,172	123,453	29.7%	60.0%
Kennet Valley	159,064	37,080	50,770	70,795	23.3%	44.5%
Guildford	61,637	20,709	28,172	37,537	33.6%	60.9%
Henley	21,292	3,011	4,870	7,427	14.1%	34.9%
Total	**3,602,900**	**1,257,580**	**1,968,783**	**2,562,521**	**34.9%**	**71.1%**

3.107 The evaluation of the level of uncertainty associated with the combined plan-based and long-term forecasts is a key component of the revised draft WRMP19 process. Section 5: Allowing for risk and uncertainty, considers this uncertainty, using UKWIR's technical guidance to inform the calculation of a Target Headroom allowance.

Draft WRMP19 representations and new evidence

3.108 Following the submission of the draft WRMP19 in December 2017, we received formal feedback, both from regulatory bodies and from other stakeholder organisations. A number of points were raised with regard to the demographic evidence supporting the draft WRMP19, identifying the availability of new housing and demographic evidence and the need for us to compare the draft WRMP19 growth forecasts with this new evidence.

3.109 Since the draft WRMP19 was first submitted the ONS has published its 2016-based population projections, the first release of future SNPP growth estimates since the Brexit referendum in June 2016[10]. A new Draft London Plan[11] has advocated higher housing growth across the 33 London Boroughs over the next ten years, with demographic evidence to inform these new housing numbers provided by the GLA[12]. Finally, new Local Plan evidence has been published by local authorities outside London, with revisions to the housing growth trajectories that informed the core draft WRMP19 demographic forecasts.

3.110 In response to these specific points of representation we asked Edge Analytics to consider the new housing and demographic evidence in order to establish its comparability with our 'final forecast' presented above.

3.111 The full report on this review of evidence is provided in Appendix E: Population and property projections (Part C). A summary of the key components of the evidence is presented here.

Latest ONS evidence

3.112 Every two years, the ONS publishes its national and sub national population projections. The 2016-based NPP was released in October 2017[13]. The 2016-based suggests a *lower* rate of population growth than under the earlier NPPs, driven by assumptions on lower natural change (i.e. increased deaths and fewer births) and lower net international migration

3.113 In May 2018, the ONS released its 2016-based -S*NPP*s, providing a new suite of 'official' statistics for all local authority areas in England. These are 'trend' based projections, aligning to the NPP and do not take account of any planned trajectories of housing growth for individual local authorities. However, the 2016-based SNPPs provide an important benchmark against which to compare the 'core' Baseline scenario.

3.114 The latest 2016-based scenario evidence from the ONS has been considered alongside the Baseline scenario. ONS-2016 High and ONS-2016 Low scenarios have been formulated, which consider the potential for higher or lower international migration growth over the 25-year projection horizon.

3.115 The analysis has also considered how the latest ONS assumptions on population growth influence the 'return-to-trend' assumptions, which are a key component of the plan-based scenarios for non-London local authorities over the second half of the core WRMP plan period, 2030-2045.

London Plan and GLA projections

3.116 In December 2017, the GLA published a draft update to the London Plan, setting out revised 10-year targets for net housing completions by Borough. Totalling approximately 64,935 homes

[10] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/subnationalpopulationprojectionsforengland/2016based
[11] Mayor of London, December 2017. The London Plan: The spatial development strategy for Greater London (Draft for Public Consultation) https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan
[12] https://data.london.gov.uk/dataset/projections/
[13] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2016basedstatisticalbulletin#quality-and-methodology

per year over the 2019/20-2028/29 period, the new housing target is informed by an updated range of evidence, including 2016-based population and household projections, the 2017 Strategic Housing Market Assessment (SHMA) and 2017 Strategic Housing Land Availability Assessment (SHLAA) .

3.117 The latest GLA 2016-based growth projections include its 'Housing-led' scenario, informed by housing growth data drawn from the latest SHLAA for London. For all London Boroughs, the latest GLA housing-led scenario has been combined with updated Local Plan evidence from non-London local authorities, to produce a revised plan-based population and housing growth outcome for the London WRZ.

New Local Plans

3.118 In response to the draft WRMP19 representations, Local Plan housing evidence published since the Baseline forecast was formulated has been collected and reviewed. This process has focused only on those local authorities within the supply area (not the extended waste-water geography) which excluding the London Boroughs, represents a total of 31 local authorities.

3.119 The final report presented in Appendix E: Population and property projections (Part C) provides a comparison of previous and revised housing growth totals for the core 2016-2045 WRMP plan period and annual growth for 2016-2030 and 2030-2045.

3.120 The revised housing totals include a 'return-to-trend' assumption to estimate housing growth beyond each local authority's Local Plan horizon (typically from approximately 2030 onwards, although sometimes earlier). Housing totals used in the Baseline scenario, include a 'return-to-trend' assumption based on ONS 2014-based population projections. Updated housing totals presented for August 2018, include a 'return-to-trend' assumption based on ONS 2016-based population projections.

3.121 There are changes in the housing growth trajectories associated with individual local authorities but in total (taking account of both Local Plan and 'return-to-trend' evidence) the overall difference is just +225 in favour of the August 2018 evidence.

3.122 Generally the pattern is for higher housing growth in the 2016-2030 time period; reducing in 2030-2045 beyond the Local Plan horizons. With the ONS 2016-based projections generally resulting in lower growth than their 2014-based equivalents, the revised 'return-to-trend' assumptions will invariably result in a dampening of estimated housing growth for most local authorities beyond the end of each Local Plan period.

3.123 These new Local Plan housing trajectories in conjunction with the new ONS and London Plan / GLA evidence, have been used in the formulation of an updated Plan-based (August 2018) scenario.

Summarising the Evidence

3.124 In the new Plan-based (August 2018) scenario, population and property growth evidence from the GLA's 2016-based Housing-led projection has replaced the original London Borough forecasts from the Baseline scenario. Updated Local Plan evidence for non-London districts has provided the basis for a revised housing-led growth scenario in these areas. Additionally, the original 'return-to-trend' assumptions that were based on ONS 2014-based evidence and applied to all local authority areas where plan-based evidence was not available, have been replaced with equivalent ONS 2016-based assumptions for the non-London Boroughs.

3.125 Population growth profiles are presented for the supply area, in total, and for each individual WRZ. The Baseline scenario and the updated Plan-based scenario are illustrated alongside trend-based projections. The ONS 2016-based projection is presented alongside two variant 2016-based projections (ONS-2016 High and ONS-2016 Low). An ONS 2014-based scenario (ONS-2014) is included to illustrate how the official projections have altered in the latest round.

3.126 For the supply area, the latest evidence, presented in the Plan-based (August 2018) scenario estimates slightly higher population growth (22.8%) than the previous Baseline scenario (21.5%), and an additional +120,300 population (Table 3-12).

Table 3-12: Growth in population and properties for each All WRZs, 2016-2045

All WRZs	Total population		Change in population	
	2016/17	2044/45	Absolute	%
Baseline	9,779,115	11,883,642	2,104,527	21.5%
August 2018	9,779,115	12,003,988	2,224,874	22.8%

All WRZs	Total Properties		Change in Properties	
	2016/17	2044/45	Absolute	%
Baseline	3,602,900	4,860,480	1,257,580	34.9%
August 2018	3,602,900	4,770,650	1,167,750	32.4%

3.127 This higher population growth is achieved on a lower property growth total: 32.4% in the latest evidence, versus 34.9% in the Baseline scenario. The Plan-based (August 2018) scenario records higher property growth than the Baseline scenario in the first half of the core 2016-2045 WRMP plan period, but lower growth thereafter. This trend is a reflection of two key factors:

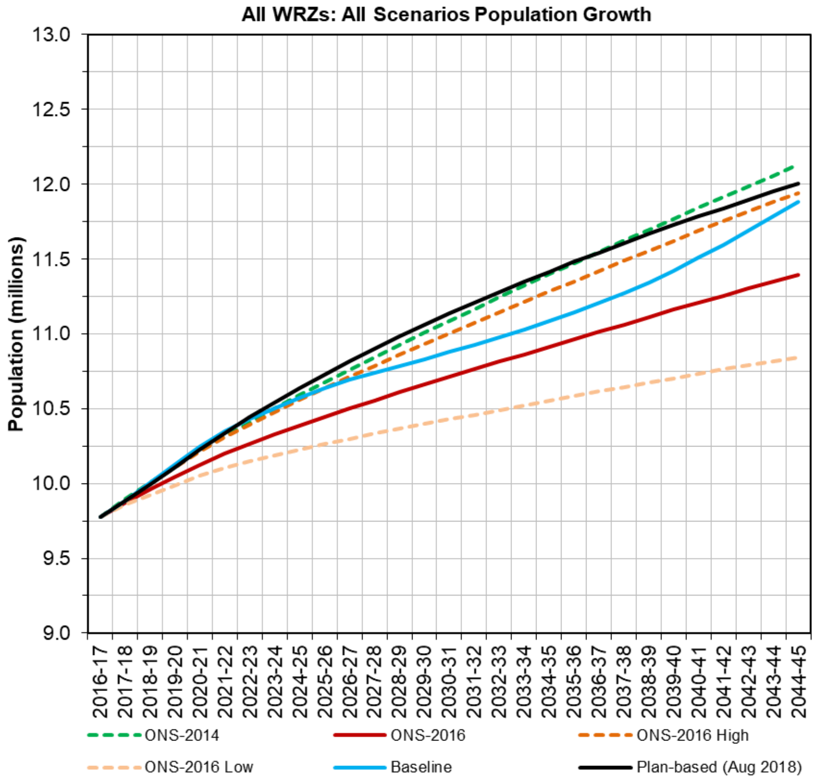
- Higher property growth totals in the new Draft London Plan and in the latest Local Plan statistics for non-London local authorities, both of which primarily relate to the period prior to 2030.
- Lower property growth totals associated with the GLA's Housing-led scenario for London Boroughs post-2030, plus lower property growth totals in non-London local authorities resulting from the dampened 'return-to-trend' assumptions to 2045.

3.128 Population projection evidence from the ONS has been considered alongside the Baseline and Plan-based (August 2018) scenarios. For the supply area in total, the Plan-based (August 2018) scenario follows a similar trajectory to the ONS-2014 projection. The ONS-2016 projection estimates lower overall population growth at just 16.5%, reflecting the lower international migration assumptions and the altered fertility and mortality outlook that are implied by this projection. The High and Low variants of the ONS-2016 projection, based on higher and lower international migration assumptions, suggest a growth range of 10.9%-22.1% by 2045 (1.1 million-2.2 million additional people), each lower than the Plan-based (August 2018) evidence.

3.129 The relationship between the scenarios varies by WRZ. The growth in the London WRZ drives the overall profile for the supply area, although its Plan-based (August 2018) scenario outcome is lower than the ONS-High, in contrast to all other WRZs. The new evidence and assumptions driving the Plan-based (August 2018) scenario result in an additional 110,000 population growth in the London WRZ compared to the Baseline scenario.

3.130 In the SWOX and Henley WRZs, the Plan-based (August 2018) scenario results in a higher population growth outcome than the Baseline scenario. The Plan-based (August 2018) and Baseline scenarios produce similar outcomes for the Kennet Valley WRZ, whilst the newer evidence suggests slightly lower growth in the Slough, Wycombe Aylesbury (SWA) and Guildford WRZs. In all non-London WRZs, the new Plan-based evidence exceeds the growth outcomes of the latest ONS trend scenarios.

Figure 3-9: Population growth summary: WRZ total



3.131

Table 3-13: Population growth summary: WRZ total

All WRZs	Total population		Change in population	
	2016/17	2044/45	Absolute	%
ONS-2014	9,779,115	12,130,067	2,350,953	24.0%
Plan-based (Aug 2018)	9,779,115	12,003,988	2,224,874	22.8%

ONS-2016 High	9,779,115	11,941,524	2,162,409	22.1%
Baseline	**9,779,115**	**11,883,642**	**2,104,527**	**21.5%**
ONS-2016	9,779,115	11,390,784	1,611,669	16.5%
ONS-2016 Low	9,779,115	10,843,156	1,064,041	10.9%

Figure 3-10: Population growth summary: London WRZ

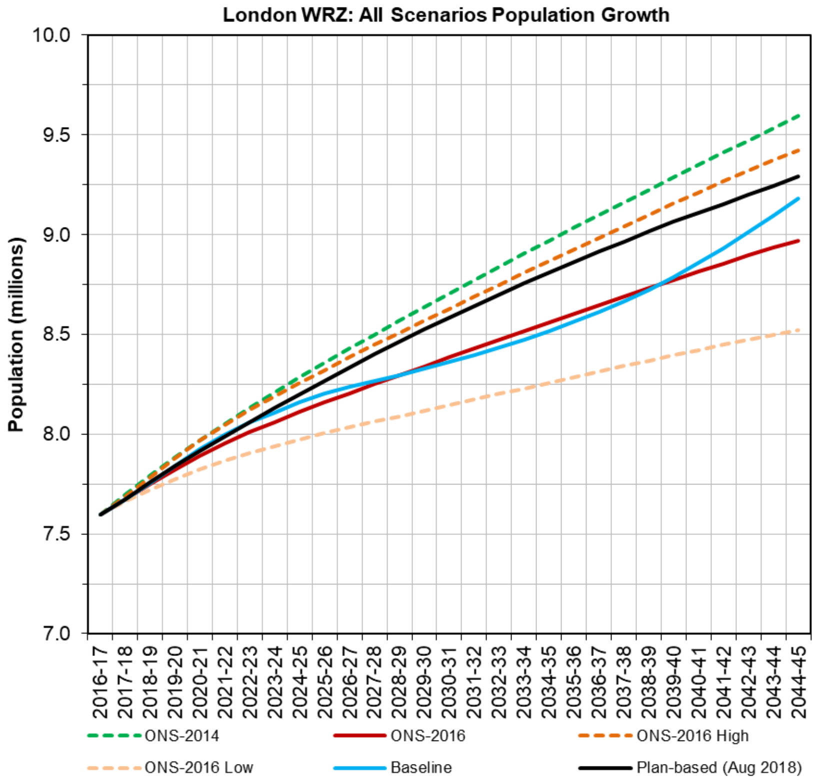


Table 3-14: Population growth summary: London WRZ

London WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
ONS-2014	7,595,624	9,593,722	1,998,098	26.3%
ONS-2016 High	7,595,624	9,422,978	1,827,354	24.1%
Plan-based (Aug 2018)	7,595,624	9,289,686	1,694,062	22.3%
Baseline	**7,595,624**	**9,179,714**	**1,584,089**	**20.9%**
ONS-2016	7,595,624	8,970,567	1,374,943	18.1%
ONS-2016 Low	7,595,624	8,520,185	924,561	12.2%

Figure 3-11: Population growth summary: SWA WRZ

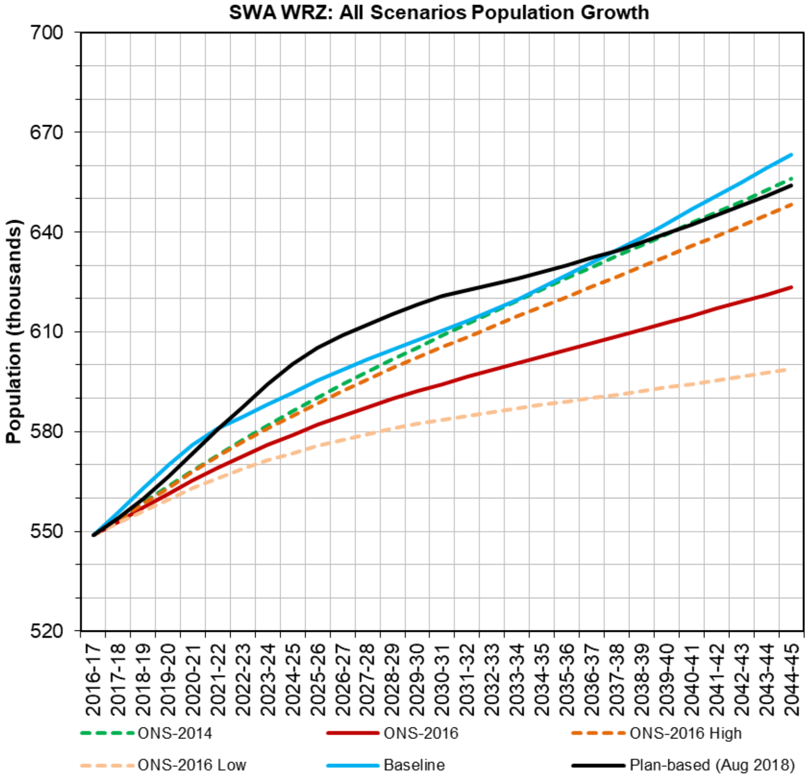


Table 3-15: Population growth summary: SWA WRZ

SWA WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Baseline	**548,844**	**663,353**	**114,509**	**20.9%**
ONS-2014	548,844	655,950	107,106	19.5%
Plan-based (Aug 2018)	548,844	654,035	105,191	19.2%
ONS-2016 High	548,844	648,113	99,269	18.1%
ONS-2016	548,844	623,372	74,528	13.6%
ONS-2016 Low	548,844	598,948	50,104	9.1%

Figure 3-12: Population growth summary: SWOX WRZ

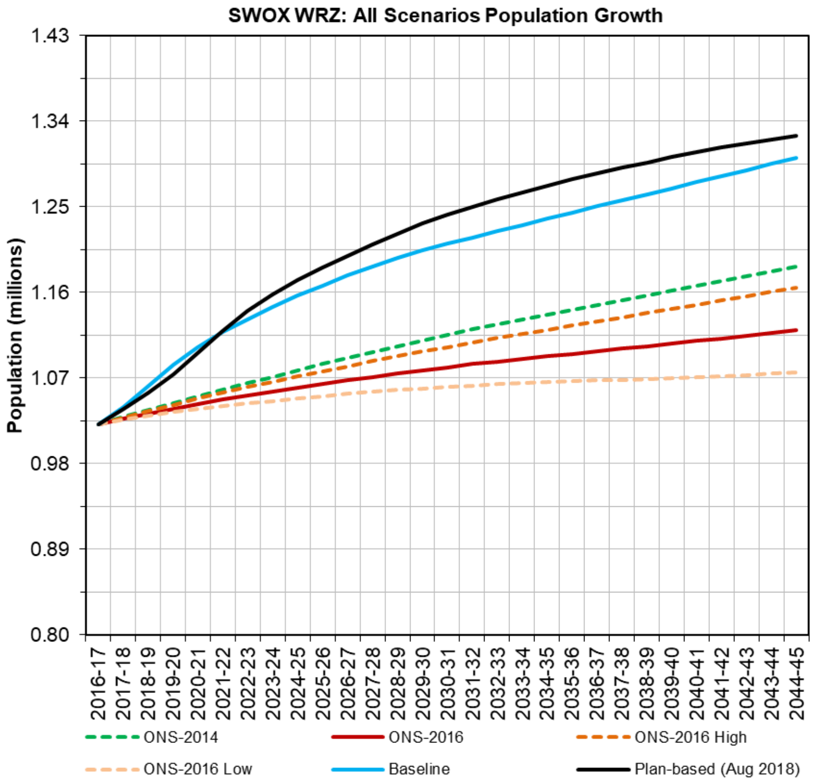


Table 3-16: Population growth summary: SWOX WRZ

SWOX WRZ	Total Population		Change in Population	
	2016/17	**2044/45**	**Absolute**	**%**
Plan-based (Aug 2018)	1,021,824	1,324,389	302,564	29.6%
Baseline	**1,021,824**	**1,301,332**	**279,508**	**27.4%**
ONS-2014	1,021,824	1,186,855	165,031	16.2%
ONS-2016 High	1,021,824	1,165,421	143,597	14.1%
ONS-2016	1,021,824	1,120,320	98,496	9.6%
ONS-2016 Low	1,021,824	1,075,615	53,790	5.3%

Figure 3-13: Population growth summary: Guildford WRZ

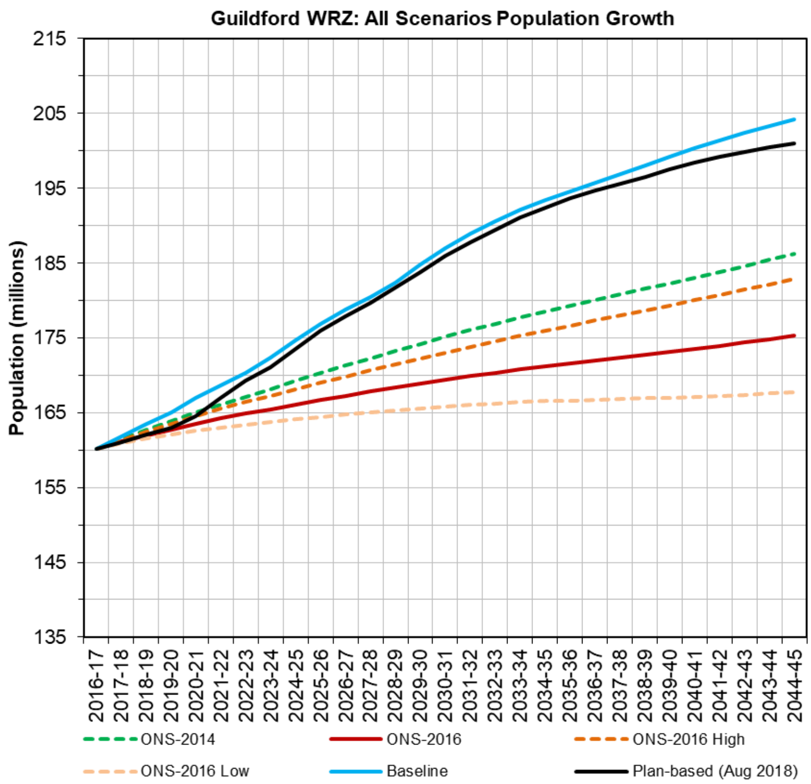


Table 3-17: Population growth summary: Guildford WRZ

Guildford WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Baseline	**160,186**	**204,205**	**44,019**	**27.5%**
Plan-based (Aug 2018)	160,186	200,952	40,766	25.4%
ONS-2014	160,186	186,181	25,996	16.2%
ONS-2016 High	160,186	182,889	22,703	14.2%
ONS-2016	160,186	175,278	15,092	9.4%
ONS-2016 Low	160,186	167,717	7,531	4.7%

Figure 3-14: Population growth summary: Kennet Valley WRZ

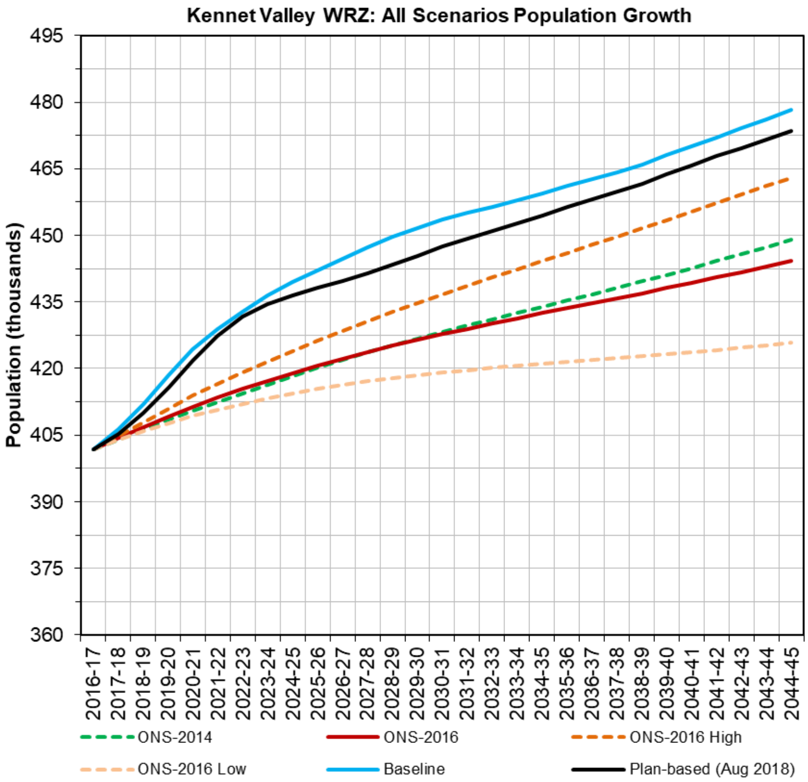


Table 3-18: Population growth summary: Kennet Valley WRZ

Kennet Valley WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Baseline	**401,735**	**478,241**	**76,506**	**19.0%**
Plan-based (Aug 2018)	401,735	473,456	71,721	17.9%
ONS-2016 High	401,735	462,978	61,243	15.2%
ONS-2014	401,735	449,032	47,297	11.8%
ONS-2016	401,735	444,228	42,492	10.6%
ONS-2016 Low	401,735	425,776	24,041	6.0%

Figure 3-15: Population growth summary: Henley WRZ

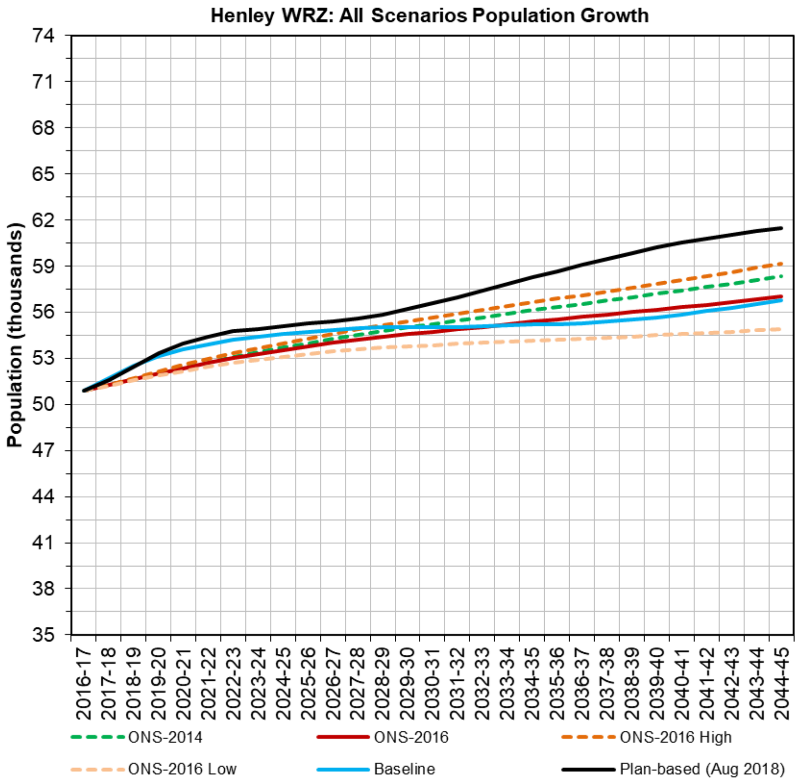


Table 3-19: Population growth summary: Henley WRZ

Henley WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Plan-based (Aug 2018)	50,901	61,471	10,570	20.8%
ONS-2016 High	50,901	59,145	8,244	16.2%
ONS-2014	50,901	58,327	7,426	14.6%
ONS-2016	50,901	57,019	6,118	12.0%
Baseline	**50,901**	**56,796**	**5,895**	**11.6%**
ONS-2016 Low	50,901	54,914	4,013	7.9%

Measured and unmeasured property forecasts

3.132 Now that we have a total population and property forecast for each WRZ we look to disaggregate this to produce estimates for measured and unmeasured household properties, and measured, unmeasured and non-household populations for the baseline forecast.

3.133 The first stage in this process is to calculate the change in measured and unmeasured households each year which is done using simple arithmetic.

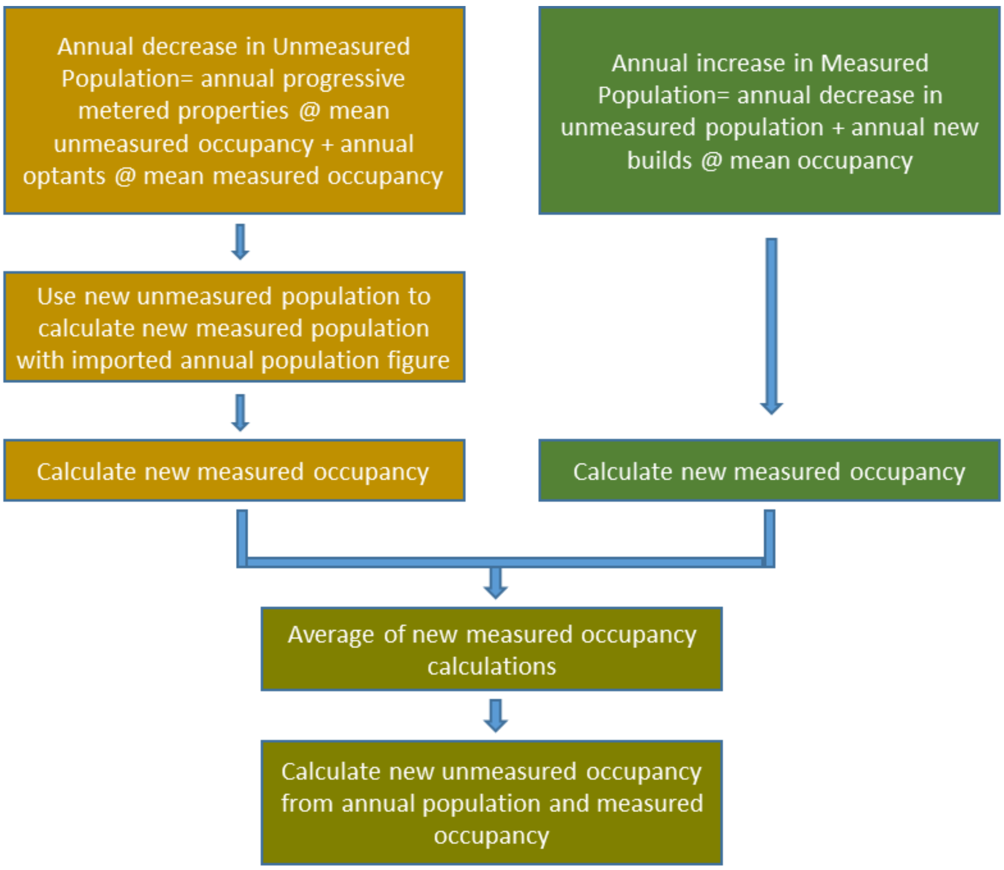
3.134 The increases in the total number of household properties each year is attributable to new households being built and, as all new household properties have a meter, these are added to the measured category.

3.135 The effects of metering are also accounted for. The total of optant and progressive meters are calculated for each year and this number is subtracted from the unmeasured household category and added to the measured household category.

3.136 These simple calculations allow us to produce household property forecasts segmented by their metering status.

3.137 The calculation of populations for metered and unmetered properties is more complex. Forecasts of population are not available for measured and unmeasured property types and therefore are required to be calculated. An algorithm, shown in Figure 3-16, to forecast the changing occupancy for measured and unmeasured population as metering progresses has been developed. This algorithm is initiated by calculating the change in population expected from shifts in metering status and new build properties for both measured and unmeasured populations. These are then used with forecast population changes to reconcile the two calculations against total population on an annual basis. Figure 3-16 shows how this algorithm calculates these values.

Figure 3-16: Occupancy recalculation algorithm



3.138 The calculated occupancy can then be multiplied by the total number of households in each segment giving a total population value for each. Population totals for each segment and their associated occupancy are shown in Table 3-20. Now we have forecasts of properties and population for each WRZ and each segment this information can now be used in the production of demand forecasts.

Table 3-20: Population, properties and average occupancy forecasts for each WRZ (baseline)

WRZ	Parameter	Type	2016/17	2019/20	2024/25	2029/30	2044/45	2069/70	2099/2100
London	Population (000s)	Measured	2,368,703	3,243,969	3,820,970	4,251,849	5,754,967	7,694,249	9,433,457
		Unmeasured	5,226,922	4,597,860	4,337,151	4,077,262	3,424,747	2,447,117	1,403,456
		Non Household	51,443	52,434	55,201	58,649	74,688	102,642	129,122
	Properties (000s)	Measured	912,337	1,245,432	1,502,105	1,708,461	2,382,308	3,272,353	4,071,813
		Unmeasured	1,817,250	1,615,373	1,559,704	1,504,035	1,337,028	1,058,683	724,669
	Occupancy	Measured	2.60	2.60	2.54	2.49	2.42	2.35	2.32
		Unmeasured	2.88	2.85	2.78	2.71	2.56	2.31	1.94
		Overall	2.78	2.74	2.66	2.59	2.47	2.34	2.26
SWOX	Population (000s)	Measured	585,481	664,365	771,289	854,607	1,063,930	1,233,050	1,355,299
		Unmeasured	436,344	419,581	385,172	349,308	237,402	145,847	126,935
		Non Household	32,589	33,110	34,271	35,774	40,717	46,059	52,145
	Properties (000s)	Measured	273,437	304,042	351,874	390,533	492,202	573,632	637,698
		Unmeasured	152,244	146,787	133,327	119,853	79,431	44,398	44,398
	Occupancy	Measured	2.14	2.19	2.19	2.19	2.16	2.15	2.13
		Unmeasured	2.87	2.86	2.89	2.91	2.99	3.29	2.86
		Overall	2.40	2.40	2.38	2.36	2.28	2.23	2.17

WRZ	Parameter	Type	2016/17	2019/20	2024/25	2029/30	2044/45	2069/70	2099/2100
SWA	Population (000s)	Measured	247,666	282,045	327,001	366,610	491,620	636,759	701,676
		Unmeasured	301,178	287,951	264,662	240,816	171,733	79,422	67,611
		Non Household	5,281	5,491	5,896	6,422	8,331	11,076	13,915
	Properties (000s)	Measured	106,686	119,271	138,656	156,273	211,081	274,838	307,119
		Unmeasured	98,954	95,707	87,701	79,686	55,639	21,974	21,974
	Occupancy	Measured	2.32	2.36	2.36	2.35	2.33	2.32	2.28
		Unmeasured	3.04	3.01	3.02	3.02	3.09	3.61	3.08
		Overall	2.67	2.65	2.61	2.57	2.49	2.41	2.34
Kennet Valley	Population (000s)	Measured	189,855	212,623	247,545	275,301	353,346	430,066	470,219
		Unmeasured	211,881	205,778	191,921	176,339	124,895	71,618	64,511
		Non Household	6,791	6,910	7,203	7,581	8,902	10,540	12,187
	Properties (000s)	Measured	87,337	94,711	109,151	121,383	158,023	192,858	212,883
		Unmeasured	71,727	69,208	62,996	56,777	38,120	16,976	16,976
	Occupancy	Measured	2.17	2.24	2.27	2.27	2.24	2.23	2.21
		Unmeasured	2.95	2.97	3.05	3.11	3.28	4.22	3.80
		Overall	2.53	2.55	2.55	2.54	2.44	2.39	2.33
Guildford	Population	Measured	73,423	81,918	97,411	113,838	153,704	192,645	211,422

WRZ	Parameter	Type	2016/17	2019/20	2024/25	2029/30	2044/45	2069/70	2099/2100
	(000s)	Unmeasured	86,763	83,178	77,201	70,952	50,501	24,939	21,379
		Non Household	7,468	7,535	7,704	7,905	8,588	9,682	10,928
	Properties (000s)	Measured	32,506	35,566	41,946	48,775	66,284	83,421	92,786
		Unmeasured	29,131	28,151	25,736	23,317	16,062	6,388	6,388
	Occupancy	Measured	2.26	2.30	2.32	2.33	2.32	2.31	2.28
		Unmeasured	2.98	2.95	3.00	3.04	3.14	3.90	3.35
		Overall	2.60	2.59	2.58	2.56	2.48	2.42	2.35
Henley	Population (000s)	Measured	28,562	31,141	33,736	35,881	43,099	49,023	53,885
		Unmeasured	22,339	21,997	20,863	19,152	13,697	10,702	9,807
		Non Household	271	324	429	542	896	1,248	1,618
	Properties (000s)	Measured	14,226	15,014	16,071	17,177	20,971	23,936	26,492
		Unmeasured	7,066	6,786	6,096	5,405	3,332	2,226	2,226
	Occupancy	Measured	2.01	2.07	2.10	2.09	2.06	2.05	2.03
		Unmeasured	3.16	3.24	3.42	3.54	4.11	4.81	4.41
		Overall	2.39	2.44	2.46	2.44	2.34	2.28	2.22

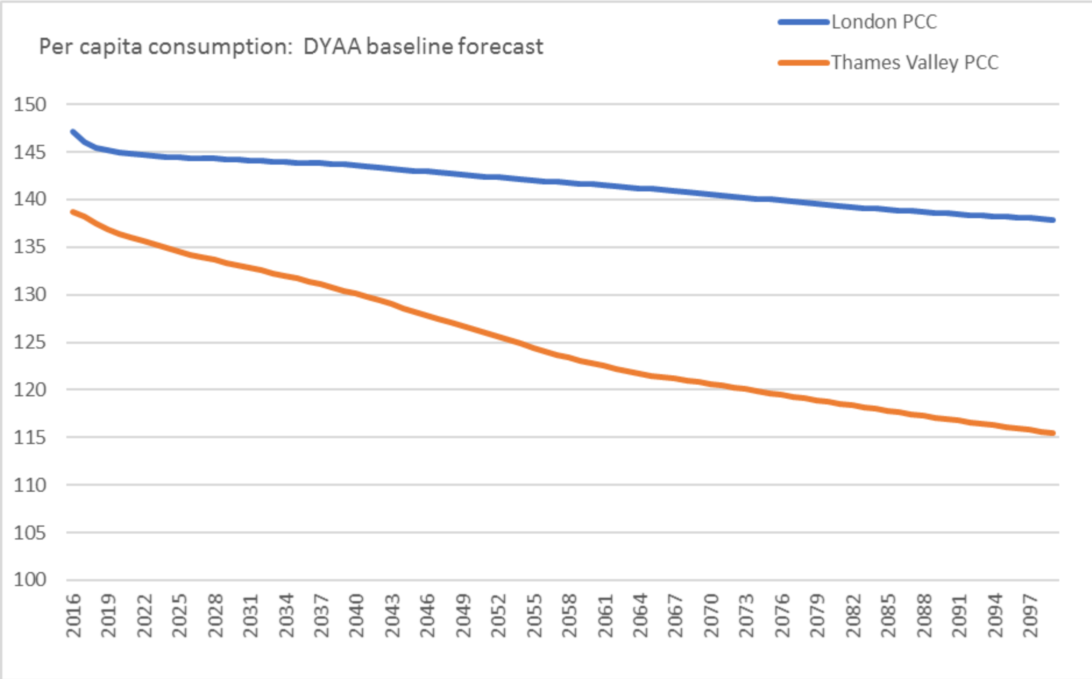
D. Household water use

Introduction

3.139 For the draft WRMP19 we developed a forecast for household consumption that shows baseline PCC across the region declining from the base year through to 2100. This is illustrated in Figure 3-17. The figure presents the DYAA PCC for the London region and for the remaining WRZs (collectively referred to as 'Thames Valley'). From the figure we can see that the projections for average PCC for the two regions are different, with the London region starting with a higher PCC that reduces at a lower rate than the PCC for the Thames Valley region. The difference in scale and trend in PCC in the London region is due to a number of factors:

- Lower metering penetration, London has only 33% metering penetration in the base year compared to ~59% for Thames Valley
- The larger proportion of rented properties results in less interest in water saving. Tenants are also reluctant to change fittings or install water efficiency devices as it is not their property
- There is a larger number of Indian, Pakistani and Bangladeshi households in London compared to most of our other areas. Indian, Pakistani and Bangladeshi households have been observed to have significantly higher usage than other households and these differences are thought to be cultural. This in combination with London's lower metering penetration results in higher PCC
- The higher proportion of flats within London also results in few opportunities for saving water due to lack of garden usage

Figure 3-17: Overview of household consumption forecasting process



3.140 The household consumption forecasts for both regions have been developed using multiple linear regression models. This is a different approach to the forecast developed for WRMP14, when the forecast was developed using micro-component models. Updating of the industry best practice for household demand forecasting[14], introduced the option to select from a range of forecasting methods based on an analysis of the planning challenges in each WRZ.

3.141 After careful consideration and peer review, we decided to move to a forecasting method based on multiple linear regressions for all WRZs. The detailed reasons for this are explained below and in Appendix F: Household water demand modelling, but in summary:

- the forecasts could be built on good quality historic household consumption
- the availability of demographic and housing type data from across the Thames Water region
- the models are based on demographic and housing factors that are known to influence household consumption
- the models could be constructed using standard statistical method that allow the robustness and uncertainties of the models to be quantified
- the models could be validated using historic and regional data

3.142 The sections below provide an overview of the modelling approach and each of the steps in the process for developing the household demand forecasts, shown in Figure 3-18, and further detailed explanation is included in Appendix F: Household water demand modelling.

[14] UKWIR 2015 WRMP19 Methods – Household Consumption Forecasting 15/WR/02/9

Demand forecasting model

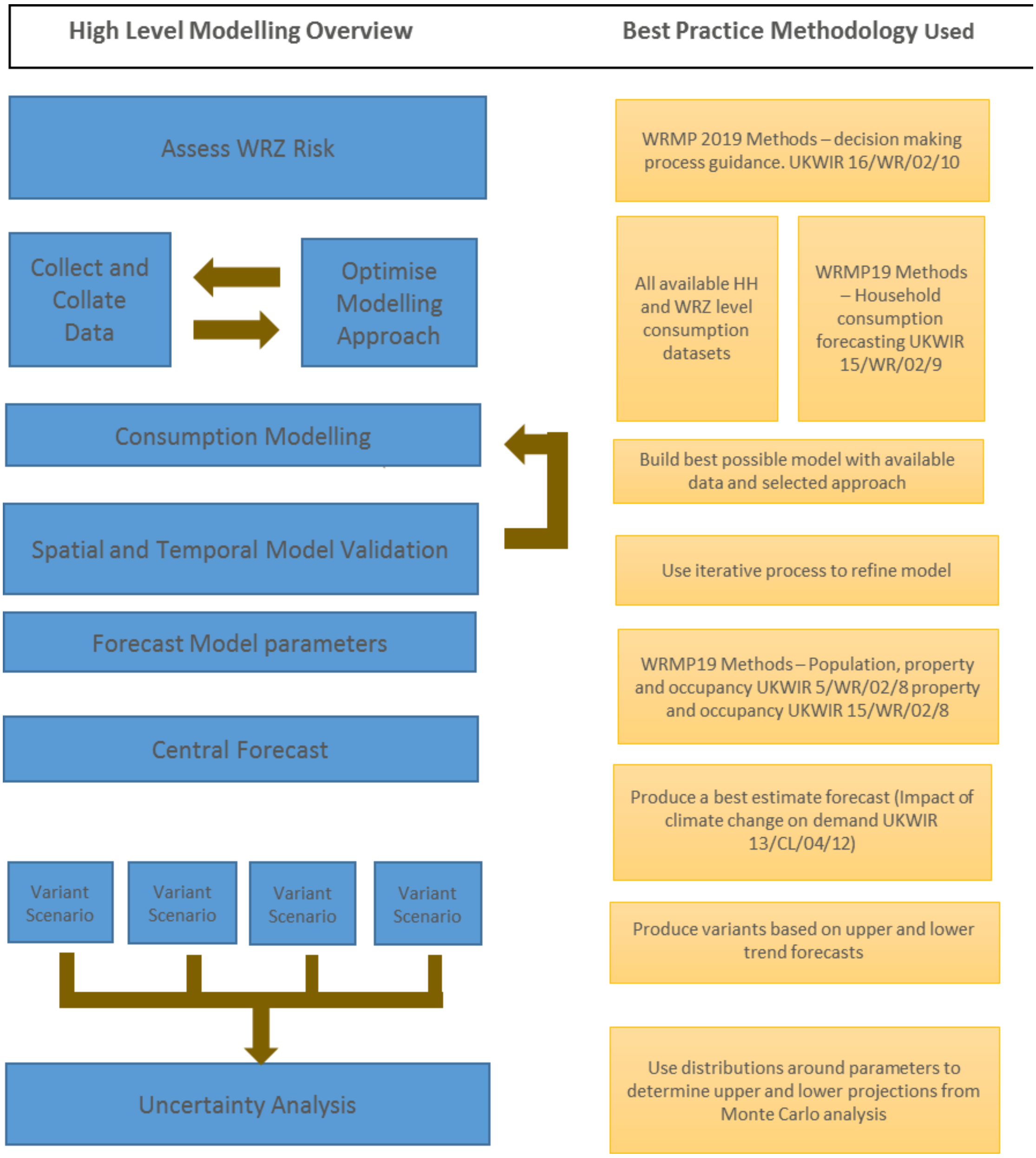
3.143 For the draft WRMP19 we have developed a new model for the purposes of forecasting future household consumption.

3.144 In line with the methods set out by "WRMP19 Methods – Household Consumption Forecasting" we have developed a household consumption model. We tasked Artesia Consulting with developing and delivering a model to produce a baseline household consumption forecast, which could be projected forward to the year 2100.

3.145 We are required to use the most appropriate forecasting method for household consumption in each of our WRZs. This identified that the London WRZ required a bespoke model due to the importance of this area. Separating the Thames Valley dataset from the London modelling mitigated the risk of potentially skewing the model for the largest area (London) by the five Thames Valley WRZs.

3.146 The high level modelling process used to develop the model is shown in Figure 3-18.

Figure 3-18: Overview of household consumption forecasting process



3.147 Section 5 of the WRPG describes the approaches that water companies should take to forecast demand, including household consumption. In particular, section 5.4 of the guidelines states that:

> *'You should select demand forecasting methods appropriate to the data available and the supply-demand situation in individual WRZ'.*

3.148 To identify the most appropriate method for forecasting household consumption we need to consider how the differing options address the regulatory, business, stakeholder and risk requirements so that it provides a sound foundation for our draft WRMP19.

3.149 The first stage is to determine in water resource planning terms, the planning challenges that exist, how they differ between WRZs, the length of forecast required, what data is available and which method or methods will be most suitable for the household consumption forecast.

3.150 The draft outputs from the UKWIR 'Decision making process' framework[15] were used to characterise the water resources planning challenge in each of our WRZs, as shown in Table 3-21. More information on problem characterisation of our WRZs can be found in Appendix D: Water resource zone integrity.

Table 3-21: Problem characterisation based on WRMP14

Zone	Problem characterisation
London	High
SWOX	High
SWA	Medium
Kennet Valley	Low
Guildford	Low
Henley	Low

3.151 The UKWIR household consumption forecasting guidance identifies the following methods for forecasting household consumption:

- Use existing study data
- Trend based models
- Per-capita methods
- Variable flow methods
- Major consumption groups
- Micro-components
- Regression models
- Proxies of consumption
- Micro-simulation

3.152 A full review of these methods can be found in the UKWIR Household consumption forecasting guidance.

3.153 The following criteria, shown in Table 3-22, were developed in the UKWIR consumption forecasting guidance to assess the forecasting methods.

[15] WRMP 2019 Methods – decision making process guidance. UKWIR. 2016. Ref: 16/WR/02/10

Table 3-22: Criteria for evaluation consumption forecasting methods

Criteria	Comment
Acceptance by stakeholders	The method should stand up to scrutiny from the regulators and other external stakeholders, including customers.
Explicit treatment of uncertainty	The method should recognise that there will be uncertainty around the forecast, and should quantify the level of uncertainty.
Underpinned by valid data	The method should be based on data that is valid for the area under consideration.
Transparency and clarity	The method needs to be understood and should be able to be replicated by others.
Appropriate to level of risk	The method should be appropriate in terms of cost and data requirements for the planning problem being addressed; i.e. the degree of vulnerability to a supply demand deficit.
Logical and theoretical approach	The method should command confidence to practitioners and decision makers. It should address those factors that people believe drive water demand, and it should be relevant to historical trends.
Empirical validation	The method should enable comparison to outturns or past projections. It should be possible to test the method on past data to predict demand, and predict any explanatory factors used in the forecast.
Explicit treatment of factors that explain household consumption	The method should be able to take account of the different factors which drive household demand, and different segments of consumers with respect to household water use.
Flexibility to cope with new scenarios	The method should be flexible enough to run different household consumption forecasts.

3.154 UKWIR best practice guidance for forecasting household consumption recommends the use of a Red Amber Green (RAG) matrix to identify the most suitable consumption forecasting methodologies. These are presented in Appendix F: Household water demand modelling for WRZs with High, Medium and Low problem characterisations.

3.155 The analysis of the RAG matrices showed that regression models scored highly across all levels of problem characterisation. Major consumption group (MCG) modelling generally came second, although for the low vulnerability zones, this was a marginal second place and MCG modelling could potentially be used in these zones.

3.156 However, there is a benefit in terms of consistency and efficiency of analysis if a single robust method for forecasting consumption across all WRZs is used. It also allows spatial validation and residual analysis of the model across WRZ's which proved instrumental in model development. Therefore multiple linear regression (MLR) modelling was chosen as the method to be used for all six of our WRZs.

3.157 A range of potential data sources were identified at the start of the project, shown in Table 3-23.

Table 3-23: Potential data sources

UKWIR customer behaviour study	New data from smart meters

Market transformation programme	Thames Water research and development studies
DWUS	Smarter Home Visit data – skewed dataset. Water efficiency visits
VMR and meter trial data	Wastage study
Peak factors study	Multi faith water use studies
Micro-component studies	

3.158 Potential sources of data were identified and discussed with Artesia Consulting. The following data sets were considered to be the most useful due to the demographic information captured, sample size and amount of historic data:

The DWUS:

- Largest number of demographics
- Representative sample
- Consumption data from multiple zones
- Large sample size
- 10 year timeline
- Data fairly new at six months old.

- Smarter home visits:
  - Good sample size
  - Average quality consumption values.
  - Smart metering data:
  - Useful for checking range of data (per household consumption and leakage) against DWUS.

3.159 Of these, the DWUS data was likely to be most useful as it:

- Contained a representative sample of our household customers due to the way in which the sample was derived.
- Included a long-period of quality checked consumption data;
- Provided information on individual properties; and
- Collected annual survey data on their occupants, and the ownership and frequency of use of water using devices.

3.160 Therefore, the DWUS data became the principal focus of analysis for this project.

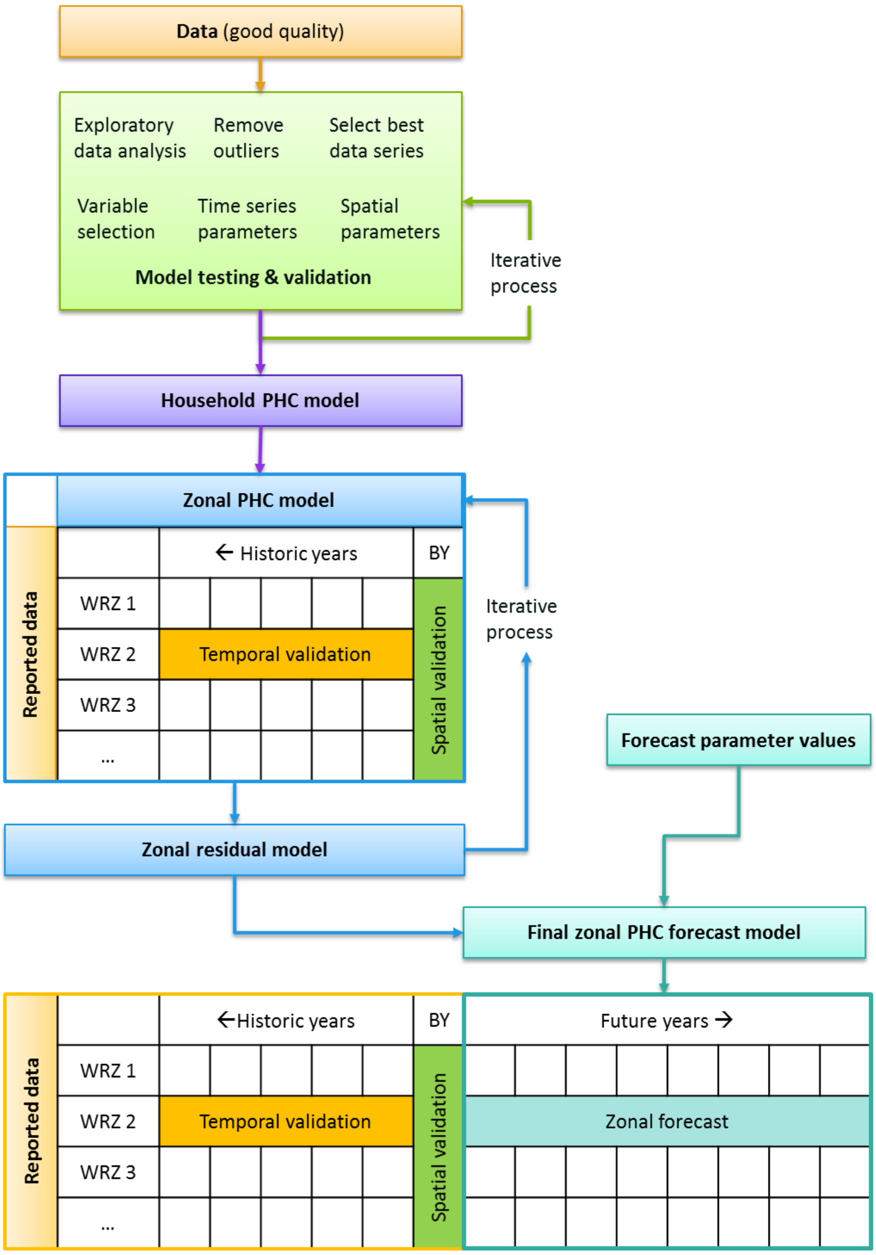
3.161 For the previous three WRMPs we used a micro-component modelling approach. The switch to a different method places a greater emphasis on validation of the new model. It is not possible to directly compare the outputs between the previous micro-component model and the new approach. Therefore, we have validated the MLR models using three different approaches:

1) The models are constructed using standard statistical methods from which the uncertainty can be quantified.
2) Temporal validation by using historic data as a model input and forecasting forwards to the current year. The outputs can then be compared with reported figures.

3) Spatial validation by applying the model to approximately 240 sub-zones across the Thames Water region and comparing with reported data. This is a level of validation that could not be carried out with previous micro-component based models.

3.162 Development of a MLR based model is a long and complicated process, therefore, only an outline of process is given here. However full details of the development can be found in Appendix F: Household water demand modelling. The process is summarised in Figure 3-19.

Figure 3-19: MLR household demand modelling and forecasting process



3.163 A more detailed description of the Figure 3-19 is described in the following steps:

1) **Obtain data** and explanatory variables from the Water Company.
2) **Select data** with which to build the model, based on:

- Sample size – sample needs to be sufficiently large so that extremes of the distribution can be modelled
- Amount of historic data – long term availability of data is important for modelling trends, calibrating the base year against annual weather effects and for testing data stability
- Representativeness of population – does the sample adequately reflect the characteristics of the population it is trying to model?
- Number of explanatory variables – is there a sufficient amount of demographic data collected at household level?
- Age of data – has the data been recently collected, and could external drivers have caused bias in the data since its collection?

3) **Exploratory data analysis** on the selected data set, to determine:
    - The presence of outliers and how to deal with them
    - The distributions of the data, specifically the response variable
    - If missing values are present, and how to deal with them
    - The presence and removal of duplicate observations
4) **Selection of variables** for inclusion within the model. Once the data has been analysed, and outliers and missing data are removed, both automatic and manual variable selection techniques, e.g. stepwise selection, are performed to identify variables which are significant in the model build
5) **Identify variables which can be forecast,** and remove other variables from the model. It is likely that the 'ideal' model includes variables which cannot be forecast into the future, for example dishwasher usage. Therefore, a secondary version of the model is created which includes all significant parameters which can be forecast into the future
6) **Test model assumptions** and validate the usage of MLR modelling. Using MLR requires that the data be tested for:
    - A linear relationship between the response variable and the explanatory variable. This is verified by analysing a plot of the residuals versus the fitted points
    - The expectation of the error term is zero for all observations, i.e. $\mathbb{E}(\varepsilon_i) = 0$ for all i
    - Homoscedasticity – the variance of the error term is constant across the variables and over time. A plot of the standardised residuals versus the predicted values can show whether the points are equally distributed or not. If the variance is not constant, then the model uncertainty will vary for different observations leading to heteroscedasticity
    - No multicollinearity, which assumes that the explanatory variables are not highly correlated with one another. Again, this can be determined using the standard residuals as well as looking at variance inflation factors
7) **Model testing and validation** at household level, by way of coefficient resampling, and cross validation

8) **Aggregate model to zonal level** so that zonal consumption figures can be derived as per the WRMP requirements
9) **Zonal model validation,** similar to the household level validation, but using zonal reported figures. Again this is done using cross validation by excluding data by time period (years) and by zone to test the model spatially and temporally
10) **Residual analysis** to determine if other factors which cannot be considered at household level (such as weather or climate effects) can be incorporated into a secondary model which will act upon the initial outputs
11) **Trends and scenarios** are finally applied to the forecast based on the most likely scenarios for future behavioural and technological changes
12) **Uncertainty** calculations are performed on the final forecast to give a 95% confidence interval for future predictions

3.164 The resulting model has a number of model variables; each has a coefficient that is derived from the model and there is a residual error term. The residual is essentially the consumption component that cannot be explained by the model variables. Residuals are used for estimating error and developing further modelling refinements.

Final unmeasured household model

3.165 Following a thorough analysis of model parameters, their interaction with other explanatory variables and their ability to be forecast, the final model is given below.

$$Consumption = \alpha + \beta x_1 + \gamma x_2 + \boldsymbol{\delta} x_3 + \boldsymbol{\eta} x_4 + \upsilon x_5 + \varepsilon$$

where:

x_1 Number of adults

x_2 Number of children

x_3 South Asian Ethnic Group flagged property type flag; either Semi-detached, terraced, flats, flat block or detached

x_4 Non-IBP flagged property type flag; either Semi-detached, terraced, flats or flat block

x_5 Rateable value (RV)

and the coefficients:

α Intercept

β Number of adults

γ Number of children

$\boldsymbol{\delta}$ Vector of coefficients for South Asian Ethnic Group property types; Semi-detached, terraced, flats, flat block and detached. The appropriate coefficient is used dependent on the value of x_3

$\boldsymbol{\eta}$ Vector of coefficients for South Asian Ethnic Group property types; Semi-detached, terraced, flats, flat block and detached. The appropriate coefficient is used dependent on the value of x_4

υ Rateable value (RV)

ε Error term

3.166 These parameters are the same for both the London and Thames Valley data sets.

3.167 The coefficients of the final model are shown in Table 3-24.

Table 3-24: Final model output and coefficients

Residuals:	**Minimum**	**1Q**	**Median**	**3Q**	**Maximum**
	-1479	-104	-26	74	1440

Coefficients:	**Litres/prop/day**	**Standard error**	**T value**	**P-Value**	**Rating**
(Intercept)	52.32	10.35	5.06	0.0000	***
Number of adults	102.73	1.92	53.41	0.0000	***
Number of children	73.68	1.85	39.90	0.0000	***
Non South Asian Ethnic Group Semi-detached	-21.62	6.72	-3.22	0.0013	**
Non-South Asian Ethnic Group Terraced	-11.23	6.83	-1.65	0.0999	.
Non-South Asian Ethnic Group Flat	-47.92	7.94	-6.04	0.0000	***
Non-South Asian Ethnic Group Flat block	-18.24	8.05	-2.27	0.0234	*
South Asian Ethnic Group Detached	262.77	18.69	14.06	0.0000	***
South Asian Ethnic Group Semi-detached	88.04	15.29	5.76	0.0000	***
South Asian Ethnic Group Terrace	316.89	11.83	26.78	0.0000	***
South Asian Ethnic Group Flat	-59.34	20.49	-2.90	0.0038	**
South Asian Ethnic Group Flat block	-0.43	19.60	-0.02	0.9825	
Rateable value	0.27	0.02	11.91	0.0000	***

Notes:

Residual standard error: 184.4 on 11843 degrees of freedom

(10,813 observations deleted due to missingness)

Multiple R-squared: 0.4236, Adjusted R-squared: 0.423

F-statistic: 725.3 on 12 and 11843 DF, p-value: < 2.2e-16

Base year normalisation

3.168 The base year for calibration is financial year (FY) 2016/17; selected as the most recent year for which a full data set was available, at the time the model development was being performed, in terms of both reported consumptions and associated demographics.

3.169 If the model is to correctly forecast a 'normal' year, then the base year consumption must also be normal.

3.170 The uncalibrated temporal residuals are modelled against weather parameters using a secondary model. The model is built by first selecting the most appropriate variable from a selection including temperature, rainfall and sunshine hours. Once the variables have been selected and the model built, the resultant weather-consumption model is applied to the base year weather parameters to produce a base year consumption correction for a normal year, which is fed back into the model for base year calibration on future projections.

3.171 In the case of the London model the weather normalisation is 2.5 l/property/day, which approximates to 0.5%. This is effectively a normal year as 0.5% is within modelling error that would be expected.

Developing a metered property model

3.172 When analysing the available data for creating the demand forecast, it was noted that the measured set of properties in the DWUS comprised a 'self-selecting' group, in the sense that these people chose metering with a much larger prior knowledge than the standard optant or progressive metered households. For this reason, these properties were excluded from the analysis and an unmetered model was derived to model consumption (paragraph 3.135).

3.173 However, comparing outputs of the model with reported metered consumption revealed the need to create a metering coefficient to adequately model metered consumption.

3.174 Building a model using unmeasured consumption enables the behaviour of the unmeasured properties to be built into the model. The unmetered population of today is the metered population of tomorrow, so understanding the drivers of consumption in this cohort is a useful and necessary task for predicting metered consumption. As we move through time, metered homes will become the dominant cohort, so future forecasts will need to gather and analyse data from the progressive metered households to understand the drivers of consumption in these new cohorts.

3.175 Once metered, behavioural tendencies tend not to alter very rapidly, with the majority of savings stemming from reduced losses/leakage. Therefore, introducing a simple coefficient to scale the consumption values which have been modelled from the unmeasured behaviour, to a level consistent with the reported metered consumptions is a logical approach.

3.176 The 'self-selecting' metered group is therefore unsuitable to build an independent model, but is perfectly sufficient for understanding the potential savings, or scale difference, compared with the unmetered group.

3.177 To validate this approach, the derived metering coefficient was tested using k-fold cross validation. This process involves splitting the data into the water supply zones, and using k-1 samples to build the model, using the kth sample as the test set in which predictions of metered consumption are made using the new coefficient. The different zones all have varying meter penetrations, and provide a good measure of how the coefficient performs using areas with differing levels of metering. This exercise found that the coefficient improved the model in all regions, providing a way to forecast metered consumption without the need to build a separate metered model.

3.178 The resulting metered coefficients for the metered household model were:

- Thames Valley metered: -101 l/prop/day
- London metered: -61 l/prop/day

Trends

3.179 The household consumption model residuals from previous years produce a significant trend in time series, indicating that some of the projected change in consumption is not accounted for by dynamic time series parameters within the model such as occupancy rates and meter penetration.

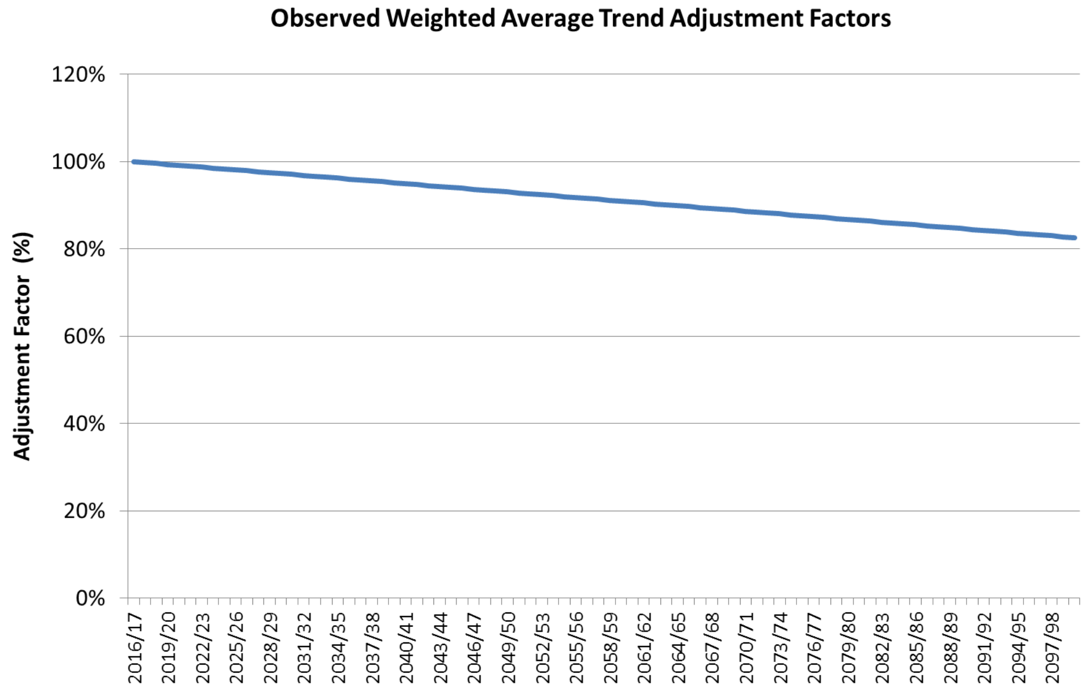
3.180 This observed un-modelled trend is thought to be driven by technological and behavioural changes.

3.181 Separate trends were derived for both London and Thames Valley data sets. The trend was observed over a ten year period and is derived from model residuals. The trend was generally downward and stronger for winter; the year round trend was applied to the initial forecast period to 2045 and also for a ten year initial period.

3.182 It is possible that the strong Thames Valley and weak London trends could switch because evidence showed more efficient appliances are installed in Thames Valley, thus leaving a greater potential for consumption reduction in the London area.

3.183 Therefore, we have used a weighted average of the two observed trends for use in the demand forecasts. The trend is presented as a percentage which is used to factor the household demand. This trend has then been linearly extrapolated to 2100. The resultant trend across the whole forecast period is shown in Figure 3-20.

Figure 3-20: Household demand trend adjustment factor



Uplifts AR17 outturn, dry year and critical period

3.184 To align with the base year reported position for the base year of 2016/17 a peaking factor is used. This peaking factor represents the difference between the outturn year and the modelled consumption from the model. Once this is done the same peaking factors as used for AR17 can be applied to uplift to dry year and the critical period.

Climate change

3.185 We commissioned the consultants HR Wallingford to carry out a study[16] to estimate the likely impacts of climate change upon household demand. No climate change effects are assumed for other components of demand based on the findings of the UKWIR report on the impacts of climate change on demand[17].

3.186 HR Wallingford undertook a statistical analysis of available data in order to derive empirical relationships that describe how weather and other factors affect household demand for water in our supply area.

3.187 We provided the following data sets:

- DWUS Unmeasured PCC by property type (2000-2010)
- PCC by property type for testDWUS[18] panel (2002-2004)

[16] HR Wallingford (2012) EX6828 Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s
[17] UKWIR 2013 Impact of Climate Change on Water Demand 13/CL/04/12
[18] testDWUS – A temporary panel of unmeasured customers used to validate DWUS

- Demand data (distribution input – minimum night line, 1998 onwards)

Climate data (temperature, rainfall and sunshine hours, 1998 onwards).

3.188 Three climate variables were considered in the statistical analysis; temperature, rainfall and sunshine hours. However sunshine hours were removed as it was found to be highly correlated with temperature, and temperature provided a stronger and better understood climate change signal which would increase confidence in the model. Including both sunshine hours and temperature could have resulted in instability within the model. For the DYAA model both rainfall and temperature were included. For the ADPW model only temperature was included as an explanatory variable, this was due to insufficient data as for most years there was no rainfall in the peak period.

3.189 To estimate the impacts of climate change, the full sample of 10,000 UKCP09 climate change projections for maximum temperature and rainfall in the Thames Valley basin in the 2030s; medium emissions scenario, was used. These scenarios provide climate change factors that are applied to the regression models.

3.190 The climate change factors are reported as the change between the baseline period (1961-1990) and the future period (2021-2050). As the baseline for the revised draft WRMP is 2016/17 a scaling factor was calculated:

$$ScalingFactor = \frac{2035 - BaseYear}{2035 - 1975}$$

3.191 As the base year is 2016/17 this results in a scaling factor of 0.4, i.e. 60% of the climate change between 1975 and 2035 has already been assumed to have occurred.

3.192 These factors were then used to provide estimates of PCC change due to climate change in the 2030s. The results of this gave 10,000 potential future PCC factors. The 10th, 50th and 90th percentiles of these factors were extracted to represent lower, mid and upper estimates of impact on PCC. The mid estimate was used in the demand forecasting models while the upper and lower estimates have been used in headroom modelling (see Section 5: Allowing for risk and uncertainty).

3.193 The climate change profiles for lower, mid and upper estimates are shown for the DYAA and DYCP scenarios in Figure 3-21 and Figure 3-22.

Figure 3-21: The impacts of climate change for the DYAA scenario

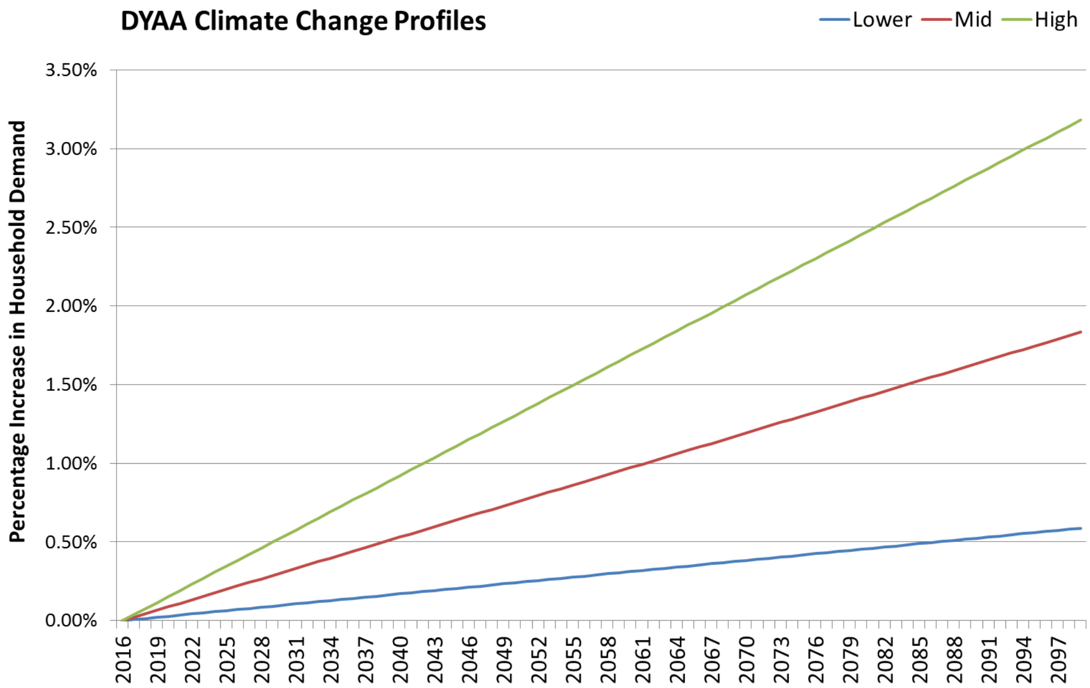
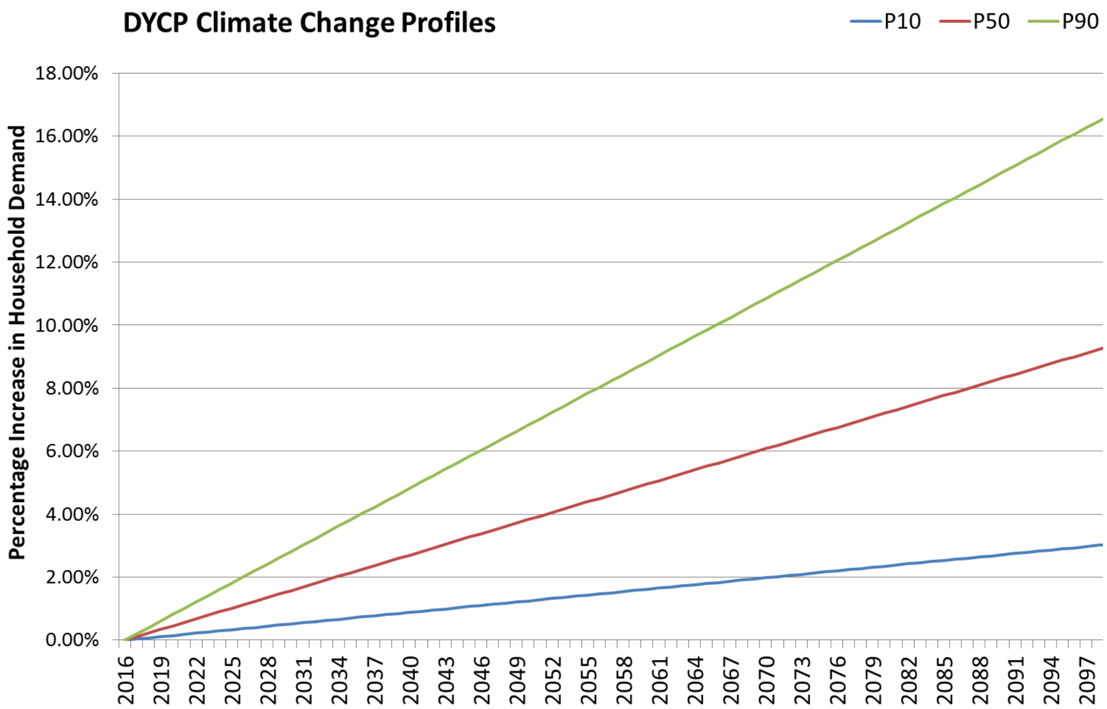


Figure 3-22: The impacts of climate change for the DYCP scenario



3.194 The volume impact of these climate change profiles for DYAA is shown in Table 3-25 and for ADPW in Table 3-26.

Table 3-25: DYAA additional demand due to climate change

Units Ml/d	2016/17	2024/25	2034/35	2044/45	2054/55	2074/75	2099/2100
Guildford	0.0	0.0	0.1	0.2	0.2	0.4	0.5
Henley	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Kennet Valley	0.0	0.1	0.2	0.4	0.5	0.7	1.1
London	0.0	2.1	4.9	8.1	11.4	18.2	26.9
SWA	0.0	0.1	0.3	0.5	0.7	1.1	1.6
SWOX	0.0	0.3	0.6	1.0	1.4	2.1	3.1

Table 3-26: ADPW additional demand due to climate change

Units Ml/d	2016/17	2024/25	2034/35	2044/45	2054/55	2074/75	2099/2100
Guildford	0.0	0.3	0.8	1.2	1.7	2.5	3.6
Henley	0.0	0.1	0.2	0.3	0.5	0.7	1.0
Kennet Valley	0.0	0.7	1.6	2.6	3.5	5.2	7.6
SWA	0.0	1.0	2.3	3.7	5.1	7.8	11.4
SWOX	0.0	1.9	4.5	7.2	9.6	14.8	21.6

Water efficiency

3.195 For AMP7 onwards it has been assumed that there would be ongoing baseline water efficiency activity of approximately 0.85 Ml/d per annum across all zones. Once decay is factored in this equates to an ongoing saving of 3.4 Ml/d across the forecast period. This total saving has then been factored across all zones based on the proportion of total population in each zone. The water efficiency saving for each zone can be seen in Table 3-27.

Table 3-27: Baseline water efficiency savings (Ml/d)

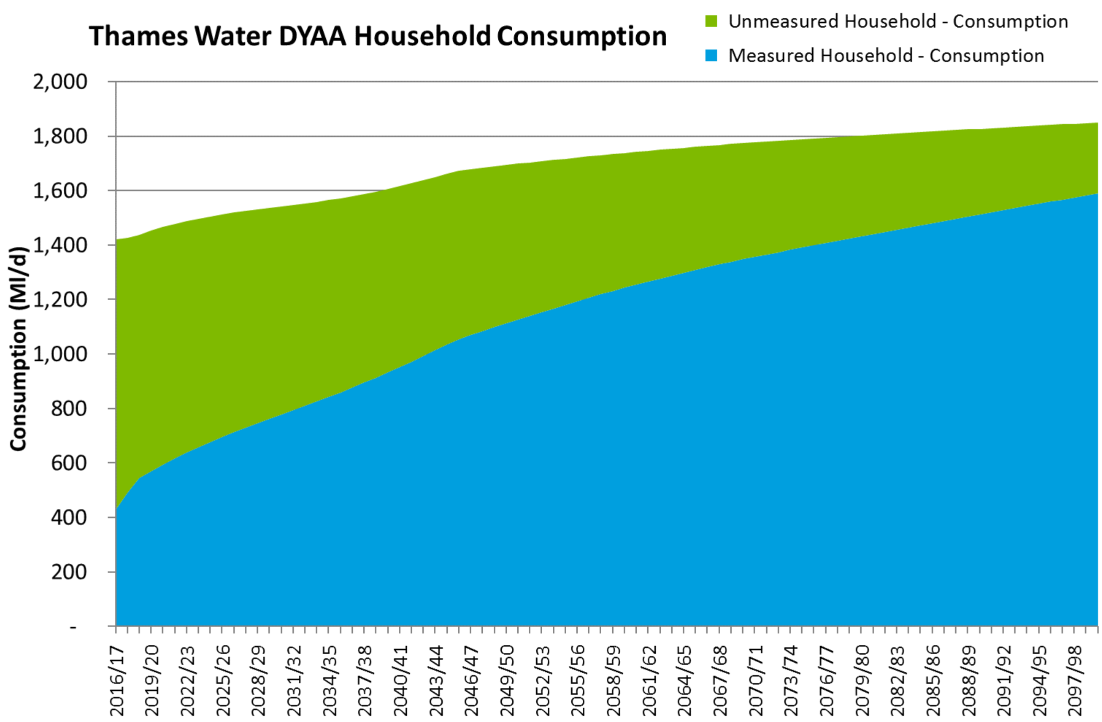
WRZ	Water efficiency saving
London	2.63
SWOX	0.36
SWA	0.19
Kennet Valley	0.14
Guildford	0.06
Henley	0.02
Total	3.4

Household forecasts

3.196 Household forecasts can now be produced for all WRZs. The charts in the sections below show total household demand in each WRZ for DYAA and ADPW where applicable. All zones show the same trend in that measured household demand increases both in absolute terms but also relative to the proportion of unmeasured household demand. This is due to two factors. The first is that all new properties are built with a meter installed and therefore drive an increase in measured demand. The second is the effect of metering (based on the AMP6 projections for the progressive metering programme, and thereafter the baseline optant and new forecasts to 2100). This continues across the forecast period until 90% of all properties are metered in the Thames Valley and 80% of all properties are metered in London.

3.197 This can be clearly seen in Figure 3-23 which shows total household demand for our whole water supply area.

Figure 3-23: Thames Water DYAA household consumption



London

3.198 London is forecast to start AMP7 with a total household demand of approximately 1,118 Ml/d. This is forecast to increase to approximately 1,314 Ml/d by 2045 and 1,494 by 2100. This change is driven by the forecast increases to population.

3.199 Unmeasured PCC is forecast to remain stable over the forecast period, from 159 l/person/d in 2016/17 to 159 l/person/d in 2044/45 and 160 l/person in 2100.

3.200 Measured PCC is forecast to increase over the forecast period from 120 l/person/d to 134 l/person/d in 2045 and to 135 l/person/d. There are several reasons for this forecast increase. Firstly, household occupancy continues to decrease across the period. In addition to this the number of adults is also continuing to grow as a percentage of the population and the modelling showed higher consumption for adults than children.

3.201 A significant factor is the change in the categorisation of large blocks of flats due to the introduction of the non-household commercial market. Historically a large block of flats, billed as a single entity, was counted as a single non-household property. These are now counted as household properties, in-line with Ofwat's new Eligibility Criteria 2016[19], and the number of flats in the building (subsidiary properties) included within the property count. The largest impact of this change was seen in London where the total number of 133,714 subsidiary properties are now included in the measured property count.

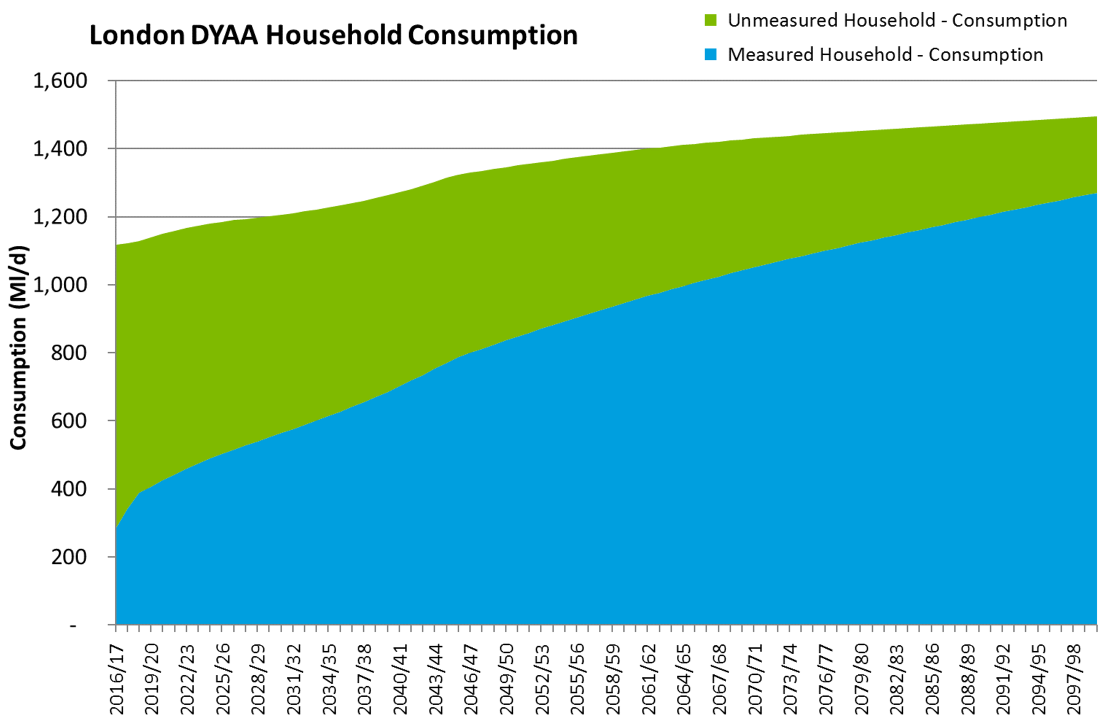
3.202 As our household forecast models use property type as a parameter this movement has a significant impact on our base PCC. Properties which fall into the category of "Large Blocks of Flats" have the lowest water use of all property types. Therefore the movement of this large number of flats has resulted in a substantial reduction in average measured household PCC from 130 l/person/d for AR16 to 119 l/person/d for AR17.

3.203 As new properties are built and progressive and optant metering continues other property types will move into our measured households category which will have higher average usage than these large blocks of flats and as a result will drive up measured consumption across the forecast period.

3.204 The result of this is a forecast increase in baseline measured household PCC. Figure 3-24 to Figure 3-26 show London DYAA household consumption and also PCC for both measured and unmeasured households.

[19] Eligibility guidance on whether non-household customers in England and Wales are eligible to switch their retailer, Ofwat 2016

Figure 3-24: London DYAA household consumption



3.205

Figure 3-25: London unmeasured PCC

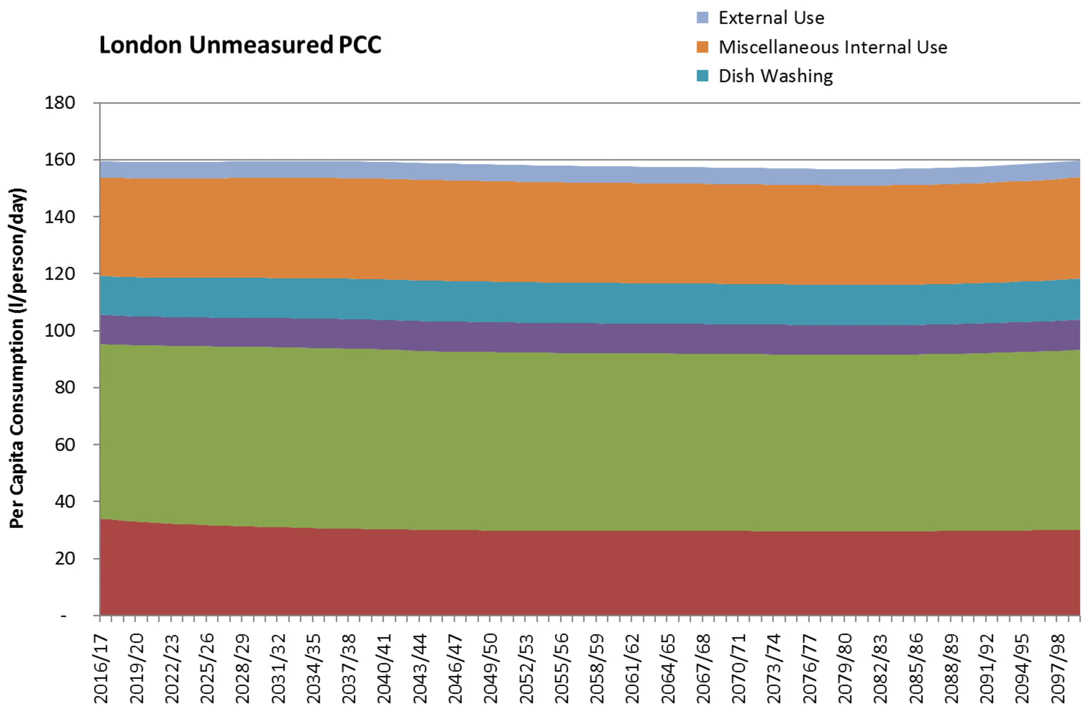
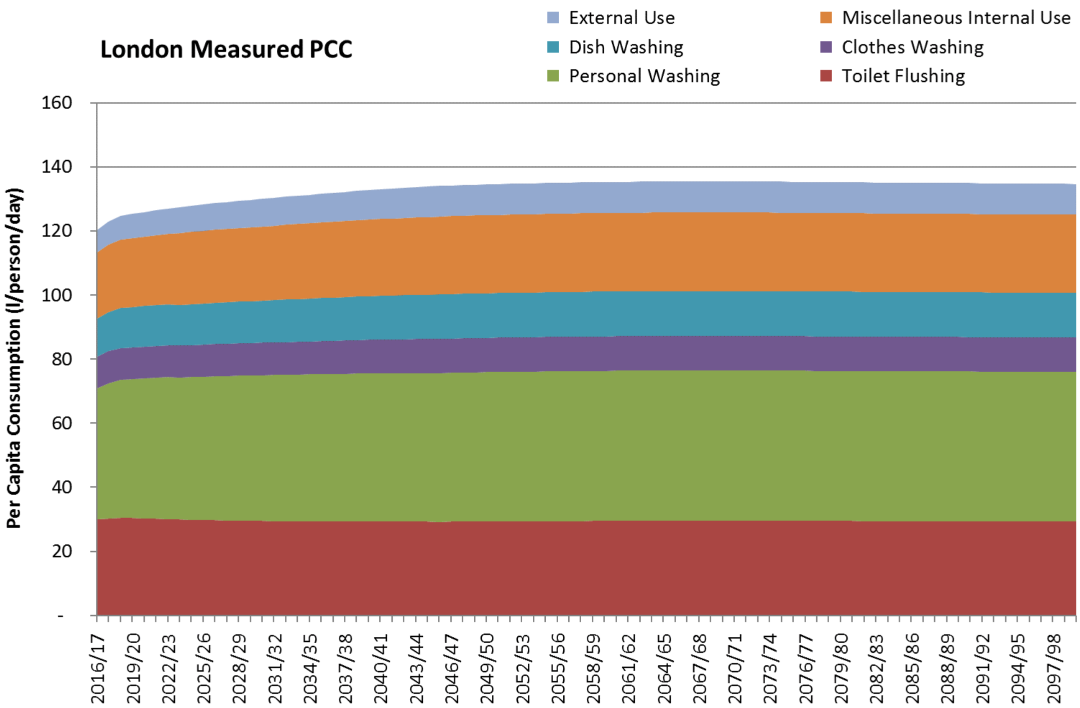


Figure 3-26: London measured PCC



SWOX

3.206 Total household consumption increases in SWOX from 141 Ml/d in 2016/17 to 170 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.207 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-27 to Figure 3-29 show SWOX DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-27: SWOX DYAA household consumption

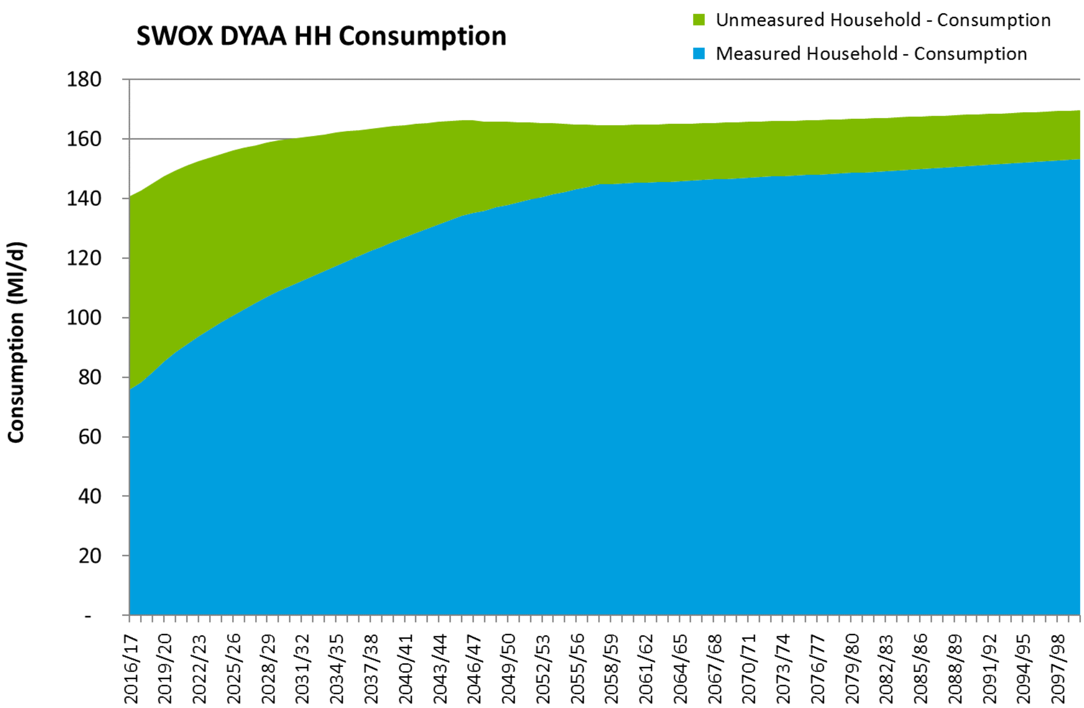


Figure 3-28: SWOX unmeasured PCC

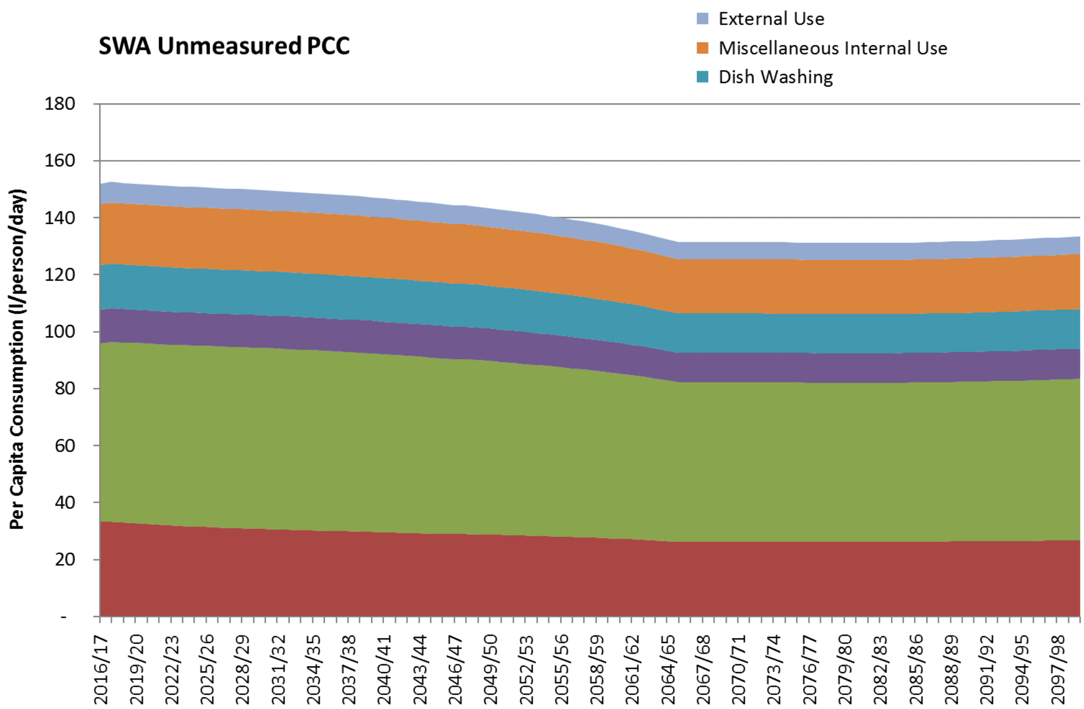
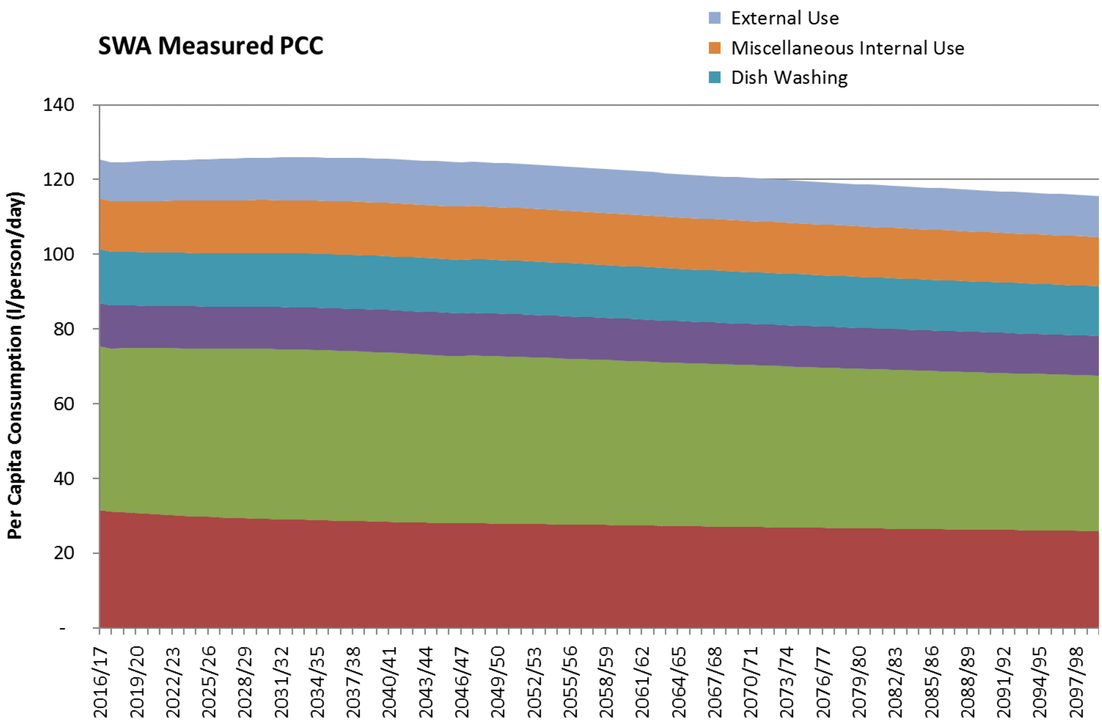


Figure 3-29: SWOX measured PCC



SWA

3.208 Total household consumption increases in SWA from 77 Ml/d in 2016/17 to 86 Ml/d in 2044/45 and then 90 Ml/d in 2100.

3.209 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a higher rate of growth. Some of this growth is offset by reducing PCC across the forecast period however substantial increase in household demand remain being forecast. This higher growth rate is driven by the Indian, Pakistani and Bangladeshi population that lives within the SWA WRZ. Figure 3-30 to Figure 3-32 show SWA DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-30: SWA DYAA household consumption

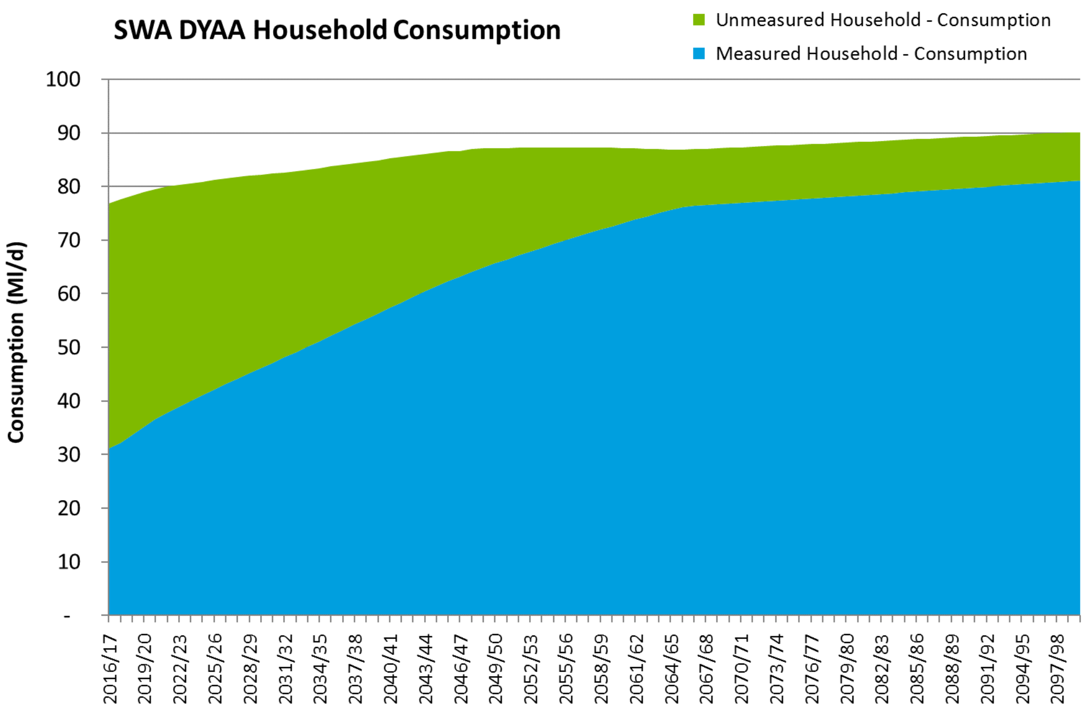


Figure 3-31: SWA measured PCC

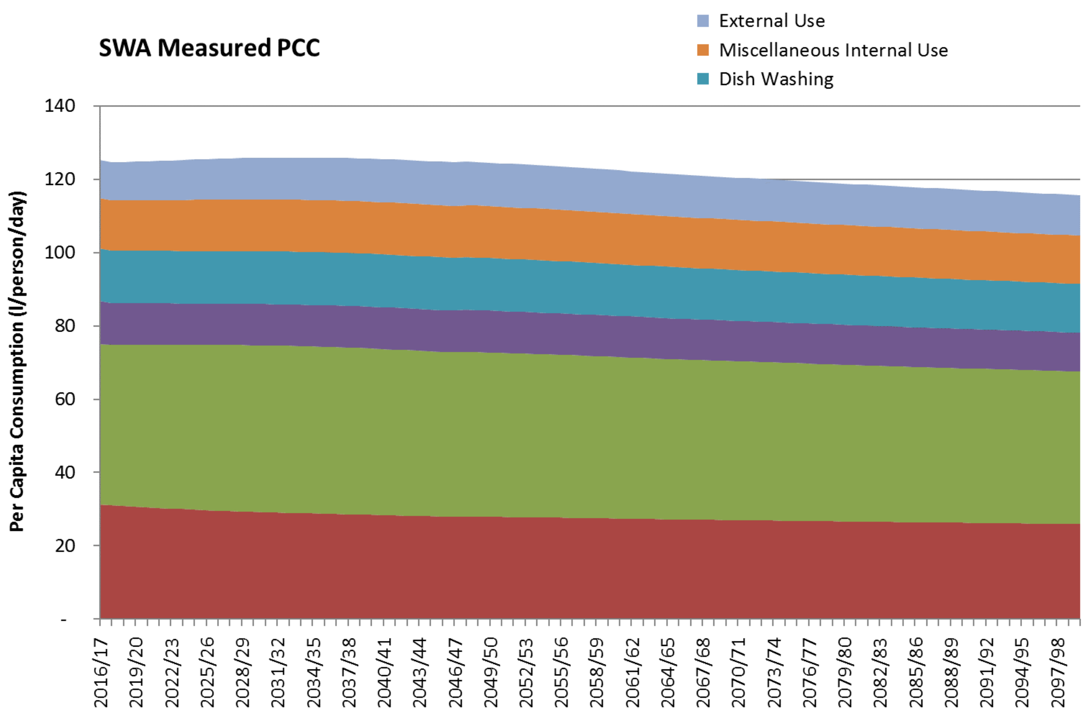
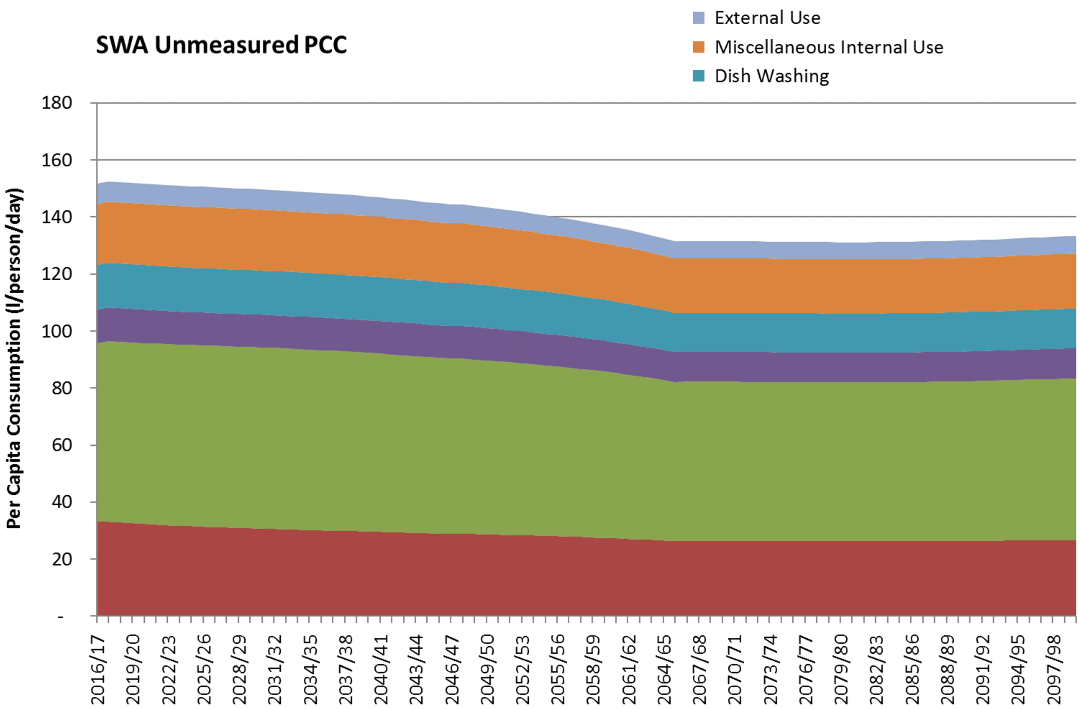


Figure 3-32: SWA unmeasured PCC



Kennet Valley

3.210 Total household consumption increases in Kennet Valley from 54 Ml/d in 2016/17 to 60 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.211 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-33 to Figure 3-35 show Kennet Valley DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-33: Kennet Valley DYAA household consumption

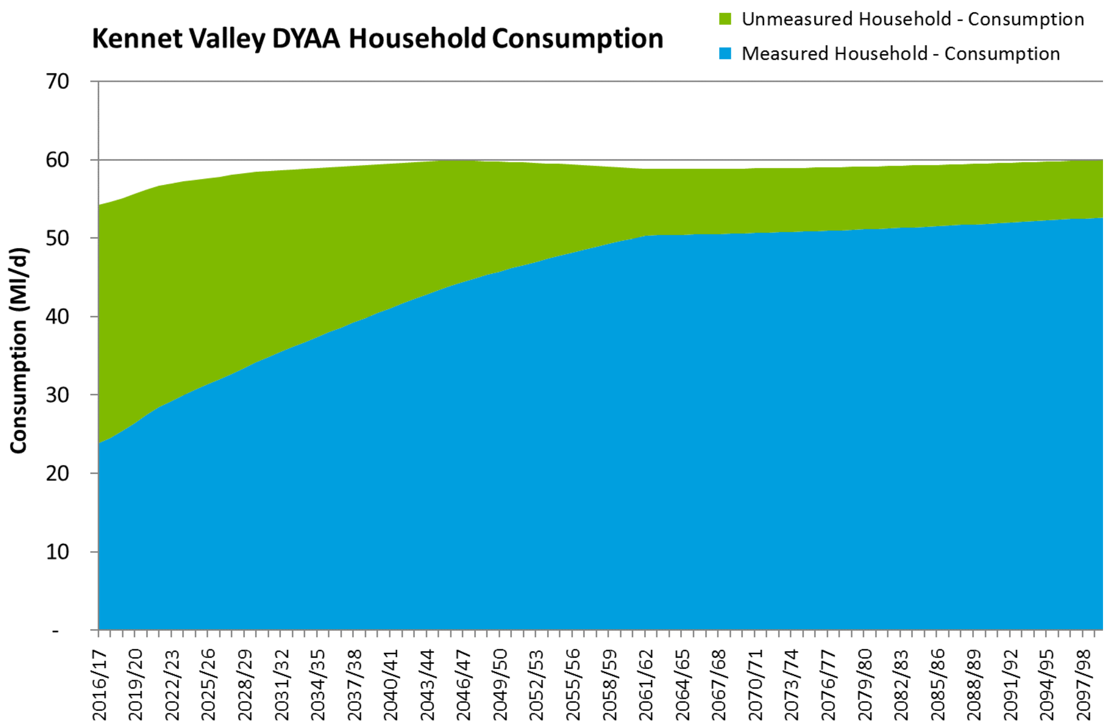


Figure 3-34: Kennet Valley unmeasured PCC

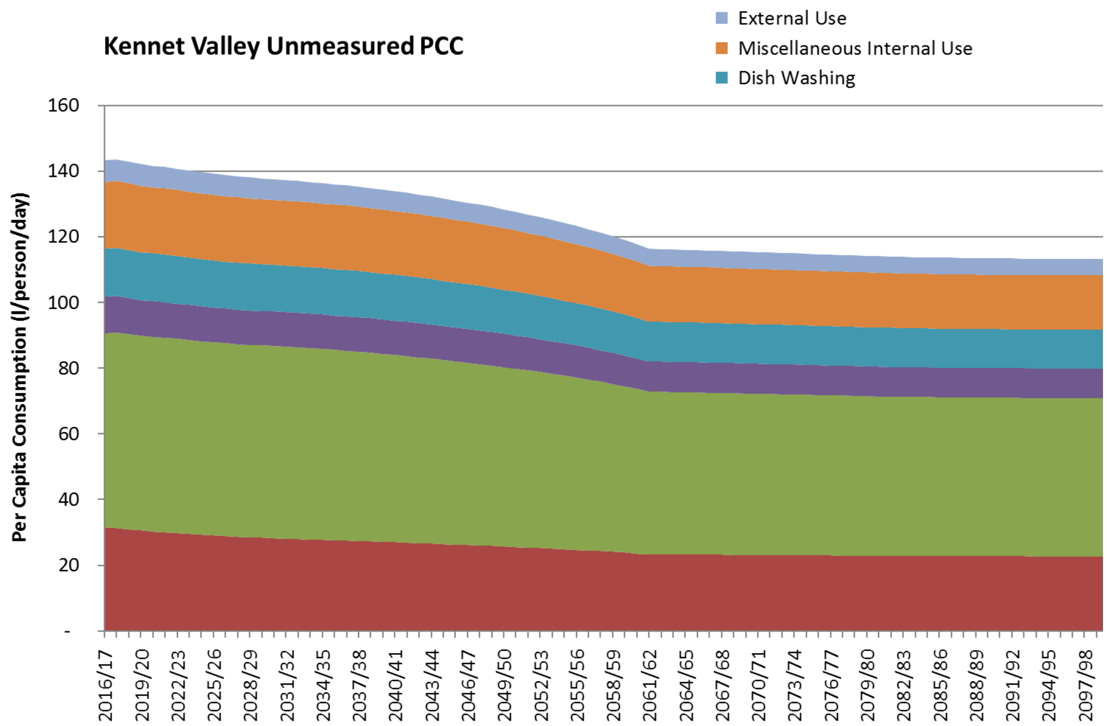
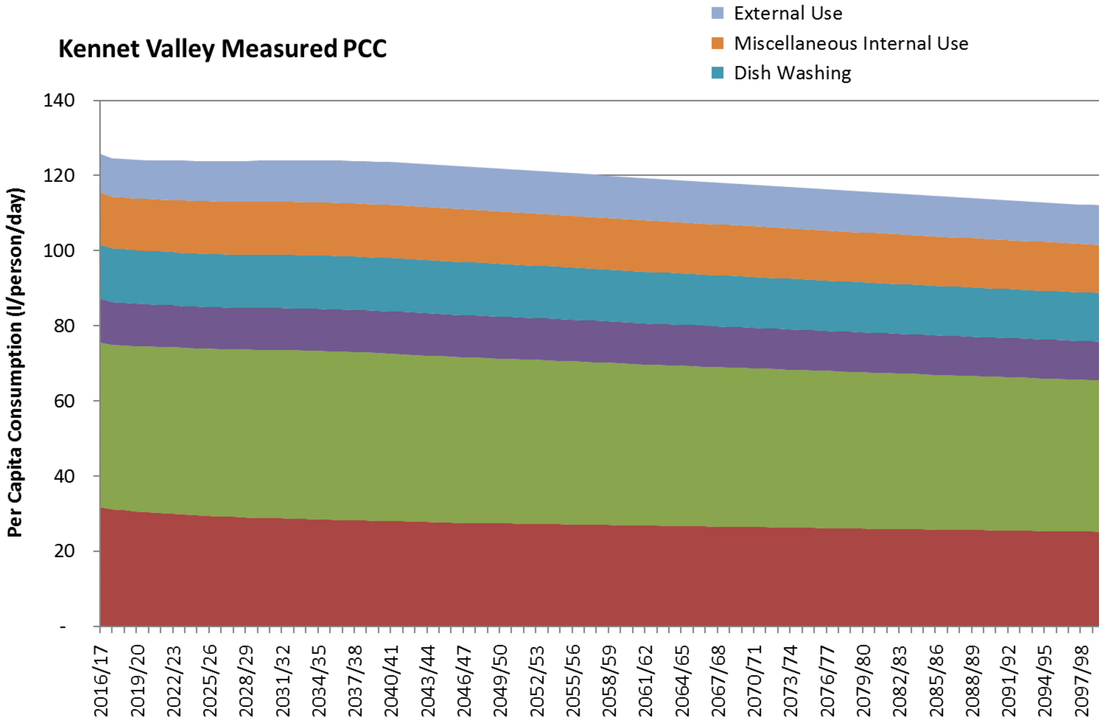


Figure 3-35: Kennet Valley measured PCC



Guildford

3.212 Total household consumption increases in Guildford from 24 Ml/d in 2016/17 to 28 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.213 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-36 to Figure 3-38 show Guildford DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-36: Guildford DYAA household consumption

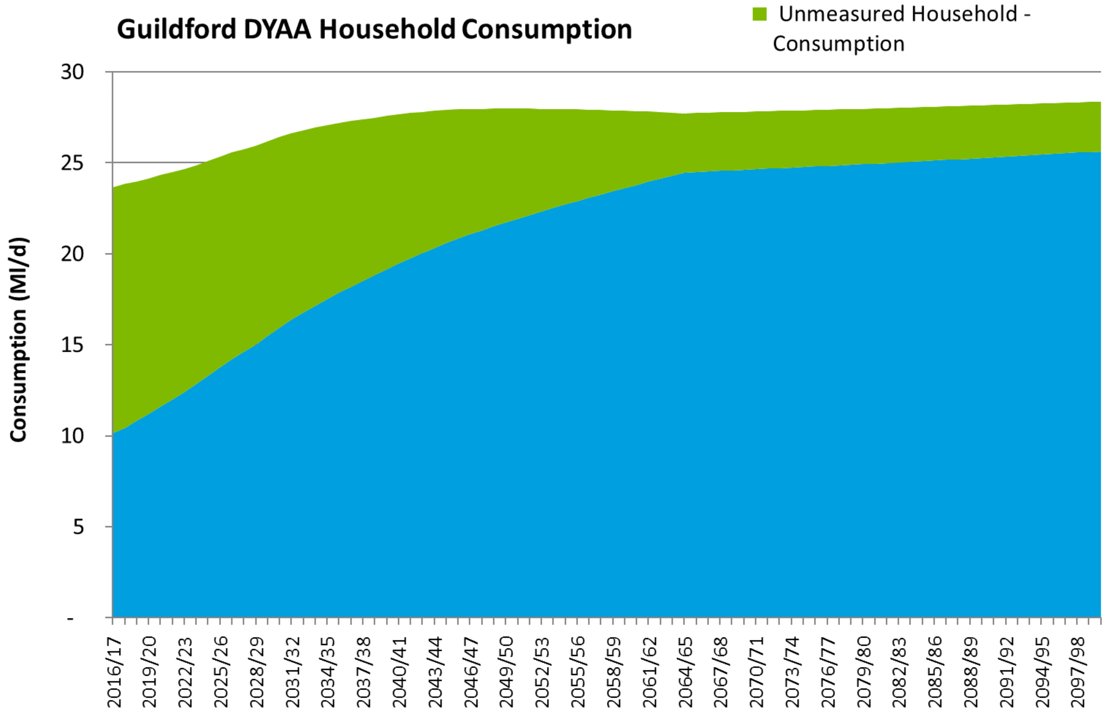


Figure 3-37: Guildford unmeasured PCC

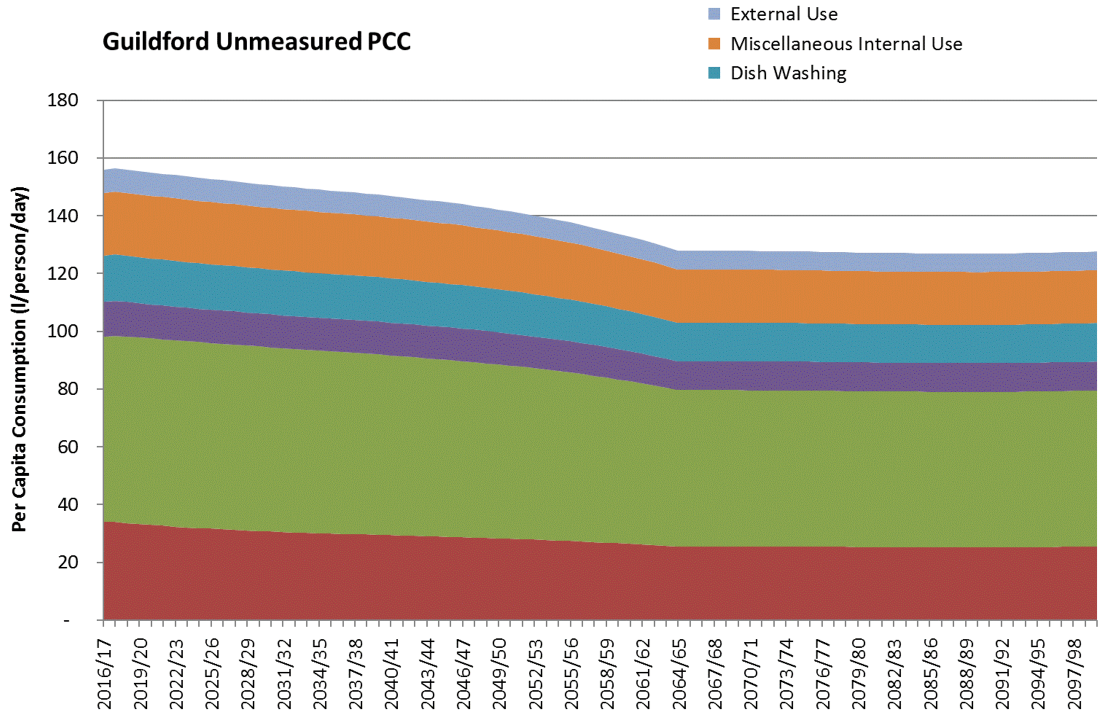
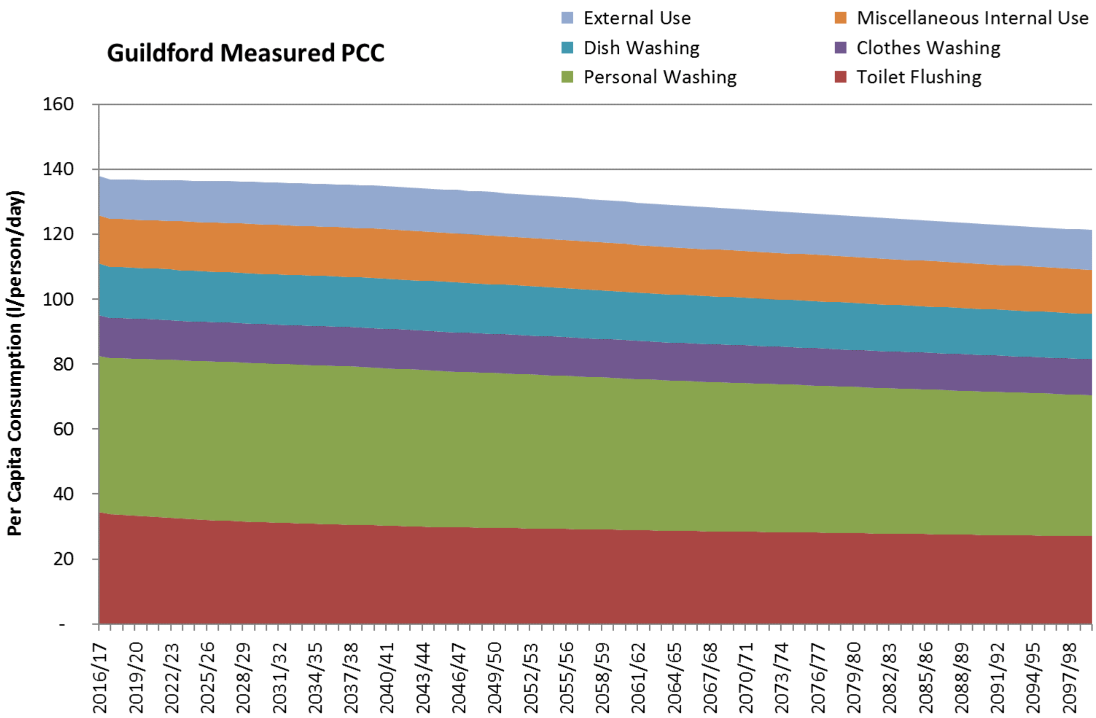


Figure 3-38: Guildford measured PCC



Henley

3.214 Total household consumption increases in Henley from 7 Ml/d in 2016/17 to 8 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.215 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-39 to Figure 3-41 show Henley DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-39: Henley DYAA household consumption

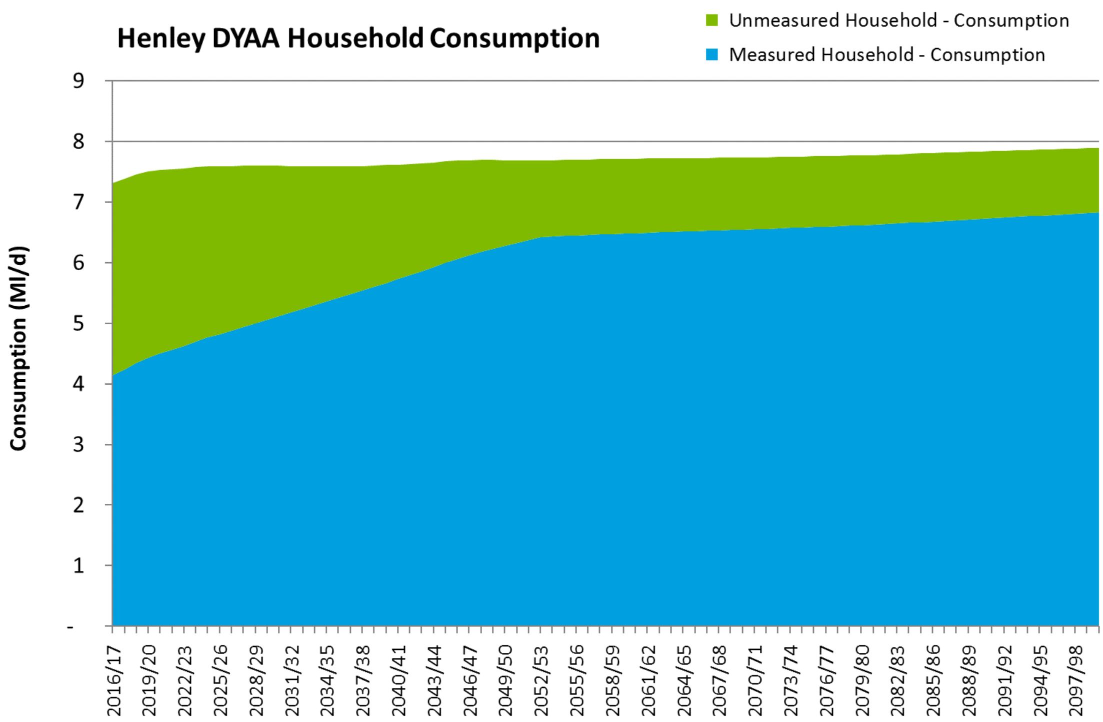


Figure 3-40: Henley unmeasured PCC

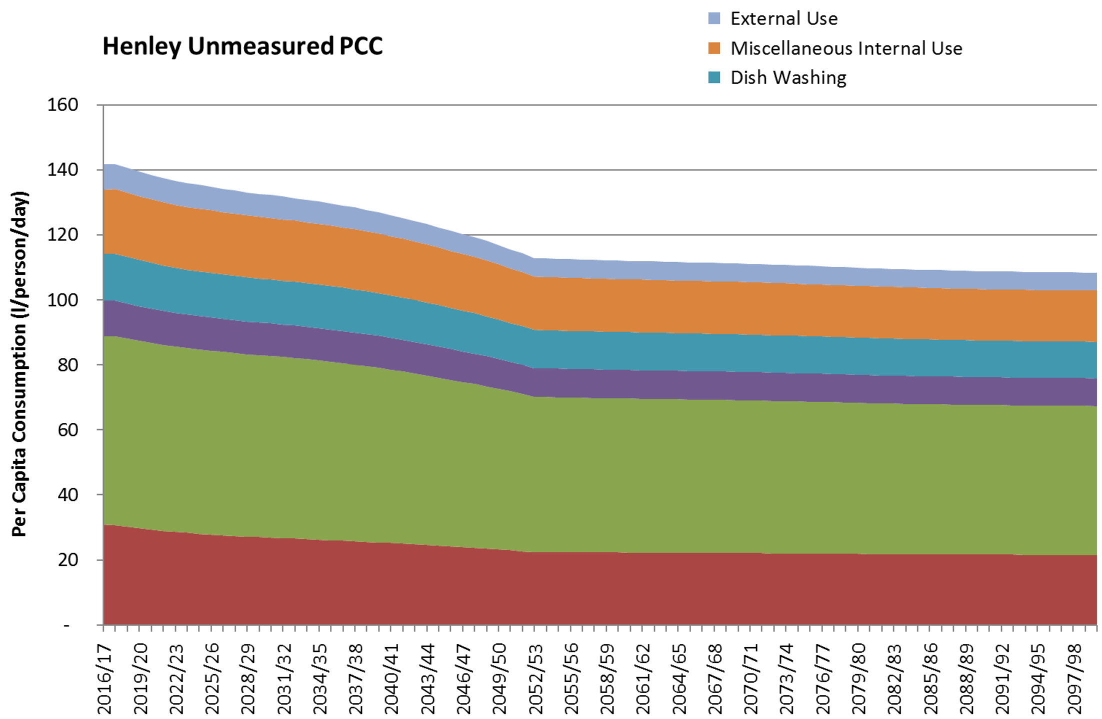
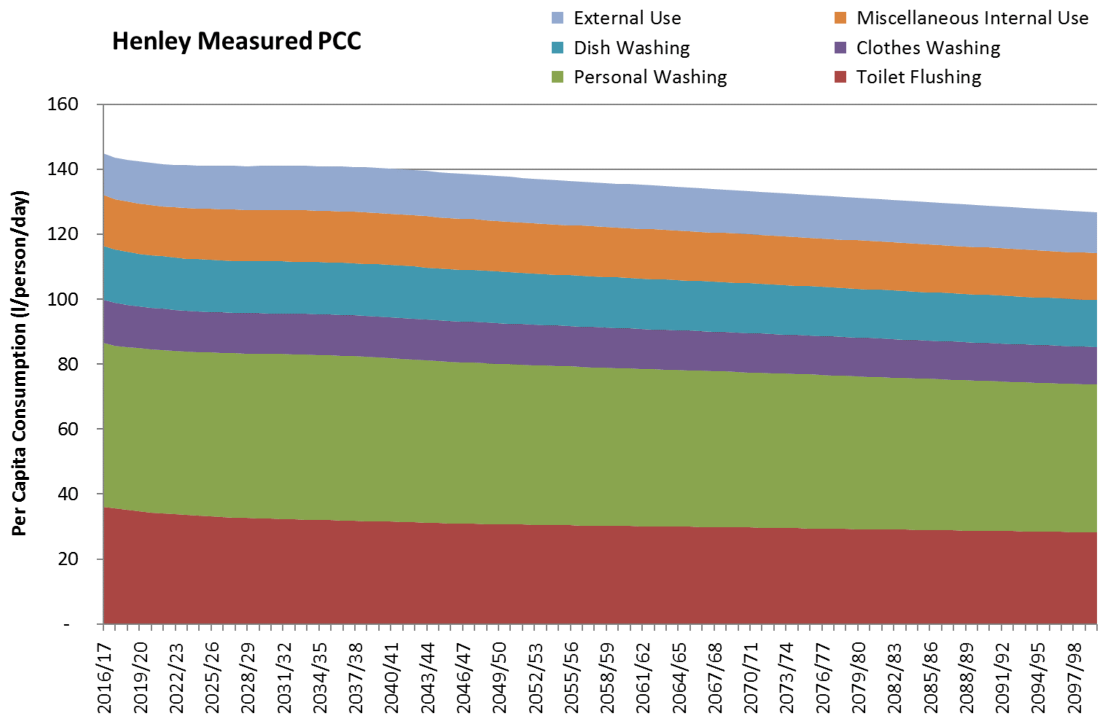


Figure 3-41: Henley measured PCC



3.216 A summary of the change in PCC for DYAA across all our zones is shown in Table 3-28

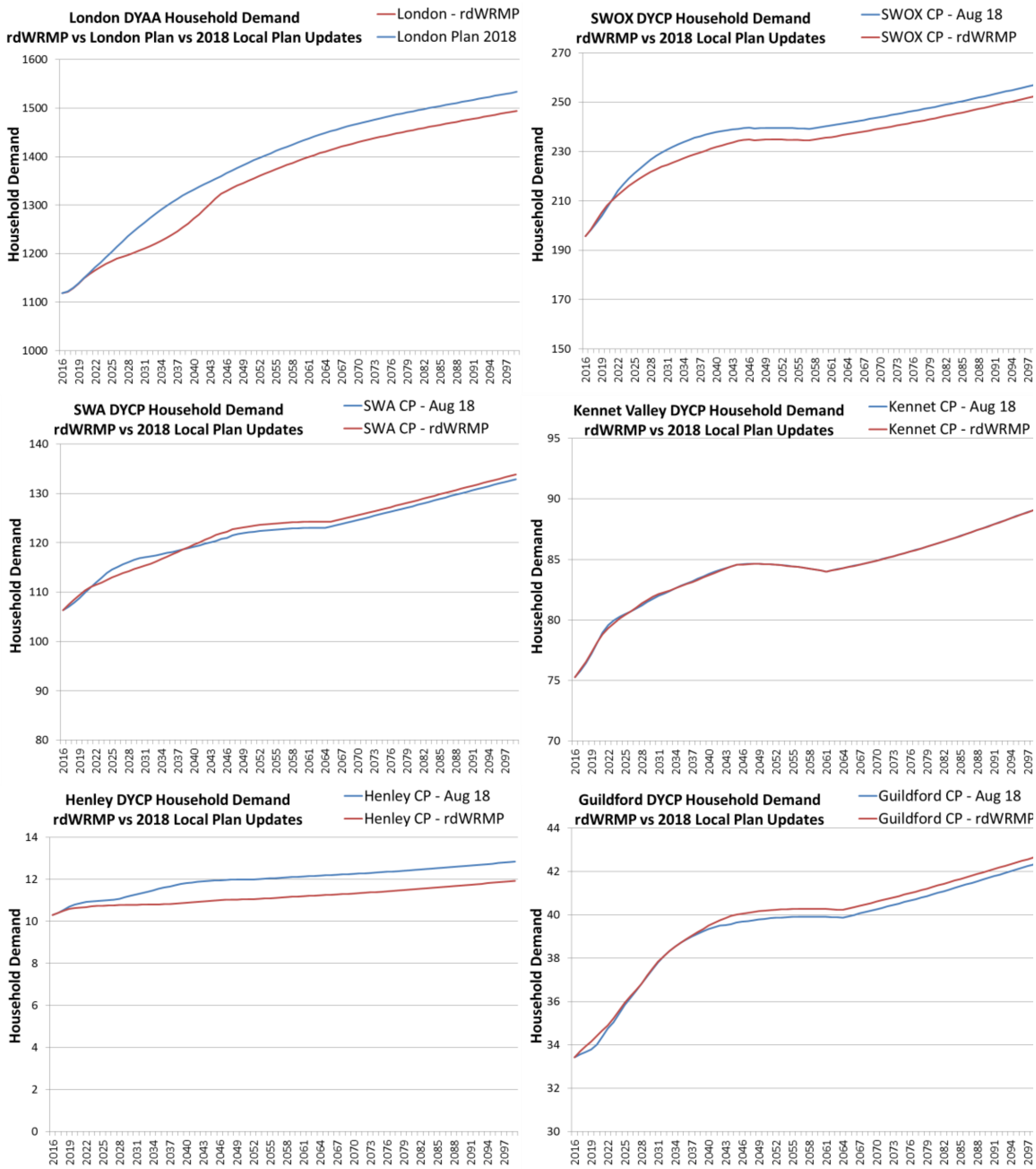
Table 3-28: Summary of forecast PCC (litres/person/day)

WRZ	2016/17	2044/45	2099/2100
London	147.2	143.1	137.9
SWOX	137.8	127.5	114.4
SWA	140.0	130.2	117.2
KV	135.0	125.1	112.1
Guildford	147.7	136.7	121.8
Henley	143.5	135.0	123.9

August 2018 household demand reforecast

3.217 Using the household and population forecasts from the August 2018 update to local authority plans we have rerun the household demand forecasting model. This data was received after production of the supply demand balances used to generate our preferred programme and, accordingly, was not available for use for this purpose. Instead we have used this data to determine if recent updates to local plans, by local authorities, produce a material change in household demand forecasts.

Figure 3-42: Comparison of demand profiles



3.218 The London WRZ demand forecast shows material increases in demand starting from around 2025. These are due to the increased rate of house building in the London Plan. The demand increases across the period of 2020 to 2045 with the largest difference in demand being in 2037 where household demand is forecasted to be approximately 67 Ml/d higher than the baseline forecast used in our revised draft WRMP. By 2044 this difference has reduced to approximately 36 Ml/d. Beyond 2044 there are minor yearly increases up to a 39 Ml/d increase above the revised draft WRMP baseline.

3.219 These increases in demand would result in a deficit in our preferred programme and within Section 10: Programme appraisal we set out how these increases in demand would change our preferred programme.

3.220 Outside of our London WRZ none of the changes in household demand are considered material. The largest change in demand, outside London, is seen in SWOX where an increase in demand of approximately 6 Ml/d is predicted from the updated forecast. When tested against our preferred plan, Section 10, all five Thames Valley zones would remain in surplus.

E. Non-household demand

3.221 Non-household water use in our supply area tends to follow wider economic trends. We do not have a large agricultural sector, as is found for example in East Anglia or a significant, declining industrial sector as has occurred in some other areas of the country. Consequently, our forecasts of non-household water use have remained fairly flat.

3.222 We commissioned Servelec Technologies to develop a non-household demand forecasting model. Servelec Technologies used multiple linear regression to formulate the model. Full details of the model development and methods used can be found in Appendix G: Non-household water demand.

3.223 Non-household customers were divided by geographical area and industry sector, and then separate models developed to forecast consumption based on one or more explanatory factors.

3.224 Explanatory factors (e.g. numbers in employment or the level of economic activity) are selected that best account for variation seen in consumption. A regression model is then developed using these factors. This allows forecasts of consumption based upon forecasts of the explanatory factors. The sensitivity of the result can then be assessed by examining different scenarios for the explanatory factors.

3.225 The historical consumption and sector allocation was provided by Teccura. They used raw billing data, matched it with their database of customer sectors, and validated the raw reading data to give the best estimate of true consumption for each year from FY2006 to FY2015.

3.226 The historical consumption data provided was then reconciled to the reported non-household consumption figures, and after an allowance for meter under-registration and other adjustments, and a small variation to account for differences in the allocation of properties to either household or non-household status, there is general agreement.

3.227 Data received from Teccura analysis/ obtained from public domain sources:

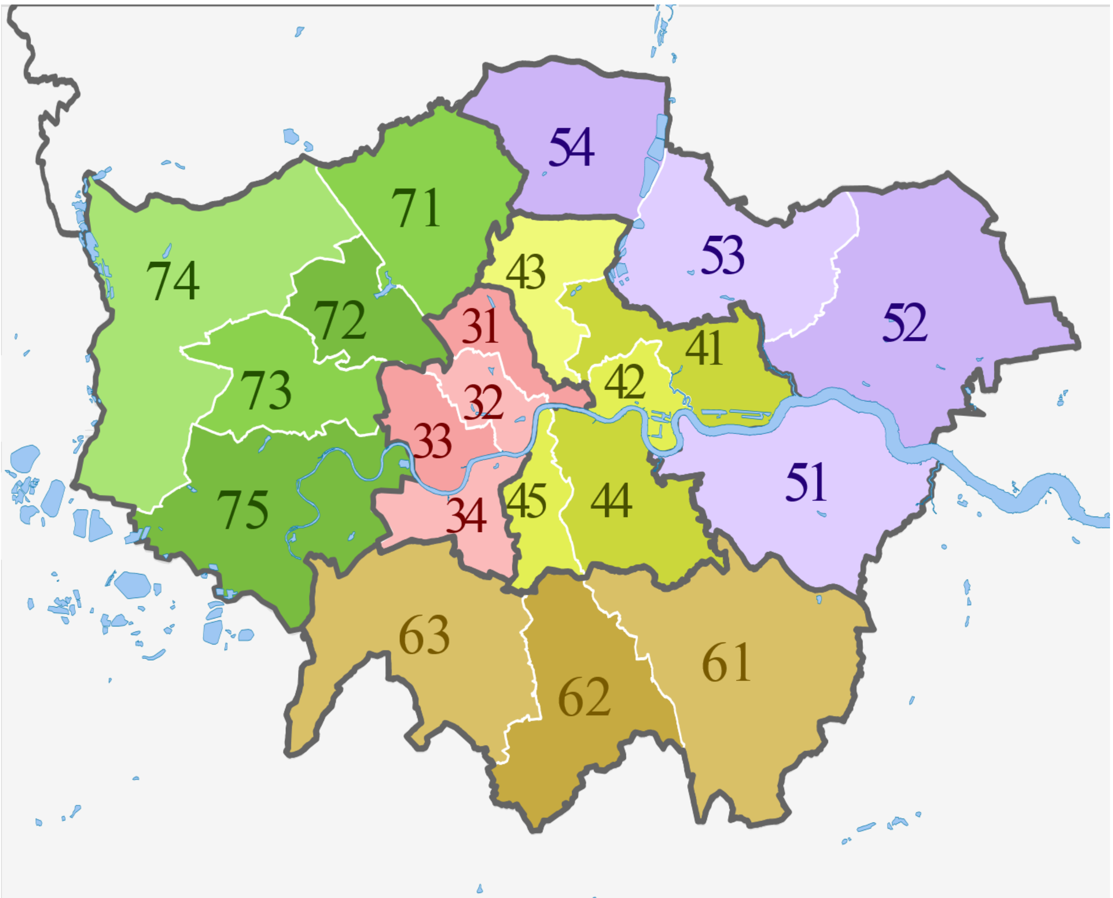
- Annual consumption for each FMZ broken down by sector for the period FY2006-FY2015
- Individual annual consumption for major customers (high users)
- Details of customers that fall into the ‘unknown sector’ type in the Teccura data set
- Gross Value Added (from the ONS)
- Employment data (from the UK commission for employment and skills)
- Population data used in household consumption forecasting

The five WRZs outside London were modelled as individual areas. The London WRZ broken down into three areas:

- Inner West (authorities 31-34)
- Inner East (authorities 41-45)
- Outer (all other London areas including those in the London WRZ that fall outside of the London Nomenclature of territorial units for statistics (NUTS) Area)

3.228 The location of each area is shown in Figure 3-43.

Figure 3-43: NUTS level 3 authorities[20]



3.229 There are strong arguments for modelling the London areas separately, given the different ways in which they have developed over the last ten years. Further subdivision is unlikely to lead to an increase in accuracy since issues around the alignment of FMZ and Nomenclature of Territorial Units for Statistics (NUTS) area boundaries will become more significant, and the model application will increase in complexity.

3.230 The industry sectors provided in the raw data set are a bespoke set of detailed industry codes. These have been mapped to Standard Industrial Classification (SIC) codes to allow alignment with publically available data for Gross Value Added (GVA) and employment levels.

[20] Dr Greg and Nilfanion. Contains Ordnance Survey data © Crown copyright and database right 2010

3.231 The SIC groups have been further grouped to give five groups for each WRZ as follows:

- Group 1 – SIC groups P, Q and O – "Education", "Human health and social work activities", "Public administration and defence"
- Group 2 – SIC groups R, S and T – "Arts, entertainment, recreation", "Households" and "Other service activities"
- Service industries – the remaining SIC groups that relate to service industries. This tends to be dominated by groups M and I, "Professional, scientific and technical activities" and "Accommodation and food service activities"
- Non-service industries – the remaining SIC groups that relate to non-service industries. This tends to be dominated by food manufacturing or waste services depending on the WRZ

3.232 Explanatory factors, such as numbers in employment or the level of economic activity, are selected that best account for variation seen in consumption, and a regression model developed. This allows forecasts of consumption based upon forecasts of the explanatory factors. Each of the parameters selected are set out below.

Demand forecasting model

Population

3.233 Population forecasts are the same as those discussed above and which are used in the household demand forecasts.

3.234 The overall population is expected to steadily increase across all our WRZs over the forecast period.

Employment

3.235 The projection of employment in London is obtained from GLA Economics London labour market projections from 1971 to 2041[21] and an average growth rate of 0.8% has been used from 2016 to 2041. The forecast growth rates are assumed to be decreasing from 0.7% in 2042 to 0.5% in 2100 because of differing levels of growth in different industry sectors. Employment in London is projected to reach 9.3 million by the end of the 21st century.

3.236 The projection of employment in the south east, excluding London, is obtained by extrapolation of the UK Commission for Employment and Skills (UKCES) forecast from 1990 to 2024 (where employment has been disaggregated by industry sectors, but not by local authorities). An average growth rate of 0.6% has been used between 2015 and 2024. This rate is assumed to decrease from an average of 0.8% in 2025 to an average of 0.5% in 2100. Employment in the south east is projected to reach 7.2 million by the end of the 21st century.

[21] https://www.london.gov.uk/business-and-economy-publications/london-labour-market-projections-2016

GDP

3.237 The review of the historical Real GDP since 1830 to 2009 by the Bank of England[22] concluded that, under the central scenario (crises-free) an average annual growth of 2.0% is appropriate for the forecast period.

3.238 This assumption aligns with the reported UK total GDP growth rate forecast by HSBC Global Research[23] which is forecast to increase from 1.7% per annum in 2020 to 2.2% by 2050. The UK GDP average growth rate estimated by the Environment Agency for the UK is 2%, under the 'Restoration' scenario (sustainability-led governance, dematerialised UK consumption), whereas under the 'Alchemy' scenario (sustainability-led governance, material consumption) the annual growth is estimated at 2.5%.

3.239 The GVA growth rate in each of the WRZs in the our supply area has therefore been assumed at 2%, with the exception of London whose regional economy is expected to grow faster in which the GVA growth rate is assumed 2.5%.

Model

3.240 The general model previously used for each sector group in each area has been retained, with the following form:

$$\ln(Consumption_i) = C + \alpha_1 Empl_i + \alpha_2 \ln(GVA_i) + \alpha_3 Pop_i + \alpha_4 Year_i + \alpha_5 Tariff_i$$

where:

$Consumption_i$ - the consumption in year *i* for the particular sector group in the particular area

$Empl_i$ – the number of employees in the sectors modelled (in London for the three London areas and in south east England for the other WRZs) in year *i*

GVA i - the GVA in £million for the relevant SIC groups in the relevant area in year *I*

Pop i - the population resident in the relevant area in year i

Year i - the year, which is used to give an absolute trend to the model

Tariff i - the general user water tariff in £/m3 in year *i*

$\alpha_{1\text{-}5}$ are the coefficients determined through linear regression

C – a constant term determined by the regression analysis

Non-household forecasts

London

3.241 As per the previous modelling, the population figures in London Outer East and West refer to the Inner London East and West NUTS areas, and the population in London Outer. Outer refers to the Outer London NUTS area. Water demand in London is forecast to rise in nearly all service sectors. The non-service sector and unknowns are forecast to decrease over the forecast

[22] www.bankofengland.co.uk/Fpublications/Documents/quarterlybulletin/threecenturiesofdata.xls
[23] http://www.gbm.hsbc.com/solutions/global-research

period. The overall combined demand from London Overall East, West and Outer London is shown in Figure 3-44, and this has been compared with a single model of the demand in London as a whole. The two graphs generally agree until the 2050s, then diverge and follow different trends until 2100. This difference is due to a slight loss of detail in the London single model, requiring two assumptions to balance demand between the non-service and unknown sectors:

- Non-services in the London single model was assumed to remain relatively constant, whereas decreasing trends are assumed in the London Inner East and West regions for the combined model. Unknowns sector from the two models show decreases in demand, however the London single model is showing a much faster fall. The service industries are projected nearly exactly the same in both models, they are forecast to gradually increase their water demands over the forecast period. The main difference in the two models is therefore the handling of the non-service industries (which have downward trends in all London Overall, East, West and Outer) and unknown sectors.
- Demand in the London WRZ is projected to see alternate successions of increases and decreases. Increases of demand are driven by the service sector, whereas the non-service and unknown sector demands are expected to decrease over the forecast period.

London Inner East

3.242 Water demand from service industries is projected to increase. The non-service sector is decreasing by 22.8% in 2050 and by 48.5% in 2100.

3.243 The overall non-household demand generally increases, driven by service industries. Service industry demand is expected to rise by about 17.3% in 2050 and 62.7% in 2100 compared to the level in 2015. The overall magnitude of increase in 2050 is 15.1 Ml/d, and by 2100 an increase of 25.5 Ml/d will be achieved.

London Inner West

3.244 The overall demand will see an overall decrease. Demand will increase by about 9 Ml/d in around 2030 compared to the 2015 level; whilst the magnitude of the decrease from 2015 to 2100 is estimated at about 18 Ml/d.

Outer London

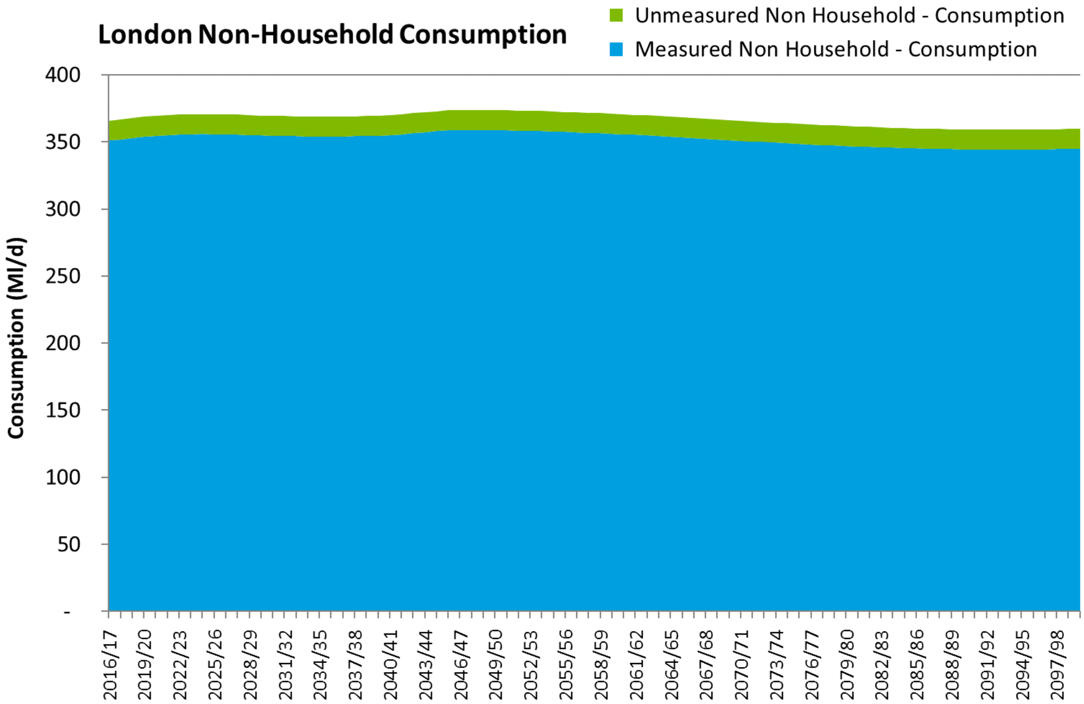
3.245 The overall demand will slightly decrease until the 2050s, and then slightly increase during the remaining period to 2100. The decreases are driven by the non-service industries. The non-service model forecasts a decrease by 21.2% in 2050 and a decrease about 62.7% by 2100 compared to level in 2015.

3.246 Demand from service industries is projected to continue its growth and will ultimately overcome the offsets from the non-service industries. The projected demand in the Outer London regions in 2100 will only be about 8.0 Ml/d lower than the level in 2015.

London overall

3.247 The overall non-household forecast for London is shown in Figure 3-44.

Figure 3-44 London non-household consumption



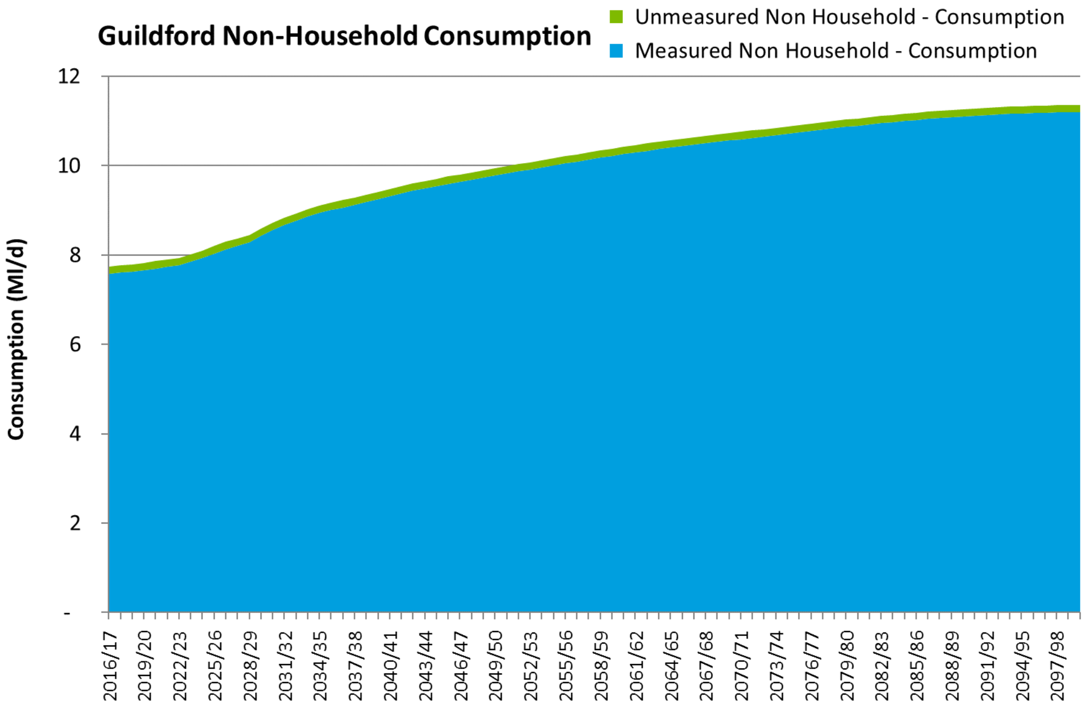
Guildford

3.248 The overall demand will increase in general, driven by the service sectors except the Group 2 (SIC groups R, S and T) group (Other Services and Household activities), whereas the non-service sector is a small demand compared to the overall service sector in Guildford.

3.249 A demand increase by 24.1% in 2050 is expected compared to 2015, and by 2100 demand will rise to about 3 Ml/d.

3.250 Overall non-household demand for Guildford is shown in Figure 3-45.

Figure 3-45: Guildford non-household consumption

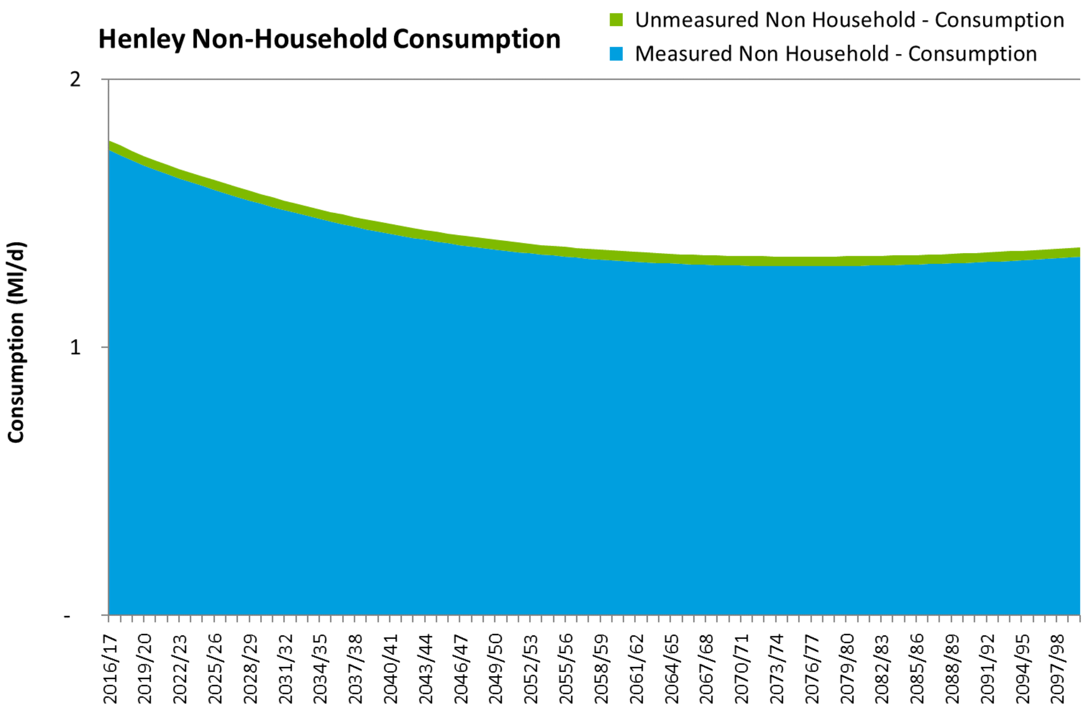


Henley

3.251 The overall demand in Henley is forecast to decrease till the 2060s and then stay level throughout the remaining period. Only the service sector demand from SIC groups G, H, I, M, N and J is forecast to increase, but will not make any significant effect in the long term. The non-household water demand in Henley is negligible compared to the overall company demand, and thus will not change much the general forecast trend at the company level.

3.252 Overall non-household consumption for Henley is shown in Figure 3-46.

Figure 3-46: Henley non-household consumption

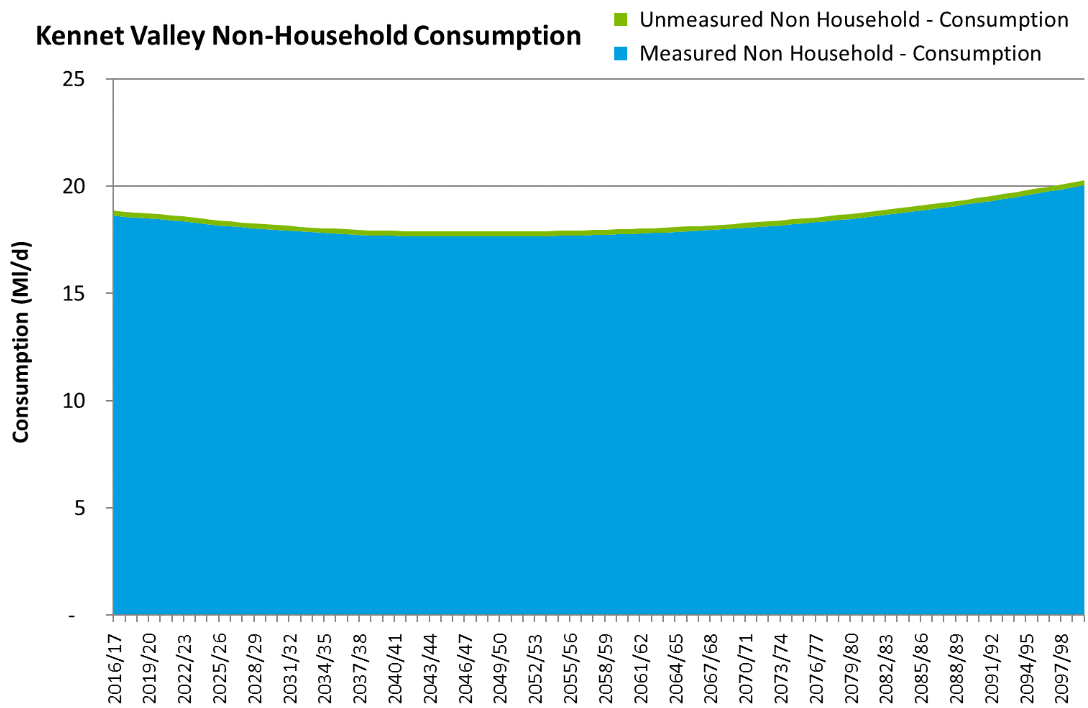


Kennet Valley

3.253 Water demand is expected to increase in the service sector, whereas the non-service sector is forecast to remain level throughout. Demand will marginally decrease until mid-century, decreasing by 5.9% in 2050 compared to 2017 level, and then slightly increasing throughout the remaining period to 2100. However, the magnitude of increase between 2050s and 2100 is only about 2.4 Ml/d.

3.254 Overall non-household consumption for Kennet Valley is shown in Figure 3-47.

Figure 3-47: Kennet Valley non-household consumption

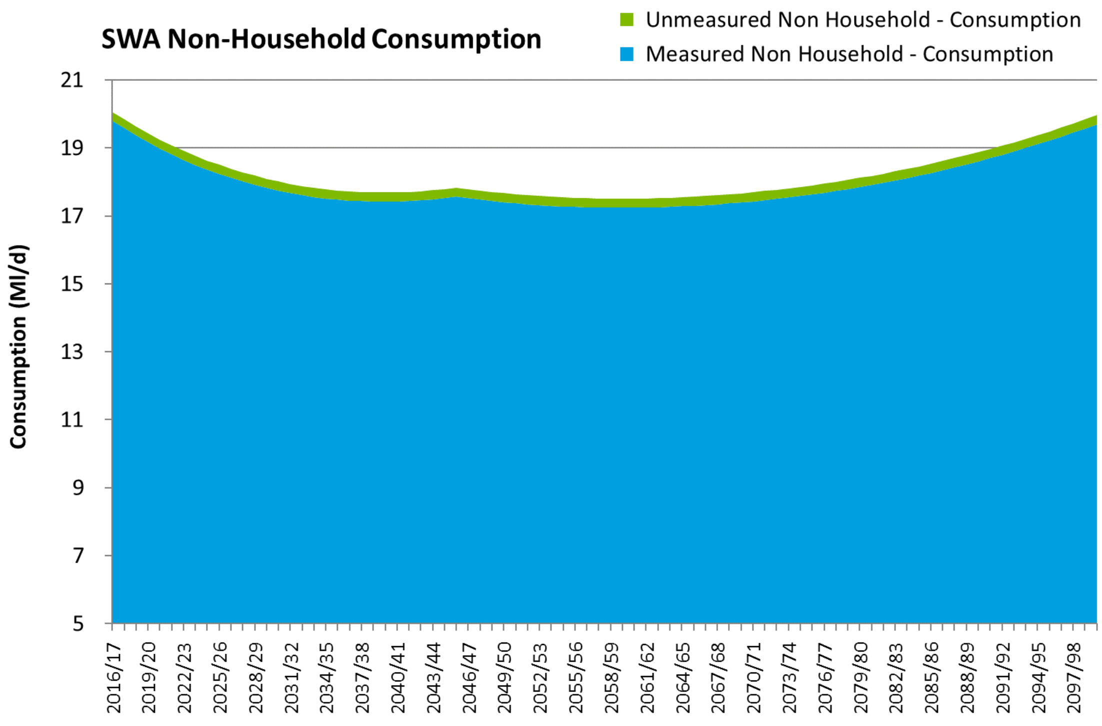


SWA

3.255 The combined sector consisting of the groups Group 1 and Service is forecast to decrease over the forecast period. The non-service sector is assumed to rise. Demand is projected to decrease till the 2050s, decreasing by 13.2% in 2050 compared to 2015 level, and then increasing throughout the remaining period to 2100, reaching 20 Ml/d. The first half decrease is driven by demand from service industries in Group 2 and unknown sector, whereas the second half increase is driven by the demand from the remaining service industries and the non-service sector. The magnitude of increase between 2050 and 2100 is estimated at about 2.3 Ml/d. The increase of demand in the non-service sector has been driven by the demand from Arla Foods Plc. However, we have assumed demand for the non-service sector will remain constant over the second half of the forecast period. We do not believe it is appropriate to continue a trend based on such a localised significant driver.

3.256 Overall Non-household consumption for SWA is shown in Figure 3-48.

Figure 3-48: SWA non-household consumption

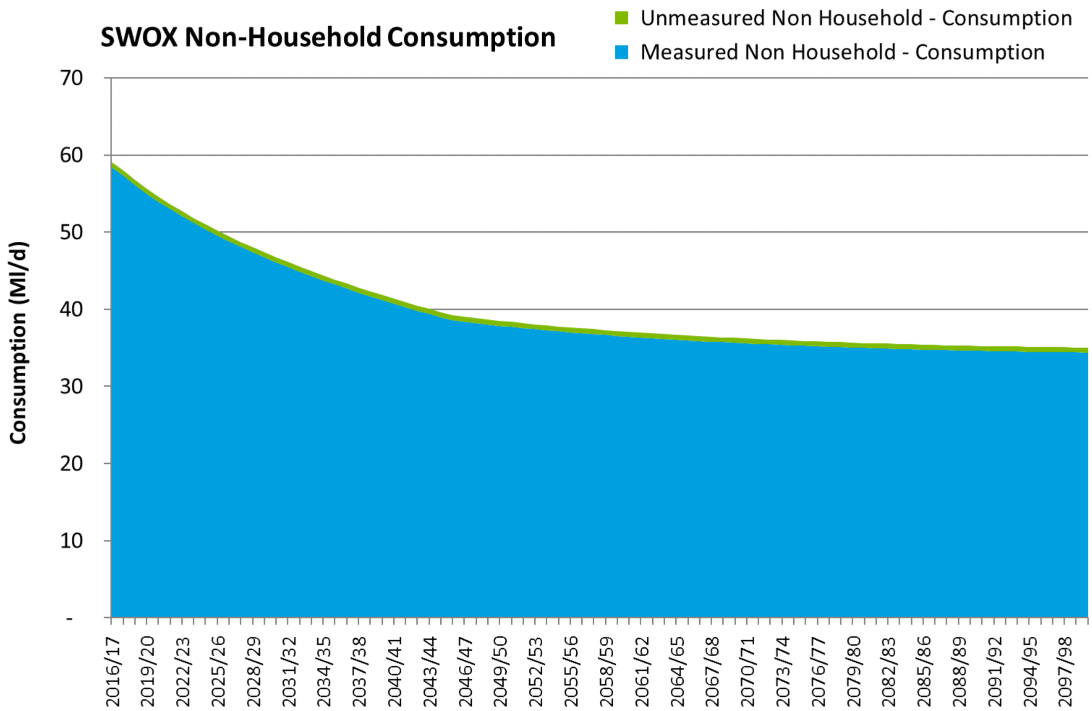


SWOX

3.258 Only the Group 1 (SIC groups P and Q) group is forecast to increase its demand over the forecast period. Demand from the service SIC groups G, H, I, M, N and J is expected to decrease by 32.9% in 2050 and by 58.3% in 2100 compared to 2015 level. The decrease of demand in the Group 2 (SIC groups R, S, T and O) is driven by the closure of Didcot power station, and the reduction of demand from defence (MOD) sites. However, it can be argued that a continued decline will not be sustained for such a group of service industries. Hence a constant demand is assumed over the second half of the forecast period. The overall demand will decrease till mid-century, with 36% decrease in 2050 compared to 2015. Then, demand will slowly decrease throughout the remaining period to 2100.

3.259 Overall non-household consumption for SWOX is shown in Figure 3-49.

Figure 3-49: SWOX non-household consumption



3.260 A summary of forecast non-household demand across all our WRZs is shown in Table 3-29.

Table 3-29: Summary of non-household demand (Ml/d)

WRZ	2016/17	2044/45	2099/2100
London	365.92	372.87	359.79
SWOX[24]	59.11	39.61	35.04
SWA[25]	20.06	17.79	19.96
Kennet Valley	18.87	17.89	20.28
Guildford	7.74	9.71	11.36
Henley	1.77	1.43	1.37

Summary

3.261 The modelling has developed forecasts of areas and groups of industry types, showing a wide variety of different patterns. The model shows slight decreases in non-household demand until the 2080s, then slight increases until the 2100s. Increase of demand in the service sector, notably in London, has been forecast, whereas demand from the non-service sector is projected to remain relatively constant over the forecast period. The unknown sector demand, i.e. demand where there is insufficient information to classify the user into either category, is forecast to largely decrease by the end of the forecast period.

F. Baseline leakage and minor components

3.262 In line with the requirements of the WRPG, leakage in the baseline demand forecasts remains flat across the forecast period. The end of AMP6 leakage forecast has been updated, as described in the update note to Section 2, paragraphs 21 to 25 Water Resources programme 2015 - 2020.

3.263 We also forecast minor components as unchanged over the planning period due to no satisfactory method by which to forecast these.

3.264 The values for leakage and minor components across the planning period can be seen in Table 3-30.

Table 3-30: Leakage, operational usage and water taken unbilled

WRZ	London	SWOX	SWA	Kennet Valley	Guildford	Henley	Total
Leakage	530.62	63.40	37.40	26.20	13.40	3.58	674.60
DSOU	6.86	0.74	0.47	0.23	0.18	0.03	8.50
Water Taken Unbilled	40.42	4.12	1.44	1.27	0.73	0.12	48.10

[24] SWOX WRZ
[25] Slough, Wycombe and Aylesbury WRZ

G. Summary of our baseline demand forecasts

3.265 The baseline DYAA demand forecast for each WRZ and the DYCP forecast for Thames Valley zone are shown in the following figures.

Figure 3-50: London DYAA distribution input

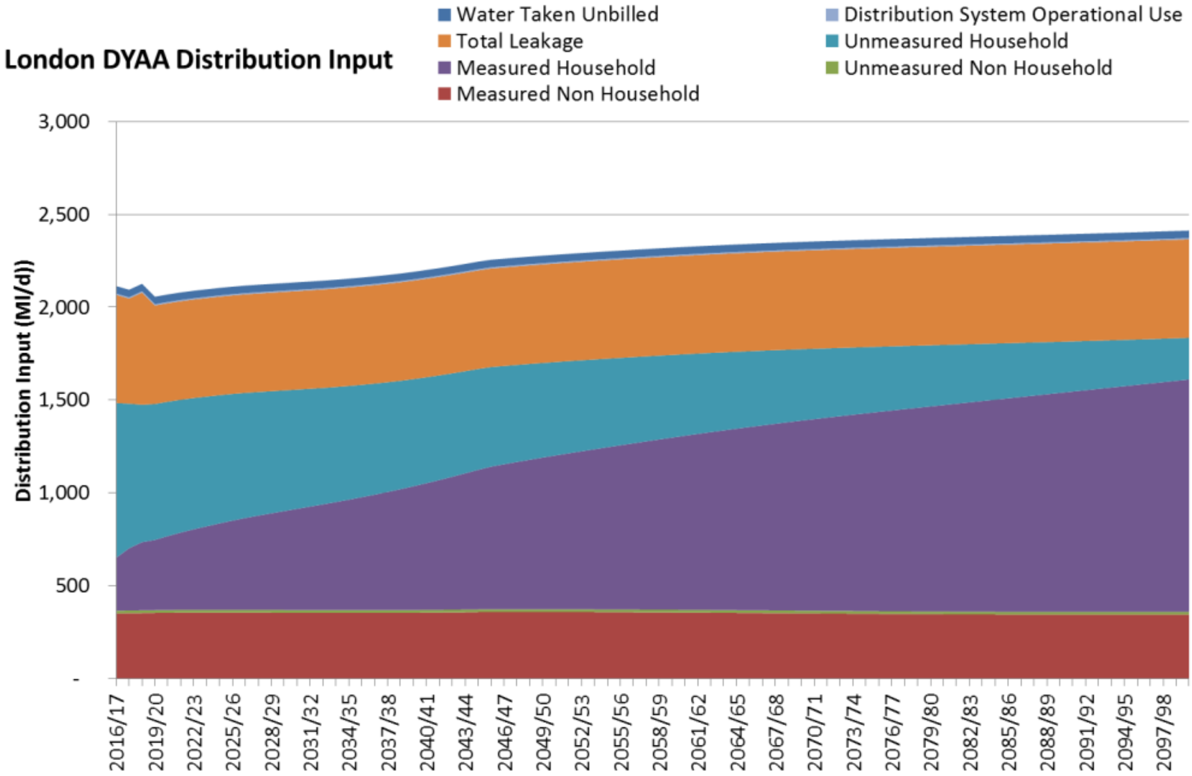


Figure 3-51: SWOX DYAA distribution input

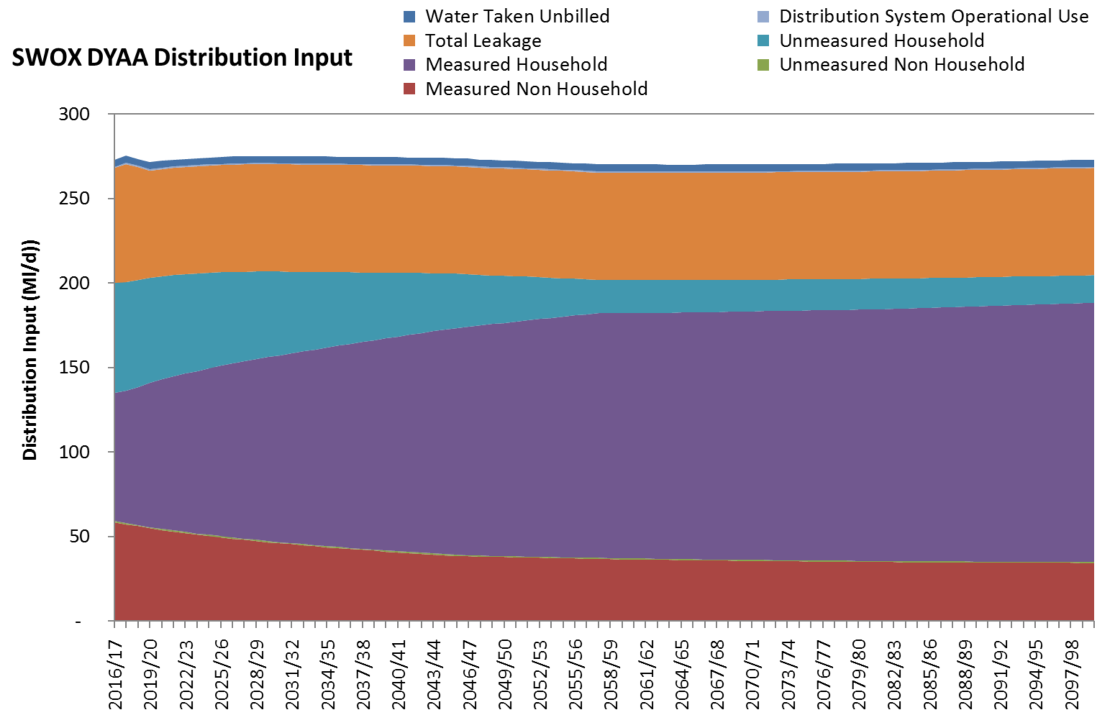


Figure 3-52: SWOX DYCP distribution input

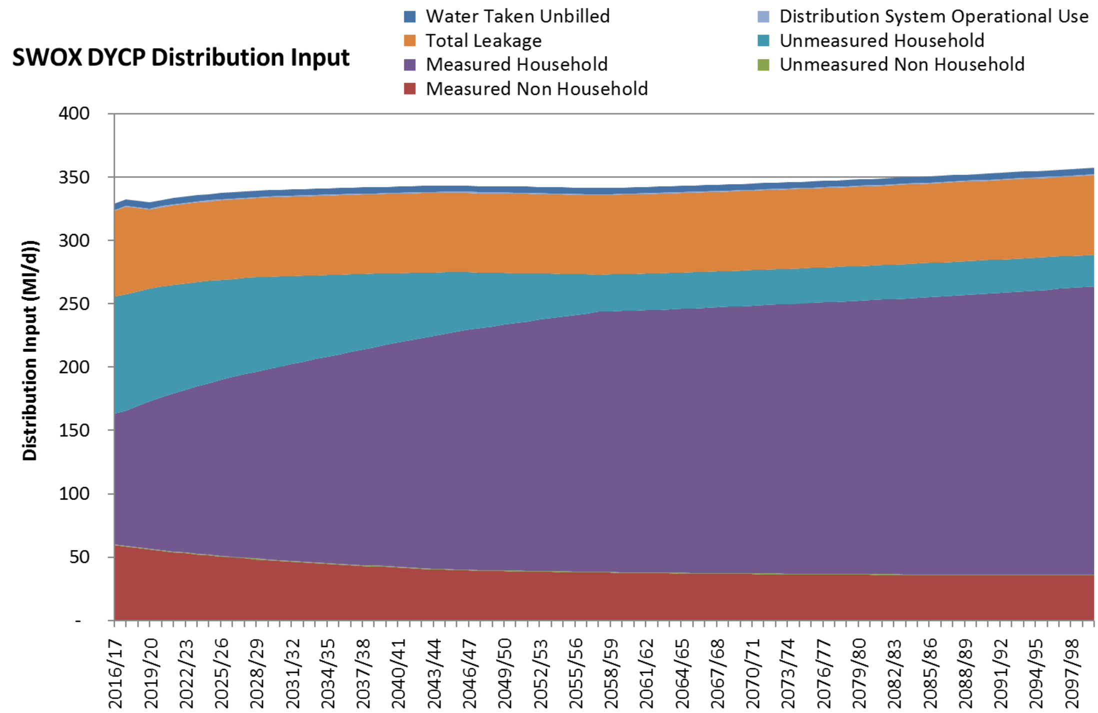


Figure 3-53: SWA DYAA distribution input

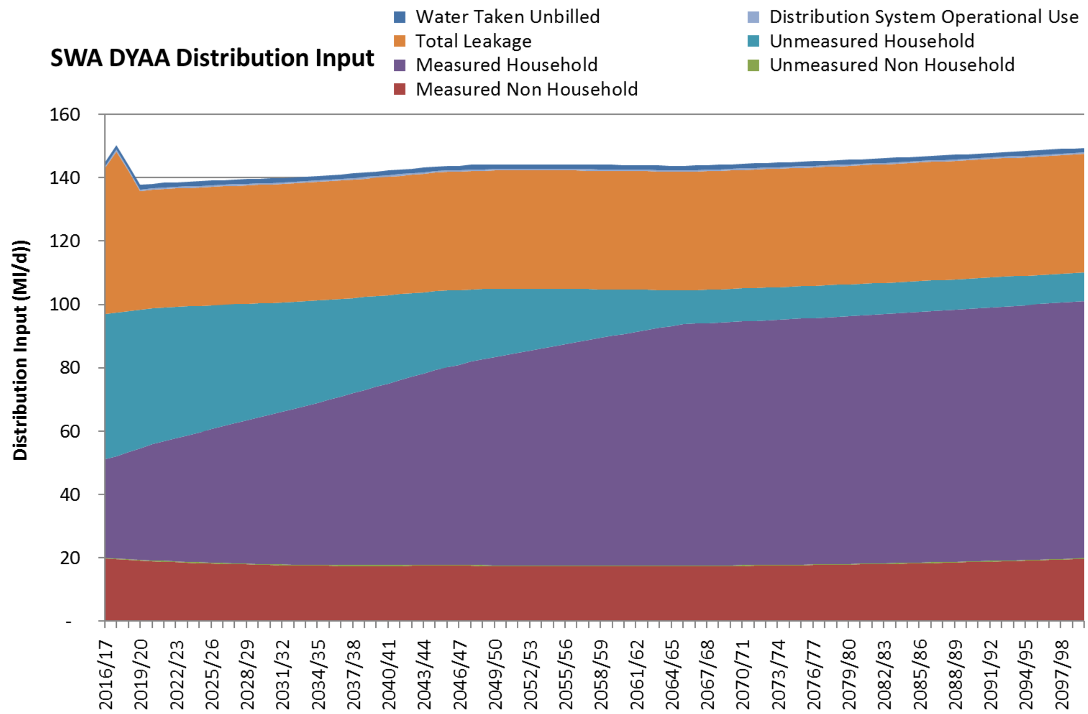


Figure 3-54: SWA DYCP distribution input

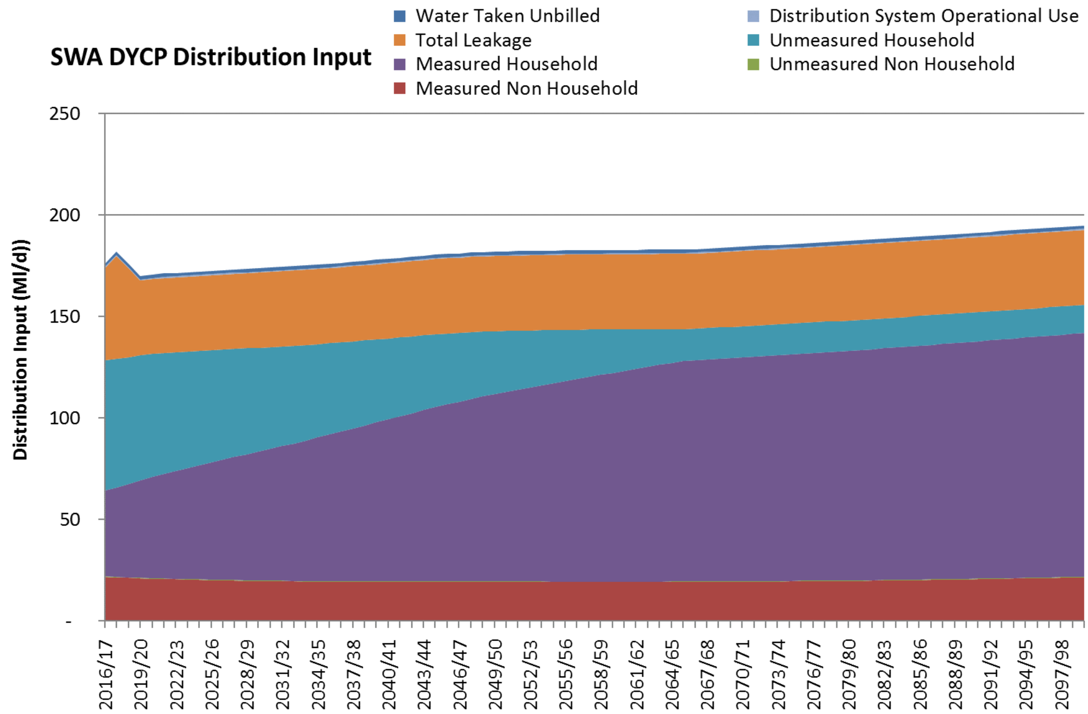


Figure 3-55: Kennet Valley DYAA distribution input

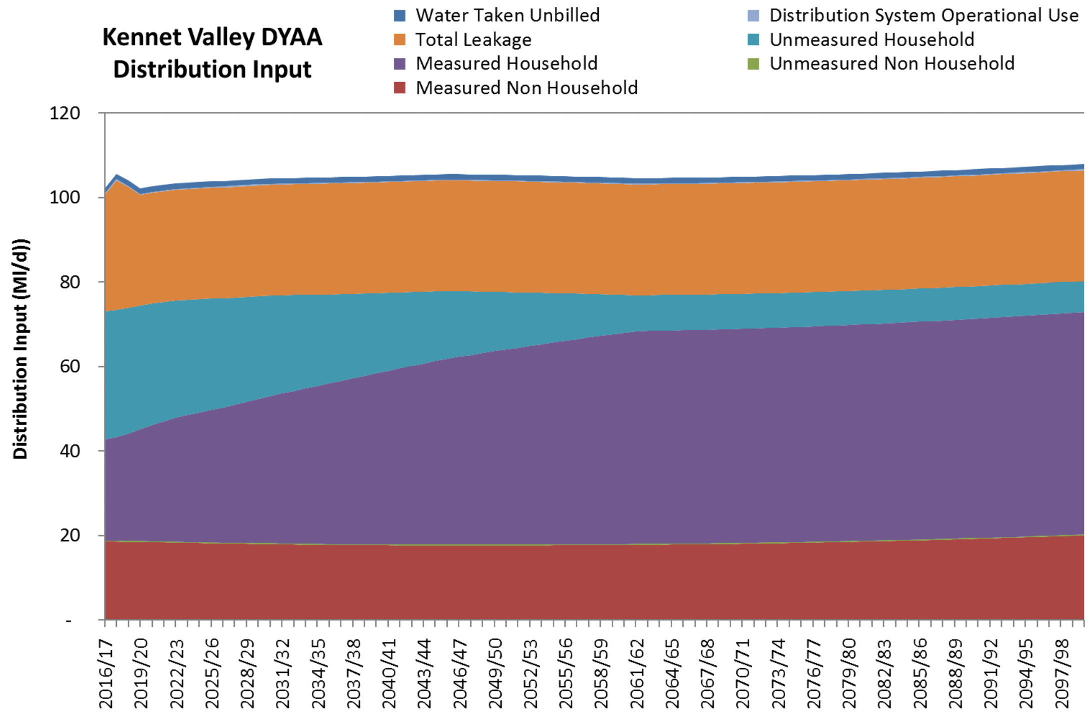


Figure 3-56: Kennet Valley DYCP distribution input

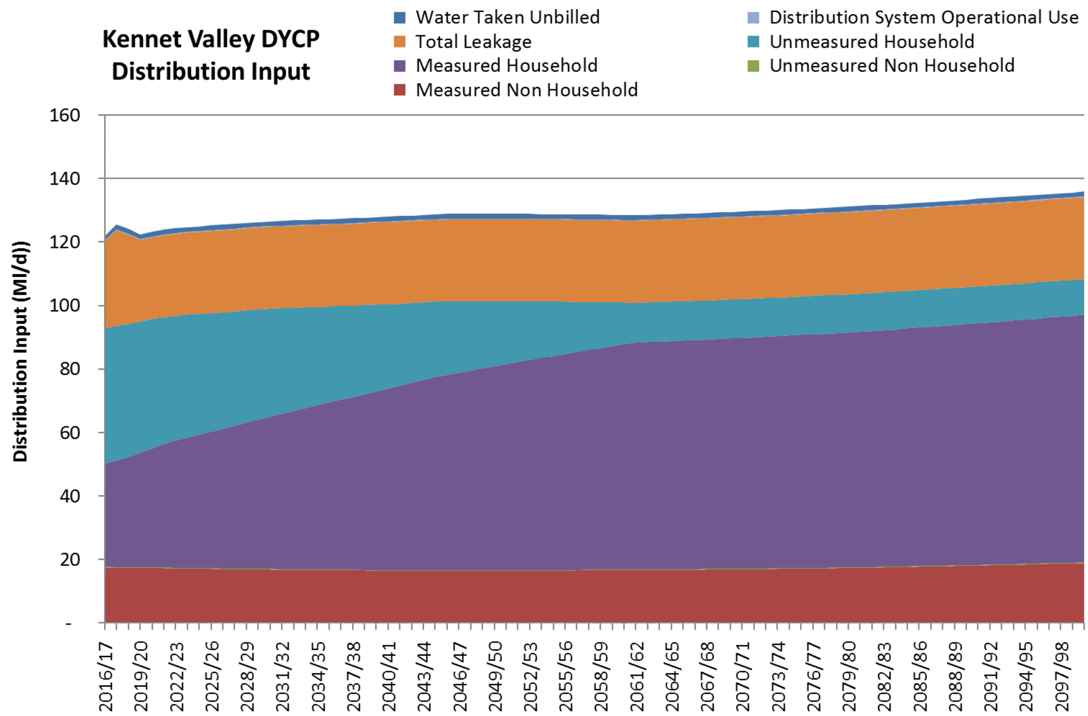


Figure 3-57: Guildford DYAA distribution input

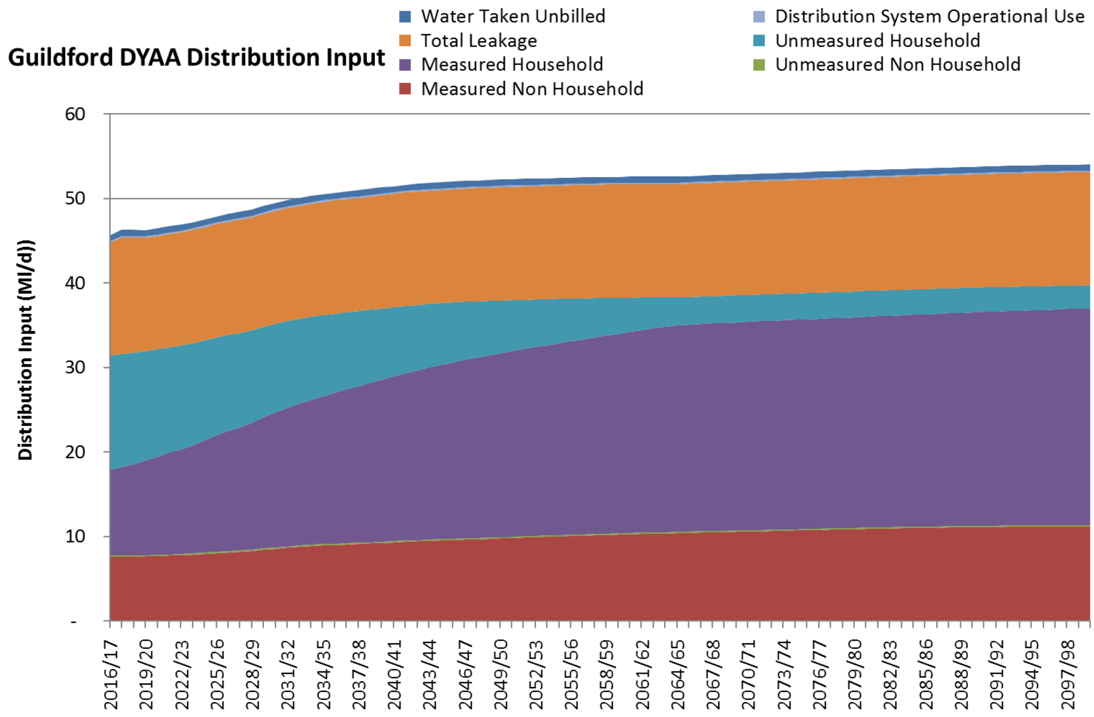


Figure 3-58: Guildford DYCP distribution input

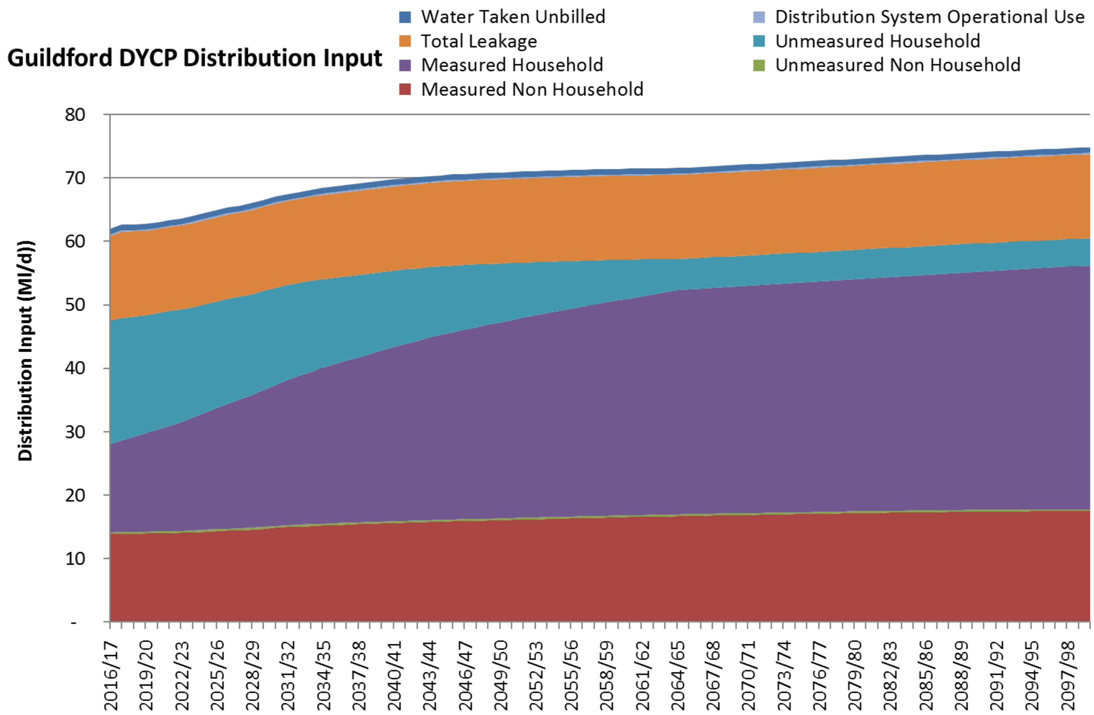


Figure 3-59: Henley DYAA distribution input

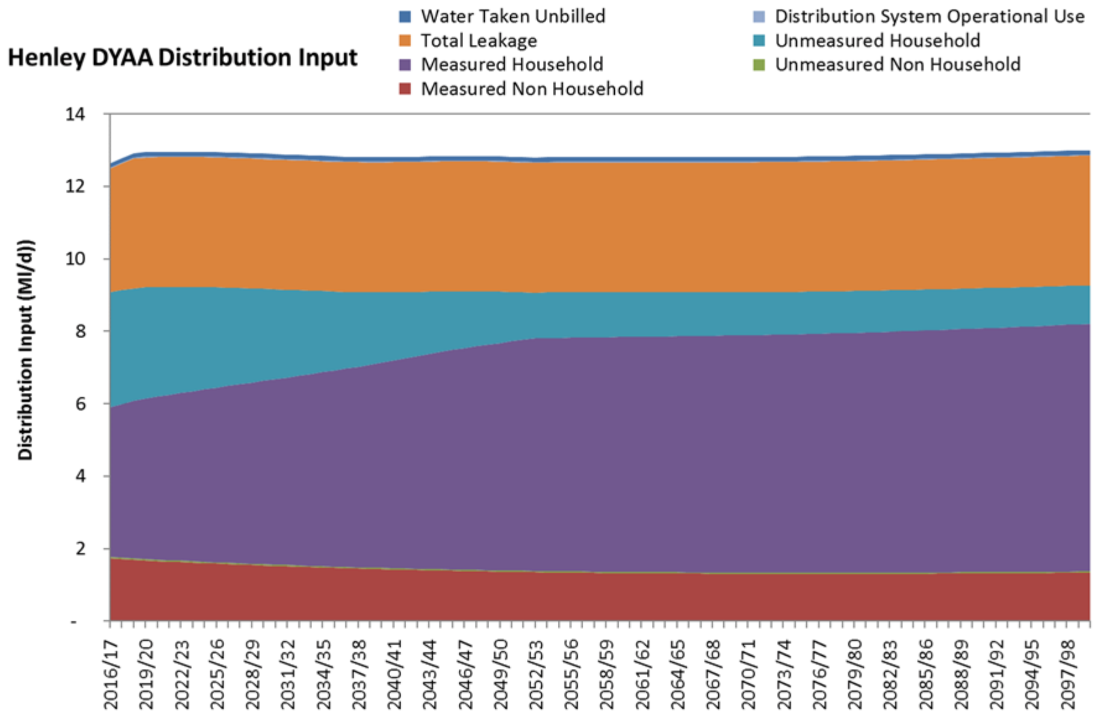


Figure 3-60: Henley DYCP distribution input