Appendix B – How much water will we need?

Appendix B provides an overview of the different uses of water supplied in our region and an explanation of the methodology we use to make projections of how demand will change over the next 25 years. We make our projections under two scenarios:

- dry year conditions as we are required to do so by the Environment Agency (EA) for water supply planning purposes, and
- average year conditions as we required to do so by Ofwat for revenue planning purposes

The demand scenarios incorporate the policy assumptions specified in the EA's Water Resources Planning Guideline (2012). We also produce our demand projections in two stages:

- a baseline demand forecast
- a final planning demand forecast

The baseline assumes that as a minimum we will continue existing demand management activity and leakage reduction. The baseline demand forecast to 2040 therefore:

- assumes a continuation of optional metering at current rates
- maintains leakage at the 2020 level
- assumes a continuation of water efficiency base activity

We then test the costs and benefits of additional leakage reduction and demand management measures to produce our final planning forecast.

We have produced demand forecasts based on assumptions about how water consumption will change over the next 25 years, including an assessment of the impacts of climate change. We have also taken account of Government water efficiency and demand management policies and aspirations. We have used the summary of current Government policies and aspirations presented in the WRMP guiding principles to inform the assumptions incorporated into our forecast of demand. In summary these are:

- Demand trends to be downwards where a company is in an area designated as water stressed, or where it has demand above the national average (147 litres per head per day)
- Where an increase in population or commercial use leads to increases in total demand, the company must ensure that its plan demonstrates a decrease in per capita consumption.
- The Government expects water companies to show in their water resources management plans how they will promote efficient water use and the impact that will have.
- The Government has concluded that a blanket approach to water metering is not the right way forward, as the costs and benefits of metering programmes will vary from region to region, depending on the level of water stress and environmental and social factors. However, where a water company is in an area designated as an area of serious water stress, it must consider compulsory metering as part of the feasible options in its options appraisal providing full costs and benefits of its proposals.

The chapters in Appendix B demonstrate how our plan aims to achieve Government policy targets and aspirations for the demand forecast, and covers the following elements of water demand:

- household consumption;
- non-household consumption;
- leakage;
- other minor areas of demand.

B1 Recent demand for water in our region

B1.1 Distribution Input

Distribution input is the term we use to describe the total quantity of treated water that we put into supply, and is composed of:

- demand from measured household and unmeasured household customers;
- demand from measured non-household and unmeasured non-household customers;
- leakage from our underground infrastructure, such as mains, distribution systems and communication pipes, the sum of which is known as distribution losses (DL);
- leakage from the underground supply pipes owned by our customers (which is referred to as underground supply pipe losses (USPL);
- minor components, such as water taken unbilled and distribution system operational use

Figure B1.1 shows the record of annual average distribution input in the previous Severn Trent region as a whole since 1989. The overall trend is one of general decline in average distribution input, but it is punctuated by the significant peak recorded during the mid-1990's. The highest levels of demand recorded in the region were experienced during 1995-96, which was a year of extreme summer temperatures and very low rainfall.

Following 1995-96, there were significant reductions in distribution input, driven by the large scale reductions in water lost through leakage. Between 1995-96 and 1998-99, estimated total leakage fell by around 220Ml/d (30%), and total distribution input fell by around 400Ml/d (15%).

Figure B1.1: Severn Trent's total Distribution Input since 1989

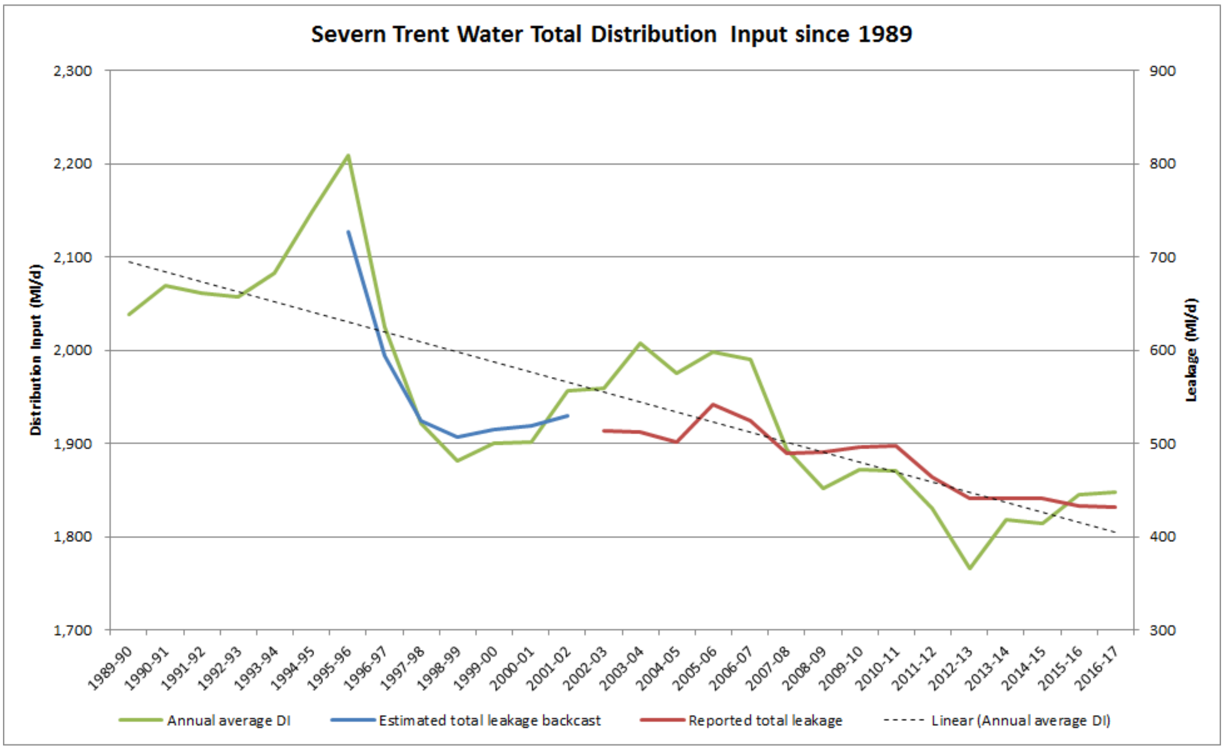


Figure B1.2 shows that the long term downward trend in distribution input (DI), otherwise known as water into supply, has been achieved against a backdrop of steadily growing regional population. The success of our leakage and demand management initiatives have helped us achieve this long term trend. Within this timeframe and long term downward trend, there have been short periods of rising and falling water into supply linked to the economic cycle affecting commercial demand, and weather trends impacting leakage in the winter, and household consumption in the summer. For example, since 2012/13 we have seen an increase in commercial demand linked to economic recovery. As we continue to deliver our leakage and water efficiency targets, we expect this long term downward trend to continue.

Figure B1.2: Index of distribution input and population growth for Severn Trent

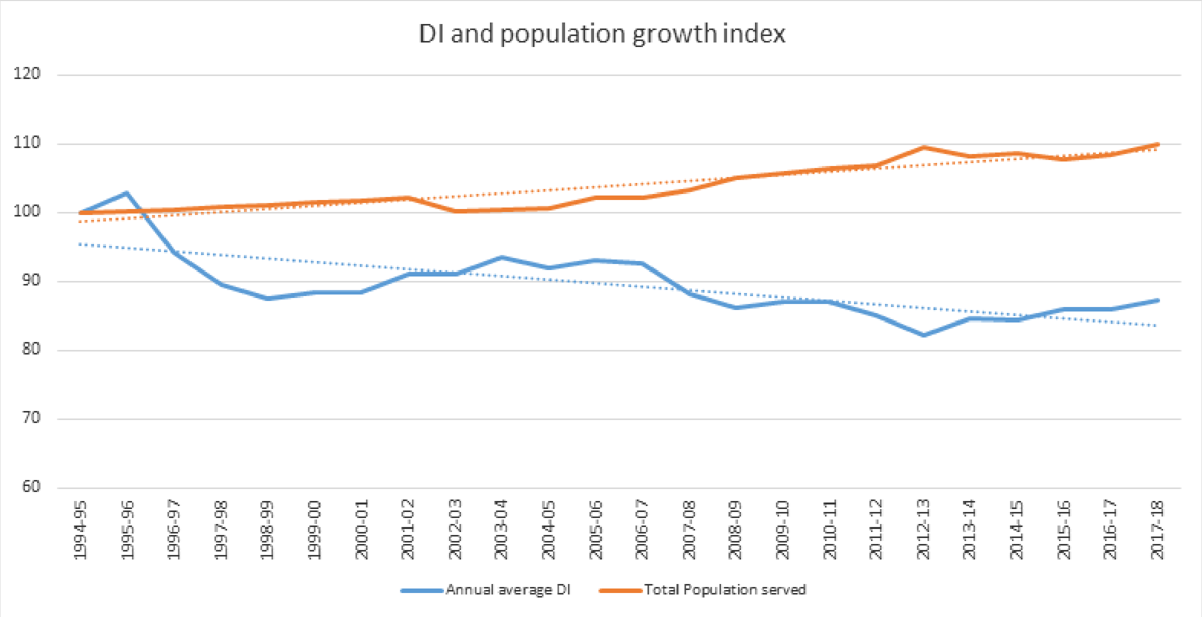
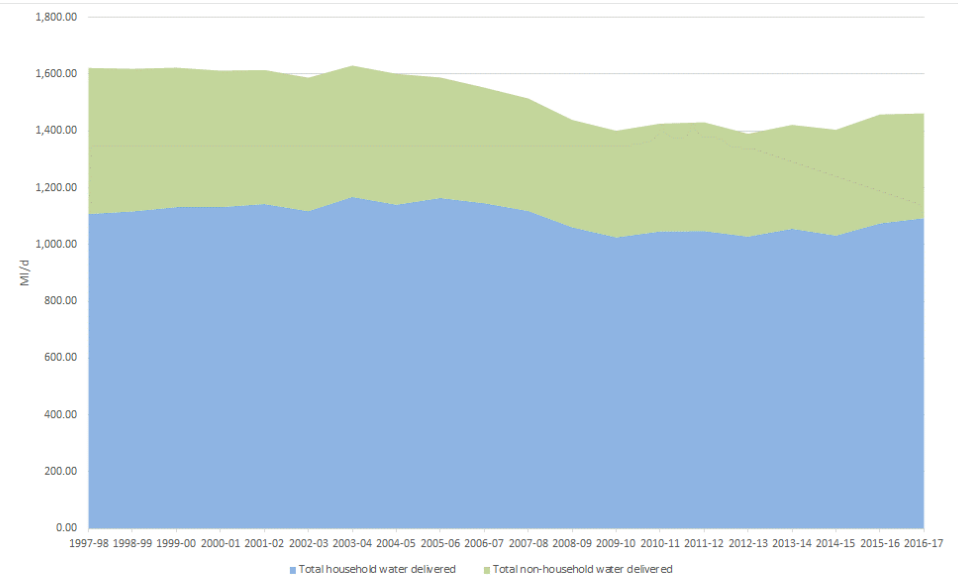


Figure B1.3 shows the trends in water demand from household and non-household customers over the last 15 years in the previous Severn Trent region. The general trends have been that household demand has shown a decrease of 5% since 1997-98, while commercial demand has shown a decline of around 25% over the same period. Despite a growing population and household customer base, the total demand for water has declined over the past 15 years. Household demand has decreased marginally despite population and household number growth and reflects the success of water efficiency efforts by our household customers and impact of metering on consumption. More recently, a series of relatively cool and wet summers has resulted in a steep decline in household consumption.

Figure B1.3: Severn Trent's total water delivered (Ml/d) since 1997



Non-household demand has steadily declined since the 1990's. Between 2007 and 2010 the rate of decline has been greater due to the economic downturn resulting in less water use as businesses close or reduce output, and continued water efficiency efforts.

B1.2 Forecasting demand for water

To estimate future distribution input, we produce projections of each component of demand separately, and sum them to derive customers' consumption and total demand inclusive of total leakage. In brief, the methodology for forecasting household customers' consumption entails producing year on year forecasts of population and the number properties to be served, along with year on year forecasts of the annual average unit consumption in each of those property types. We then multiply the property and unit consumption forecasts for each property type.

For each of our fifteen water resource zones, we have generated household property and population change projections which have been used to generate a forecast of household water consumption in measured and unmeasured properties to 2045.

Measured and unmeasured household consumption has been forecast using a model of how changes in consumption behaviour, water using appliance technology and other factors all influence demand.
Non household demand is forecast via econometric analysis to identify the historical relationship between water demand and explanatory factors such as industrial output, employment and trends in efficiency of water use. The results of this statistical analysis are combined with forecasts of output and employment by industry sector within the Severn Trent Water Supply Area to provide non-household water demand forecasts.
Our baseline distribution input scenario assumes that, as a minimum, our 2019/20 leakage target is maintained with no decline to 2044/45. It is important to note that simply maintaining this level of leakage over time will require significant investment to offset the underlying leakage breakout rate (LBR) in leakage which results from mains deterioration over time.

These assumptions are consistent with the Environment Agency's guidance in respect of the baseline scenario.

B2 Forecasting household demand for water

We forecast the demand for water from households in each of our resource zones and, by aggregation, over the company area as a whole, using the industry-standard component-based forecasting methodology. The key components used in forecasting household demand are:

- Population and household numbers
- Consumption in unmeasured households (i.e. those who do not have a metered supply)
- Consumption in measured households (i.e. those who have a metered supply)

In each case, we determine the current position in a base year, and then forecast changes in each component from that starting year over the following 25 years. We take account of demographic, social, economic, lifestyle, environmental and such other factors as are likely to influence how consumption patterns may change over the next 25 years. We break consumption in measured and unmeasured household down into micro-components which together sum to give the overall consumption total. The micro-components we use are:

- toilet flushing;
- personal washing;
- clothes washing;
- dish washing;
- miscellaneous internal use;
- external use.

We then forecast changes in water consumption at the micro-component level over the planning horizon. Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g. showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). Our forecast makes use of a national micro-component survey of 62 properties, alongside survey data which was collected at property level for the monitoring period.

The micro-component model is combined with property, population and occupancy forecasts in a unique way in that the micro-components vary with occupancy. Certain components have a valid relationship with occupancy, and others don't. This method is used to calculate base year OVF PHC values, which are then calibrated to the zonal normal year PHC values.

Forecasts of the property, population and occupancy are established by household segment via a model to allow for various assumptions and mathematical calculations as the company tends towards 100% meter penetration. Each household segment has a different base year OVF table / calculation, these are based on both measured differences between measured and unmeasured households, as well as assumptions made about devices within new properties and optant properties.

Micro-components are then forecast using a combination of longitudinal micro-component data and future market transformation programme derived micro-component values. These trends are applied to the normal year micro-component values. An additional occupancy specific trend is also added, to ensure that the varying occupancy within each of the household segments is captured.

Data from national studies was used to update previous micro-component estimates (from surveys, the Market Transformation (MTP) scenarios and other, older sources), and to consider upper and lower consumption forecasts.

Relevant data, existing survey results, and consumption data from metered customer billing records were all analysed and investigated, along with data collected in the 2016 UKWIR behaviour integration study, to estimate base year micro-component estimates.

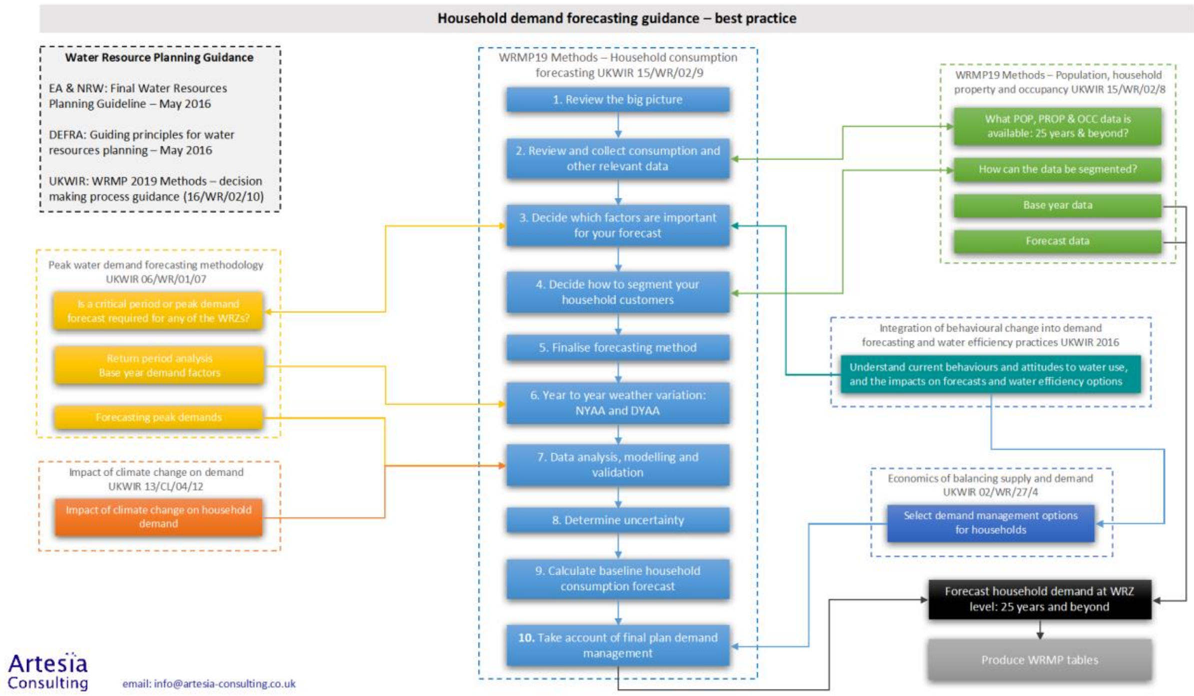
Household customers were segmented based on meter status (measured/unmeasured), with sub-divisions for meter type (existing metered, free meter optants, new property). Data was used to determine how to account for differences in consumption between segments and also the effect of meter switching.

Normal year and dry year adjustments were made to the base year consumption and the consumption forecast.

A scenario approach to modelling uncertainty was used, to reflect the various uncertainties in consumption forecasts.

Best practice guidelines (detailed in Figure B2) have been followed in deriving the baseline household demand forecast.

Figure B2 Best practice guidelines for household demand forecasting



We have produced household annual average demand forecasts for each of the following scenarios:

- baseline dry year;
- final planning dry year;

Our approach to these scenarios is provided in the following sections.

B2.1 Base year population and properties

Base year household population

Base year Resource Zone population estimates have been developed using the latest population estimates from CACI, a specialist demographic data provider, and use a combination of Census 2011 and 2014 Office of National Statistics (ONS) mid-year estimates to produce the best available population estimates for the current year. Postcode level estimates are mapped geographically to water resource zones to produce household population estimates at water resource zone level.

Adjustments are made for estimates of additional hidden and transient population, neither of which are accounted for in Census data or ONS estimates. To account for population in properties on private water supplies, private water supply data is gathered direct from local authority records.

Base year non-household population

Non-household population data is derived from the Census 2011 communal population (prisons, hospitals etc.) data at postcode sector level which is geographically mapped to the water resource zones. Non-household population data is applied only to measured non-households. Unmeasured non-household population is assumed to be zero as all communal establishments will be metered.

Base year household properties

For the base year 2016/17 the numbers of unmeasured household, measured household and void household properties are taken from our company billing system, TARGET. Property records are allocated to Water Resources Zones using their postcodes. These data form the base year numbers from which we forecast property numbers for each future year to 2045.

For new Severn Trent WRZs, Chester and Shelton, base year property and population have been apportioned on the basis of Annual Return property data mapped to the England and Wales border.

B2.2 Forecasting population

For estimates of future total population we have used the latest Government projections for England and Wales and have applied these to our base year data. These projections are taken from the 2014 base sub-national population projections for England and Wales from the ONS. The annual percentage rates of change for local authorities are applied to the base year population estimates at postcode level and then aggregated up to water resource zone level. This gives the underlying change in population due to births, deaths and migration in our region. The ONS 2014 base projections of population extend to 2039 while we are required to project to 2045. To extend the population estimates to the full planning period we have extended population trends in the latter years of the ONS forecast to 2045.

Having derived the overall population trend for our region, we next allocate future population changes across different property categories (unmeasured and measured households) and take account of population movement between these categories.

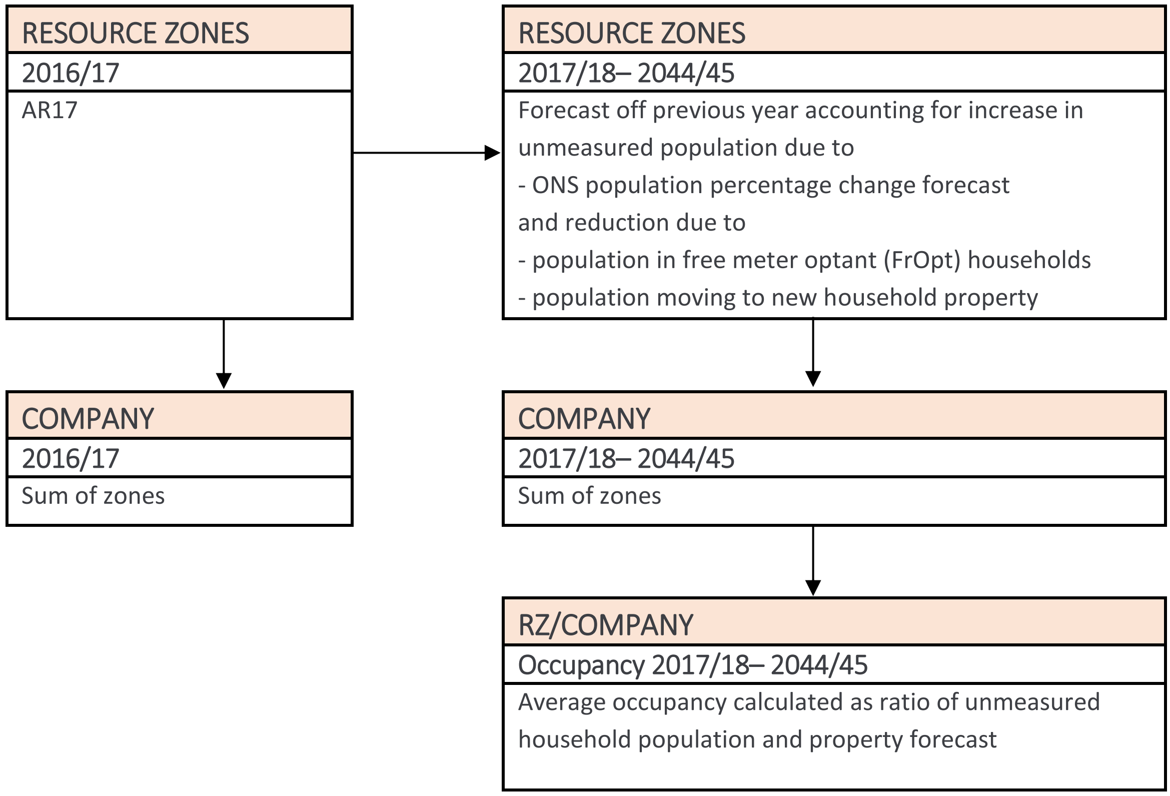
It is necessary to allocate the population forecast between property types as this defines the property occupancies which influence the level of water use in each household. The following section details the population forecast allocation methodology.

Population forecasts for new WRZs, Chester and Shelton, in Severn Trent have been derived via apportionment on the basis of Annual Return property data mapped to the England and Wales border.

Unmeasured household population forecast

For each resource zone, our starting point is the reported 2016/17 unmeasured household population from the Ofwat Annual Return 2017 (AR17). The impact of our assumptions for ONS rates of growth, future rates of metering and new property population generates the unmeasured household population forecast for each resource zone. At the company level, base year and forecast year population of unmeasured households are calculated as the sum of the population of unmeasured households in the fifteen resource zones. Figure B2.1 shows how unmeasured property population is forecast.

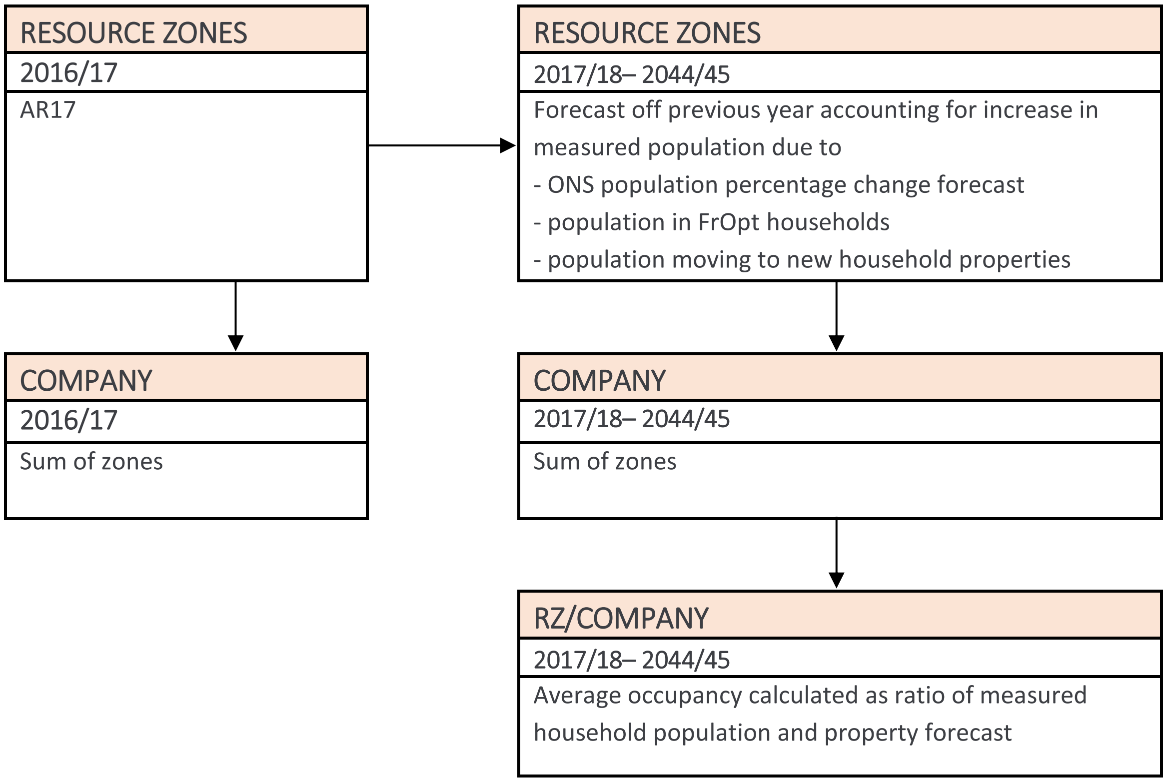
Figure B2.1: Flow chart showing derivation of unmeasured household population forecast



Measured household population forecast

For each resource zone, our starting point is reported 2016/17 number of measured households from AR17. The impact of our assumptions around future metering uptake, new property builds and demolitions generates the net measured household numbers forecast for each resource zone. At the company level, base year and forecast year number of measured households are calculated as the sum of the number of measured households in the fifteen resource zones. Figure B2.2 shows how unmeasured property population is forecast.

Figure B2.2: Flow chart showing derivation of measured household population forecast



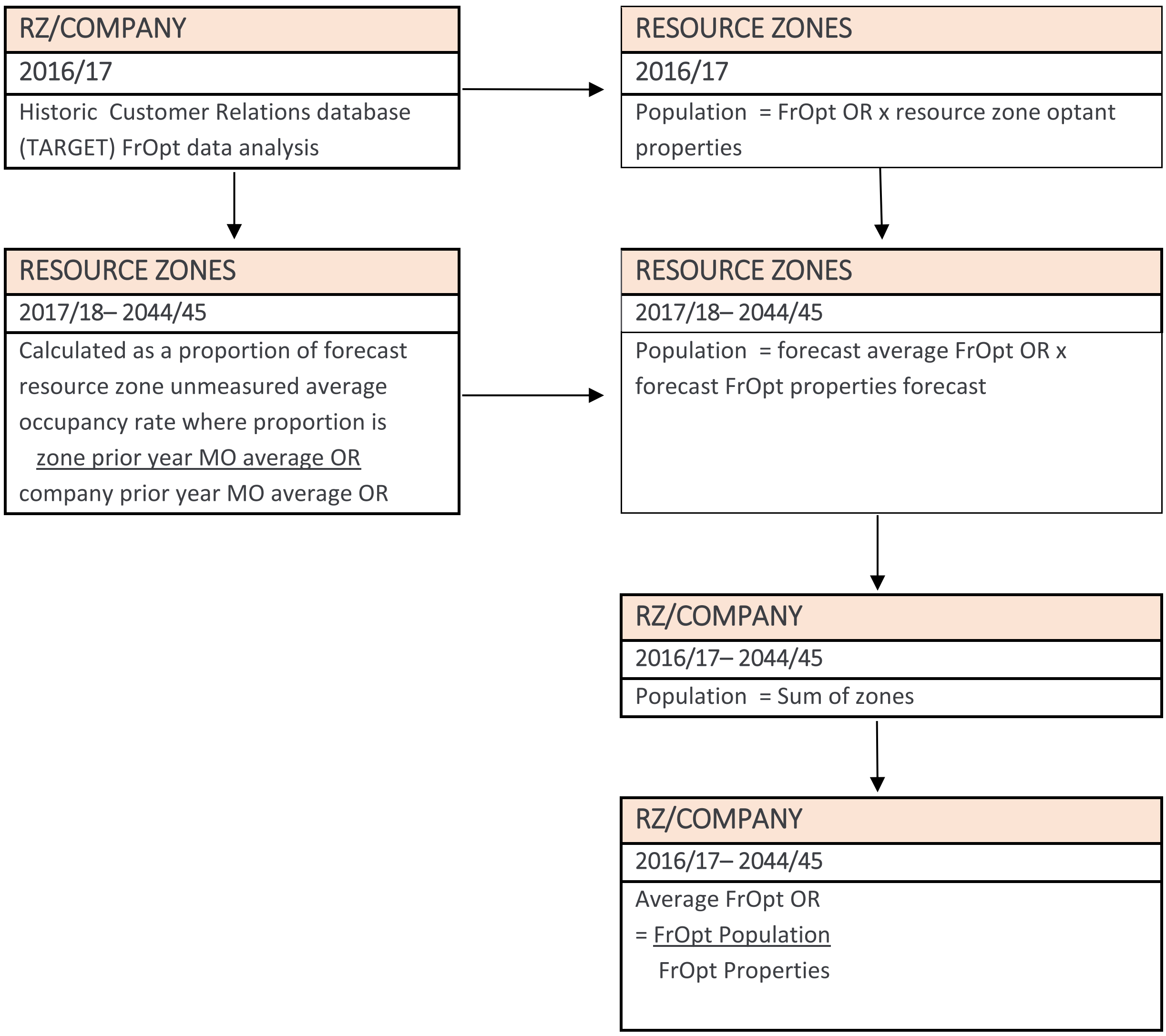
Meter optants population

Customers who opt for a meter do so to reduce their water bills, and they tend to be low occupancy properties with an average household consumption below the average unmeasured household consumption. We have analysed historic meter optant data from our Severn Trent billing system records to derive a base year meter optant average occupancy of 1.47 (for the previous Severn Trent Water region). This is lower than the average unmeasured household occupancy of 2.53.

For our forecast, we have maintained a constant ratio between meter optant average occupancy rate and unmeasured average occupancy rate. As lower than average occupancy unmeasured properties opt for a meter, the average occupancy of the remaining unmeasured customer base will rise. Year on year, the average occupancy rate of unmeasured customers that opt for a meter will also rise (since lower occupancy properties would have opted in earlier years). This ratio approach to forecasting meter optant average occupancy rate captures the changing profile of the unmeasured occupancy rate over time.

Figure B2.3 overleaf shows how unmeasured property population is forecast.

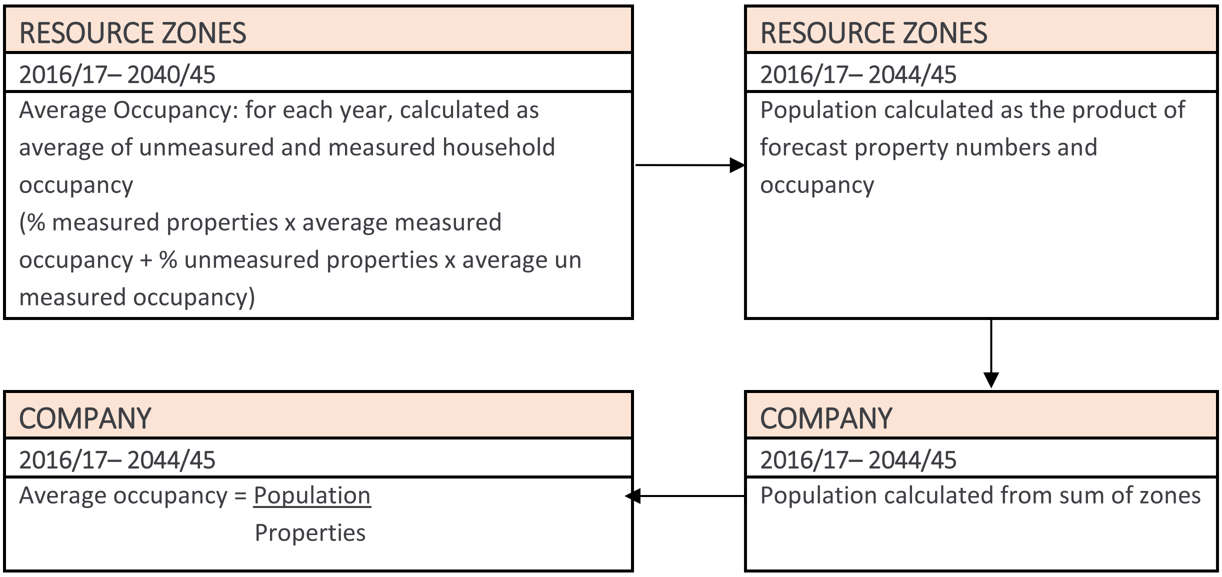
Figure B2.3: Flow chart showing derivation of free meter optant household population forecast



New household property population

Population in new household properties is the product of our forecast of the number of new households, and an assumption for occupancy. The new household property occupancy is calculated each year as the average occupancy of all households (unmeasured and measured) in our region. Figure B2.4 shows how unmeasured property population is forecast.

Figure B2.4: Flow chart showing derivation of new household population forecast



Non-household population forecast is the base year population held constant over the planning period.

B2.3 Property forecasts

We forecast household property numbers for two property categories; unmeasured household, that is properties that do not have a water meter fitted and pay for their water on the basis of property rateable value, and measured households that have a water meter fitted. Measured properties include:

- New properties
- Meter optant properties i.e. properties that were previously unmetered and opt to have water meter installed
- Selectively metered properties i.e. properties that were previously unmetered and have water meter installed during a change of occupier

Within the measured category, we forecast new household property (all such properties are metered) numbers and newly metered properties i.e. properties that were previously unmetered and opt to have water meter installed.

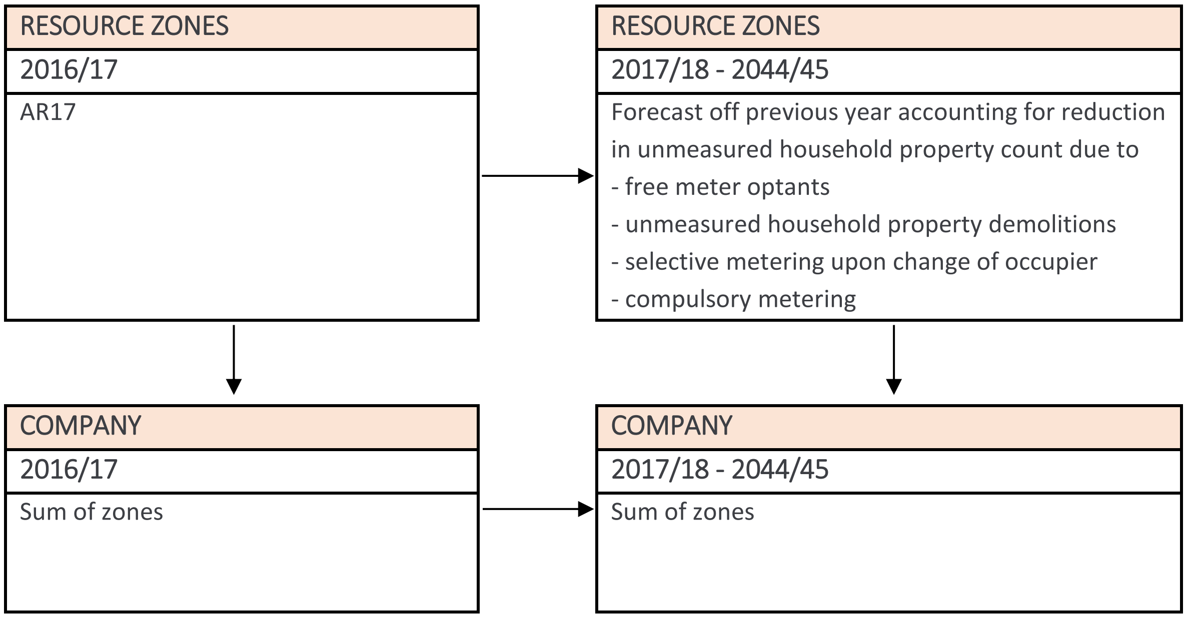
It is necessary to forecast each of these property types due to their differing consumption characteristics. The occupancy characteristics of each of these property types combined with differing consumption characteristics defined by forecast behavioural and technological change assumptions, gives rise to differing household consumption forecasts between property types. Aggregating each of the property consumption forecasts gives the overall household demand forecast.

The following section details the property forecast methodology. For new Severn Trent WRZs, property forecasts have been apportioned on the basis of Annual Return property data mapped to the England and Wales border.

Unmeasured household property forecast

For each resource zone, our starting point is the reported 2016/17 unmeasured households from the Ofwat Annual Return 2017 (AR17). The impact of our assumptions around future rates of metering and demolitions then generates the unmeasured household numbers forecast for each resource zone as shown in Figure B2.5. At the company level, base year and forecast year number of unmeasured households are calculated as the sum of the number of unmeasured households in the fifteen resource zones.

Figure B2.5: Flow chart showing derivation of unmeasured property forecast

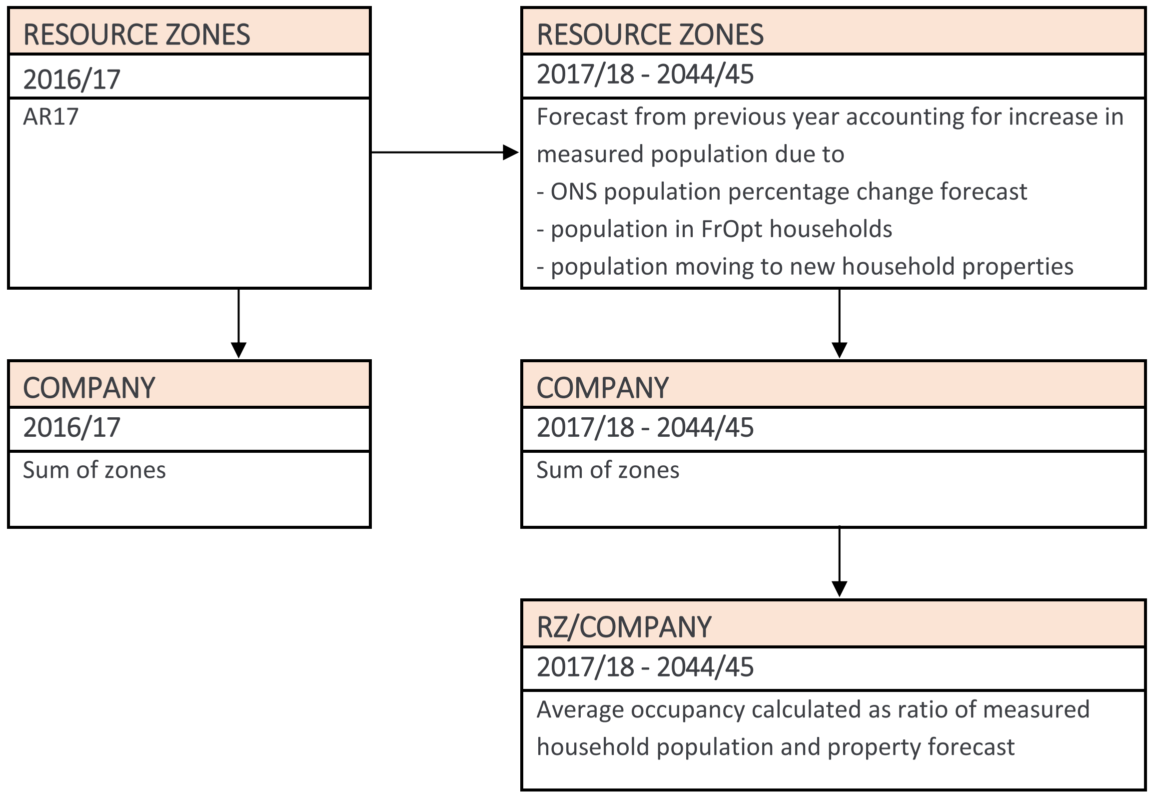


Measured household properties forecast

For each resource zone, our starting point is reported 2016/17 number of measured households from AR17. The impact of our assumptions around future metering uptake, new property builds and demolitions then generates the measured household numbers forecast for each resource zone. At the company level, base year and forecast year number of measured households are calculated as the sum of the number of measured households in the fifteen resource zones.

Figure B2.6 overleaf shows how measured property numbers are forecast:

Figure B2.6: Flow chart showing derivation of measured household population forecast



Property forecast assumptions

In arriving at our property forecast for unmeasured and measured households we make a number of assumptions to derive each profile. The following section sets out the basis for our baseline forecast assumptions for household properties.

Baseline metering

Free meter option

Our baseline demand forecasts assume a continuation of current rates of optional metering of unmeasured households. This section describes the derivation of our baseline metering forecast.

Table B2.1 below shows the past rate of uptake of the free meter option from 2005/06 to 2014/15 in the Severn Trent Water region. The table shows that the rate of uptake has fluctuated over recent years in response to factors such as changes in average unmeasured bills and the economic climate.

Table B2.1: Rate of metering from 2005/06 to 2014/15

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

For the final WRMP19 our central forecast is for baseline free meter optants (FrOpts) to continue at the observed average rate of 1.79% p.a. (average of AMP4 and AMP 5 (2005/06 to 2014/15)).

New household property forecast

At PR09, we based new household property forecasts on the policy-based projections derived from Regional Spatial Strategies (RSSs) of the English Regional Assemblies within the Severn Trent region that contain information on household projections by local authority.

By PR14, the Regional Spatial Strategies were abolished and the EA WRMP Guideline required water companies to use local government data to derive new household property forecast, and amend with justification where required. The LPA forecasts for our region represent a stepped increase in new connections over historically observed numbers. For this reason, we forecast a rising trend over the remainder of AMP5 and AMP6, reverting back to the LPA forecast at the start on AMP7.

The EA WRMP 19 guidance, explicitly instructs water companies to account for the local council projections of household growth for supply capacity planning purposes. In light of this, we are adopting Local council levels of growth from AMP7 onwards for the WRMP19 as illustrated below.

In developing our WRMP we have actively consulted with Local Authorities to gain an understanding of the projected future growth in our region. We have also followed the regulatory guidance that requires use of Local Authority growth forecasts and projections when planning for future demand.

Our liaison with Local Authorities is already an important and ongoing part of our ‘Growth Liaison’ approach and influences our water and waste infrastructure planning. The liaison ensures we have up to date insight on planned growth in the region allowing us to plan appropriate asset investment to ensure we have water and waste capacity to meet all growth needs. Any ongoing contact can be made by email, at any time, to growth.development@severntrent.co.uk. We contacted each local authority in our region requesting the following information:

- Annual housing trajectories, including data sources and assumptions.
- Annual population projections, including data sources and assumptions.
- Historic data on demolitions and new housing stock from 2010-2015.
- Is the local development plan adopted? Date of adoption or expected date. Timescales for any further revisions.

Where no response is received from the consultation a search of the LPA's websites is undertaken to gather relevant planning policy documents to gather the relevant information.

- Search for local authority website
- Search for all relevant housing policy documents. This can be done by reviewing the planning department's documents and by searching for the following documents:
  - Assessment of Housing Needs and Objectively Assessed Housing Need
  - Core Strategy
  - Local Development Plan
  - Annual Monitoring Report
  - Site Allocation Reports
  - Strategic Housing Market Assessment
  - Residential Land Availability
  - Land Supply Statement
  - Strategic Housing Land Availability Assessment
  - Housing Trajectories

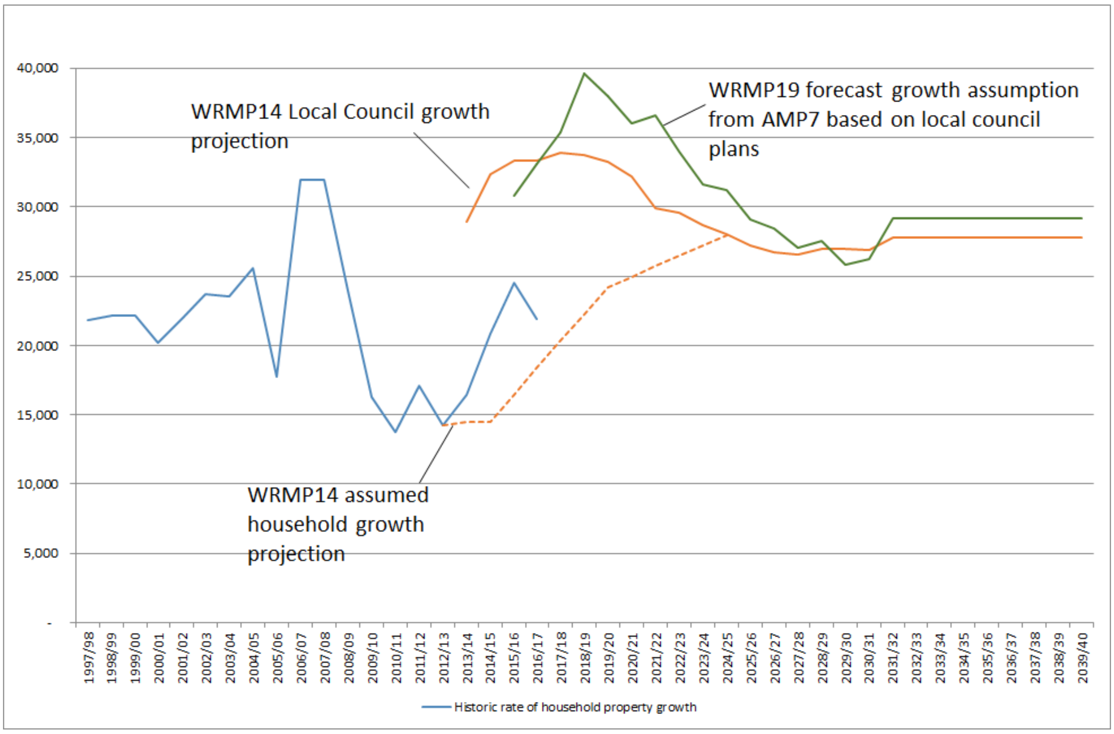
Table B2.2 below shows the Company level growth data gathered during this process and assumed in our WRMP19.

Table B2.2: Company level growth data

	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
WRMP19 forecast growth	33,201	35,419	39,614	37,971	35,941	36,448	33,872	31,464	31,068
	Annual average growth per AMP								
	AMP 8	AMP 9	AMP 10	AMP 11					
WRMP19 forecast growth	27,246	28,083	28,618	28,538					

The following chart (Figure B2.7) illustrates this data alongside historic actual growth in our previous Severn Trent region, and WRMP14 assumptions.

Figure B2.7: Historic new household property trends



B2.4 Forecasting household water consumption

B2.4.1 Method selection

The Water Resources Planning Guideline identifies the need for water companies to use methods for supply and demand analysis that are appropriate to the level of planning concern in their water resources zones (WRZs).

The overall problem characterisation for the Severn Trent region for the dWRMP18 is 'high' (see Appendix C). An assessment of suitable household consumption forecasting (HHCF) methods was carried out based on this characterisation. This indicated that regression modelling would be the preferred forecasting approach for this level of concern. However we do not have sufficient data and information on individual household consumption and property characteristics to enable regression modelling. Micro-component forecasting scored second overall, as described below and would be a suitable alternative in the circumstances.

Therefore it has been decided to develop an updated micro-component forecast for WRMP19.

Approach

Guidance on the selection of appropriate household consumption forecasting methods were developed by UKWIR (UKWIR, 2016), along with guidance on the application of these methods.

The UKWIR guidance identifies nine criteria and a weighting and scoring framework, set out in a 'RAG Matrix'[1]. The guidance recommends that practitioners adapt the weightings and scores in this matrix to reflect their own situation, in order to identify the most appropriate methods for forecasting household consumption. In particular, the matrix should be amended to reflect the level of planning concern in a particular WRZ.

We have used the RAG matrix, with amendments to reflect the status of its single WRZ to shortlist preferred methods for household consumption forecasting. The assessment that has been undertaken is presented in the following sections.

[1] Red Amber Green Matrix, used to highlight which methods score best to worst

RAG matrix and comments

Figure B2.8 illustrates the results of the RAG matrix.

Figure B2.8: Severn Trent RAG Matrix for HHCF method selection

SEVERN TRENT	Weighting	Regression models	Micro-component models	Macro-component models	Micro-simulation	Proxies of consumption
Acceptance by stakeholders	10	8	7	6	5	2
Explicit treatment of uncertainty	5	7	7	5	5	2
Underpinned by valid data	5	6	7	7	4	2
Transparency and clarity	7	7	7	5	2	2
Appropriate to level of risk	7	7	7	5	2	2
Logical and theoretical approach	7	7	6	5	4	2
Empirical validation	5	7	6	5	5	2
Explicit treatment of factors that explain HH consumption	8	7	8	6	7	2
Flexibility to cope with new scenarios	5	8	7	6	5	2
Weighted score		**423**	**409**	**328**	**257**	**118**
Ranked		**1**	**2**	**3**	**4**	**5**

Table B2.3 provides comments on the justification for the scores presented in Figure B2.8.

Table B2.3: Justification for RAG Matrix scoring

Criteria	Comment
Acceptance by stakeholders	Regression scores best on this criteria as it will be regarded sufficiently robust for highest risk zones. Data availability may be an issue due to out-of date survey data. Micro-components were used in WRMP14 and is well understood, so scores next best. Macro-components could focus on key variables but less well understood. Micro-simulation would be very uncertain method.
Explicit treatment of uncertainty	It will be easier to statistically quantify uncertainty with regression using standard error, coefficients of uncertainty etc. Proposed micro-component method allows model error to be defined and scenarios easier than regression. Spatial validation also possible with 15 WRZs. Other methods less well understood so marked down.
Underpinned by valid data	National micro-component data are available and can be supported by Company data. DCM data available but not supported by recent survey data therefore regression marked down.
Transparency and clarity	Properly undertaken, regression can be clear and transparent. Proposed micro-components approach is less complex than previous methods so scores the same. Other methods less well understood therefore marked down.

Criteria	Comment
Appropriate to level of risk	Regression is considered appropriate to WRZs with a high level of risk, whilst proposed micro-component methods more appropriate for lower risk zones, and more sophisticated than WRMP14 so OK for medium/high risk zones. Macro-components less suitable for high risk and other methods not developed enough.
Logical and theoretical approach	Regression modelling will focus on key variables. Proposed micro-component methods addresses relationships between occupancy and m/comp use, plus market trends. Macro-comps could be seen as too lumpy. Other methods logical but less well understood.
Empirical validation	Empirical validation is a key part of regression modelling (e.g. residual analysis). National/regional data are available for validating micro-component analysis and multiple zones means spatial validation also possible. Validation less easy for lumpier macro-components and other methods.
Explicit treatment of factors that explain HH consumption	Both regression and the proposed micro-component method allow for the explicit treatment of factors that influence consumption - e.g. occupancy, technology and behaviour. M/comps scored slightly higher due to experience of implementing new method with other companies. Macro-components will be less explicit. Micro-simulation scores better here due to analysis at HH level.
Flexibility to cope with new scenarios	Regression can model alternative scenarios through the variation of single terms in the regression equation. Scenarios relatively easy in proposed micro-component methods via market transformation scenarios. Other methods less flexible.

The weightings used in the matrix are based on industry standards, amended where appropriate to reflect our position.

The scoring reflects the relevance of the methods to our situation – particularly with regard to the level of planning concern in the WRZ and the availability of company-specific data, particularly for regression modelling.

The micro-component forecast has therefore been selected as per the ranking set out in the RAG matrix. This will be based on recent national micro-component data, supported by Company data, to establish a base year model of consumption.

B2.4.2 Review of data availability

Base year data

The base year selected for the development of the initial dWRMP18 model is 2015/16. Reported base year figures for per capita consumption (PCC, excluding supply pipe leakage), property, population and occupancy figures have been extracted from Table 10 of the June Returns. These base year are presented in Table B2.4 for measured and unmeasured properties. Table B2.4 also includes calculated per household consumption, based on reported PCC and occupancy figures.

Other data

We have used a number of data which are either used in the forecast, or for validation of the model. This data includes daily consumption data from the Company's domestic consumption monitor (DCM), historic trends from the June Returns, the WRMP14 forecast, the Company's forecast for population and properties, historic weather data and historic distribution input (DI) data.

In addition to Company data, several national datasets are used to increase the understanding of historic, present and future micro-component consumption. Historic micro-components are extracted from the WRc CP187 report, current micro-components are extracted from UKWIR 16/WR/01/15 Integration of Behaviour Change and future projections are extracted from the Market Transformation Programme (MTP).

Table B2.4: Base year (2015/2016) values used in the model development

	Unmeasured					Measured				
WRZ	PCC (l/h/d)	Population	Properties	Occupancy	PHC (l/hh/d)	PCC (l/h/d)	Population	Properties	Occupancy	PHC (l/hh/d)
Bishops Castle	133.91	3,572	1,610	2.22	297.15	133.12	2,362	1,079	2.19	291.45
Forest & Stroud	135.22	90,116	36,222	2.49	336.42	119.63	40,428	18,224	2.22	265.38
Kinsall	137.49	6,397	2,686	2.38	327.46	116.79	5,356	2,310	2.32	270.74
Mardy	138.83	4,171	1,631	2.56	355.00	126.90	3,242	1,410	2.30	291.71
Newark	136.31	24,771	10,473	2.37	322.39	121.94	20,051	9,585	2.09	255.08
North Staffs	142.14	315,884	127,039	2.49	353.43	111.73	207,910	94,951	2.19	244.64
Nottinghamshire	136.31	645,571	262,008	2.46	335.86	118.94	363,615	169,435	2.15	255.25
Rutland	133.21	13,748	5,464	2.52	335.19	147.14	14,415	6,257	2.30	338.97
Ruyton	131.45	5,348	2,119	2.52	331.76	120.97	6,625	2,411	2.75	332.34
Shelton (old STW WRZ)	137.33	270,553	108,118	2.50	343.65	115.88	191,094	85,648	2.23	258.55
Stafford	120.14	42,351	16,637	2.55	305.82	113.87	49,076	21,691	2.26	257.64
Strategic grid	137.60	3,055,923	1,200,007	2.55	350.42	118.75	1,900,241	856,182	2.22	263.56
Whitchurch & Wem	137.29	14,132	5,712	2.47	339.70	122.23	13,787	6,246	2.21	269.77
Wolverhampton	135.79	153,723	58,907	2.61	354.36	117.03	80,628	37,861	2.13	249.23

Measured micro-component data

By 'measured' we mean micro-component data that has been collected by measuring the different micro-components used within the household (as opposed from survey questions and assumptions). This allows ownership (O), volume per use (V) and frequency of use (F), to be calculated for each micro-component. There are two main sources of data for this:

- 2015-16 data collected using the Siloette system:
  - a sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study[2] (this contains 62 households from around England and Wales):
  - a sample of RV billed households, which does not have associated demographics (collated from other anonymous Siloette studies carried out by Artesia Consulting, from England and Wales).
- 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP1873).

Both the Siloette and Identiflow systems measure the flow into a property and compute the individual micro-components through pattern recognition (although the detailed methodology of the two systems is different). The Siloette system uses a Siloette logger that is connected to the pulsed output from a meter via a pulse unit, as illustrated in Figure B2.9.

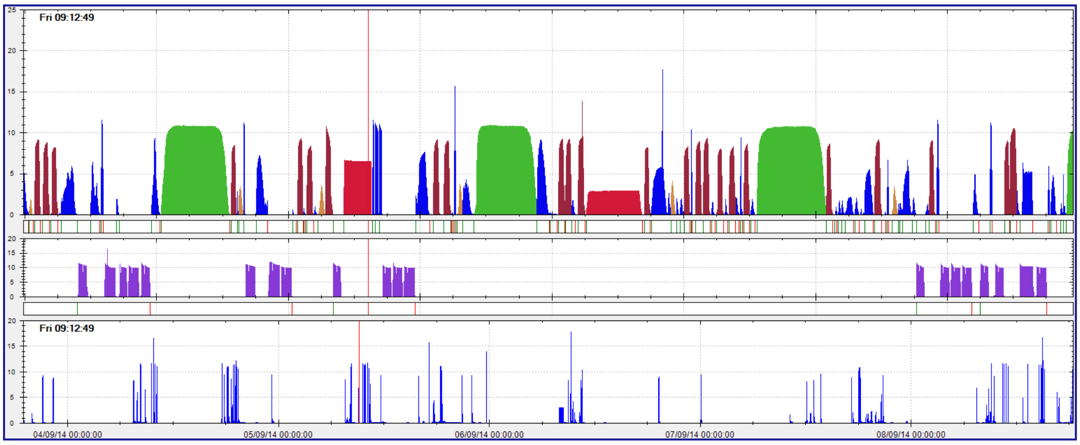
Figure B2.9: Siloette logger installed in a boundary box

The logger records the flow through the meter at sub 1-second resolution. Once downloaded an algorithm is applied to the data to create a high-resolution flow trace of the flow into the property, as illustrated in Figure B2.10

[2] Integration of behavioural change into demand forecasting and water efficiency practices, UKWIR 16/WR/01/15, 2016

[3] Increasing the Value of Domestic Water use Data for Demand Management, WRc, March 2005

Figure B2.10: Illustration of Siloette logger output



Each water-using event in the house has a flow-rate profile characterised by the time, duration and volume of water per use. Siloette takes the data from the logger and uses pattern-recognition software to disaggregate and quantify the individual micro-component events and provide information on time of event, flow rates and volumes. In Figure B2.10 the bottom trace shows the time-series of the flow profile, and the top row shows the resulting events that have been characterised, with each event type shown in a different colour (for example, baths are coloured green in Figure B2.10).

The three sources of data described above are shown in Table B2.5 to Table B2.7.

Table B2.5: Micro-component summary data from 2015/16 metered billed households

2015/16 Metered billed households					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.26	7.83	56.83	23.92
Shower	0.92	62.36	0.86	49.54	20.85
Bath	0.43	104.60	0.24	10.61	4.47
Tap	1.00	5.66	11.61	65.72	27.66
Dish Washer	0.42	16.70	0.50	3.53	1.48
Washing Machine	0.95	54.19	0.55	28.44	11.97
Water Softener	0.02	52.06	0.97	0.98	0.41
External use	0.18	285.18	0.07	3.34	1.40
Plumbing Losses	0.22	37.20	1.55	12.86	5.41
Miscellaneous	0.95	1.63	3.74	5.78	2.43

Table B2.6: Micro-component summary for 2015/16 RV billed households

2016/16 RV billed households					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.58	8.86	67.15	22.53
Shower	0.94	54.82	0.94	48.69	16.34
Bath	0.54	113.65	0.36	22.35	7.50
Tap	1.00	4.56	17.91	81.62	27.39
Dish Washer	0.37	19.68	0.28	2.02	0.68
Washing Machine	0.94	56.36	0.66	34.59	11.60
Water Softener	0.09	112.02	0.24	2.41	0.81
External use	0.51	183.03	0.19	17.58	5.90
Plumbing Losses	0.30	75.84	0.65	14.76	4.95
Miscellaneous	0.93	1.56	4.75	6.85	2.30

Table B2.7: Micro-component summary for 2002/04 RV billed households

2002-2004 (from WRc CP187)					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	9.40	11.52	108.29	29.19
Shower	0.85	25.70	1.46	31.97	8.62
Bath	0.88	73.30	0.95	61.35	16.54
Tap	1.00	2.30	37.90	87.17	23.50
Dish Washer	0.37	21.30	0.71	5.60	1.51
Washing Machine	0.94	61.00	0.81	46.30	12.48
Water Softener	0.02	182.50	0.39	1.14	0.31
External use	0.65	46.70	0.89	27.10	7.30
Plumbing Losses					0.00
Miscellaneous	0.19	20.40	0.53	2.08	0.56

Market transformation data

Defra's Market Transformation Programme produced product summaries for various water using appliances in 2011[4]. These provide predictions of water use for appliances and devices in 2030 for three scenarios:

- Reference scenario (equivalent to baseline forecast)
- Policy scenario (assuming more effective implementation and accelerated take-up of more sustainable products)
- EBP or early best practice (which assumes a more positive impact than the policy scenario and an early take up of innovative water efficient products).

B2.4.3 Household consumption forecasts

Approach to micro-component forecasting

Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g. showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). For example, per-capita (PCC) or per household consumption (PHC) can be modelled as:

PCC or PHC = $\sum_i(O_i \times V_i \times F_i) + pcr$

Where

'O' is the proportion of household occupants or households using the appliance or activity for micro-component 'i',

'V' is the volume per use for 'i',

'F' is the frequency per use by household occupants or households for 'i',

pcr is per capita residual demand.

By applying this together with the population or property data, a water demand model can be formed. By forecasting changes in each of the variables (O, V, F or daily water use for each micro-component) over time, a water demand forecast can be created. Hence the micro-component forecast model requires estimates of changes in these variables, to reflect future changes in technology, policy, regulation, and behaviour.

This report describes how the inputs have been generated for:

- Base year micro-components from a micro-component occupancy model.
- Final planning year micro-components from an occupancy model. This allows a rate of change of micro-component daily water use to be derived due to the change in occupancy over the planning period.
- Technology, policy and behaviour trend values for micro-components (based on historic analysis of trends and future predictions from the Market Transformation Programme).

[4] http://efficient-products.ghkint.eu/cms/product-strategies/subsector/domestic-water-using-products.html#viewlist

Basic inputs required
To build the micro-component forecast model, we need the following inputs:
- Base year household consumption broken down into micro-components.
- Reported base year household consumption (from water company annual return data).
- Rates of change in micro-components across the planning period.

Selection of the basic unit of consumption
Two commonly used methods of consumption forecasts are based on Per Capita Consumption (PCC) and Per Household Consumption (PHC). Linear modelling can use either approach.

In the case of PHC modelling, occupancy needs to be included as an explanatory variable, and PHC is composed of a consumption allotted to the house on the basis of its characteristics, and an additional consumption assigned to each occupant.

PCC modelling assigns a different consumption value per person on the basis of the characteristics of the property they inhabit.

In the former case, the model is property driven, which aligns with the data collection based on household meter reads.

The latter case introduces all the error associated with the household occupancy figure into the model at the very first step. If the model is based on PCC, the PCC is calculated from estimated occupancy (for which there is an error), so there is no part of the consumption modelling that is independent of occupancy error; all the error in population forecasting is propagated through the zonal forecast if it is based on PCC.
Modelling by PHC makes occupancy-driven household consumption components implicit in the model whereas PCC-driven modelling would need to incorporate a correction for changing occupancy rates in PCC forecasting. For these reasons PHC is used as the basis for aggregating up to a zonal consumption forecast.

The Environment Agency require that the micro-components are reported in the WRMP tables in units of occupancy, i.e. per capita consumption; and the model converts the PHC micro-component values at the zonal level to PCC by dividing through by occupancy.

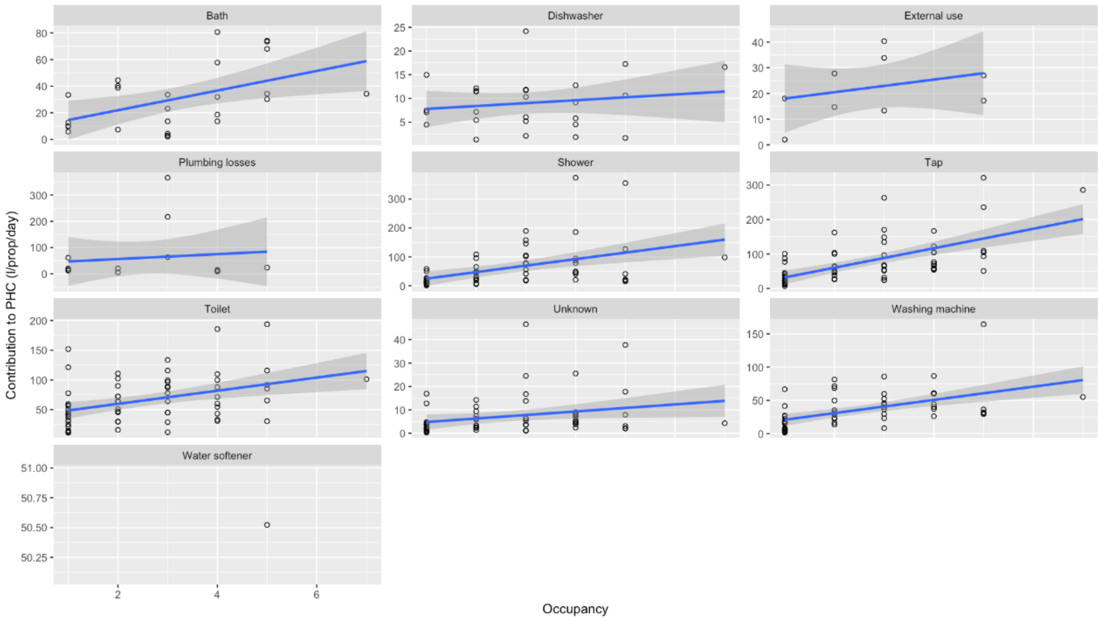
Micro-component occupancy model
Whilst we carry out the forecast model at household level, there is an influence on a selection of the micro-components from occupancy. Therefore, in calculating the base year and final year PHC values, we use a set of linear models that relate either daily use or frequency of use to occupancy in each year. The model is also used to provide the base and final year values for different metered property types: existing metered, optant metered, new property metered and selective metered.

The UKWIR 2015/16 micro-component data for measured billed households was used for the modelling because this dataset had a complete set of occupancy data for each household over the logging period. The total number of households in the sample was 62.

Figure B2.11 shows the daily use (or contribution to per household consumption) for each of the following micro-components:
- WC flushing,
- Shower use,
- Bath use,
- Tap use,

- Dish washer use,
- Washing machine use,
- Water softener use,
- External use, and
- Miscellaneous use (including internal plumbing losses).

Figure B2.11: Each micro-component daily use plotted against occupancy



Each of the micro-components were investigated to determine whether the daily volume per use, frequency of use or ownership varied significantly with occupancy. The following micro-components showed relationships where occupancy was a significant factor:

- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Washing machine use.

For each of these micro-components (WC, Shower, Bath, WM and Taps) we developed a linear model using occupancy as the predictive factor.

Figure B2.12 shows the variation of WC flushing frequency per day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use against occupancy with the following equation:

Frequency of use (uses/day) = 6.143 + 3.744 * ln(occupancy) *Equation 1*

Figure B2.12 Variation of WC flushing frequency (uses per day) with occupancy

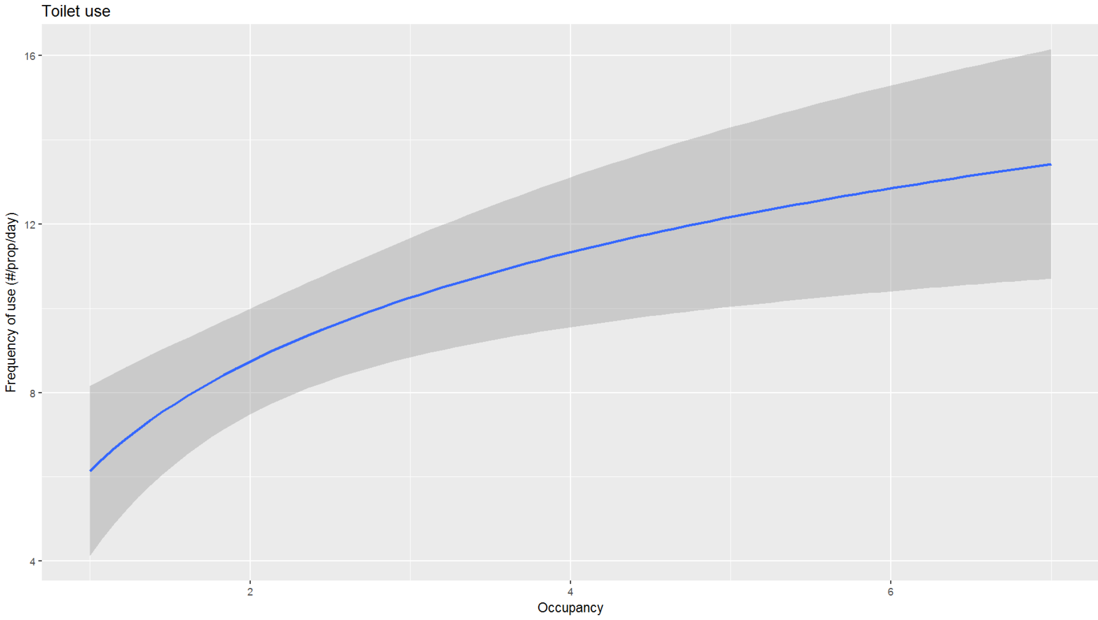


Figure B2.13 shows the variation of the water used for showering each day with occupancy, with the mean water use per day plotted against occupancy. Shower use was also explored in terms of frequency of use per day, but a more robust model could be built with volume used per day. This is probably because with increased occupancy there is increased variation in length of showering. The model is a log relationship of volume used per day against occupancy with the following equation:

Shower volume used per day = 15. 47 + 57.47 * ln(occupancy) *Equation 2*

Figure B2.13: Variation of shower volume used per day with occupancy

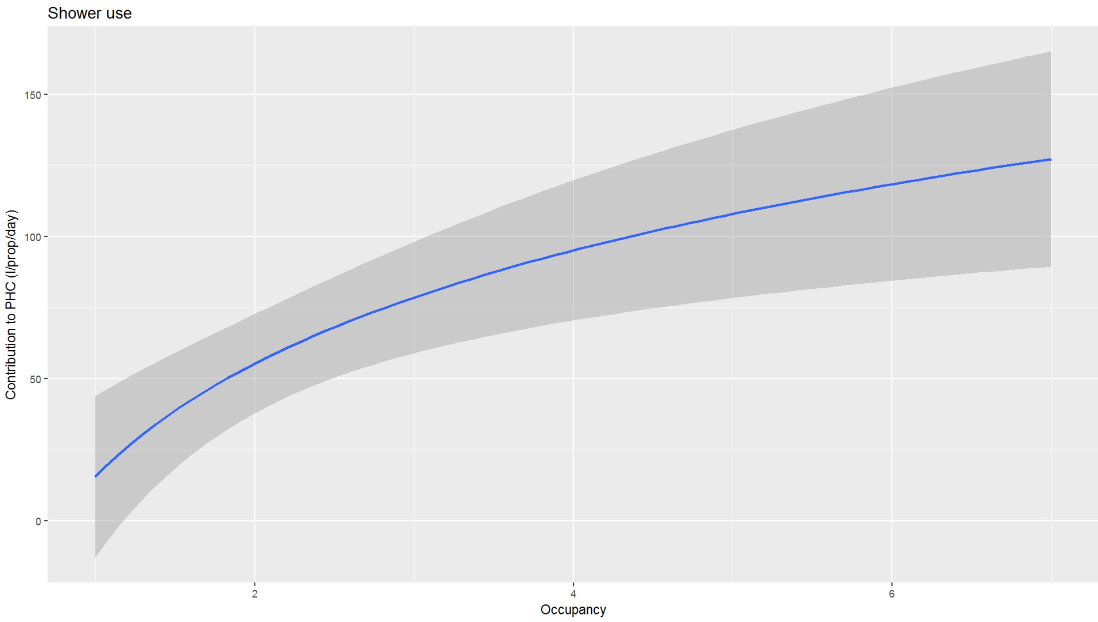


Figure B2.14 shows the variation of the water used for bath use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a log relationship of volume used per day against occupancy with the following equation:

Bath volume used per day = 7.181 + 7.378 * ln(occupancy) *Equation 3*

Figure B2.14: Variation of bath volume used per day with occupancy

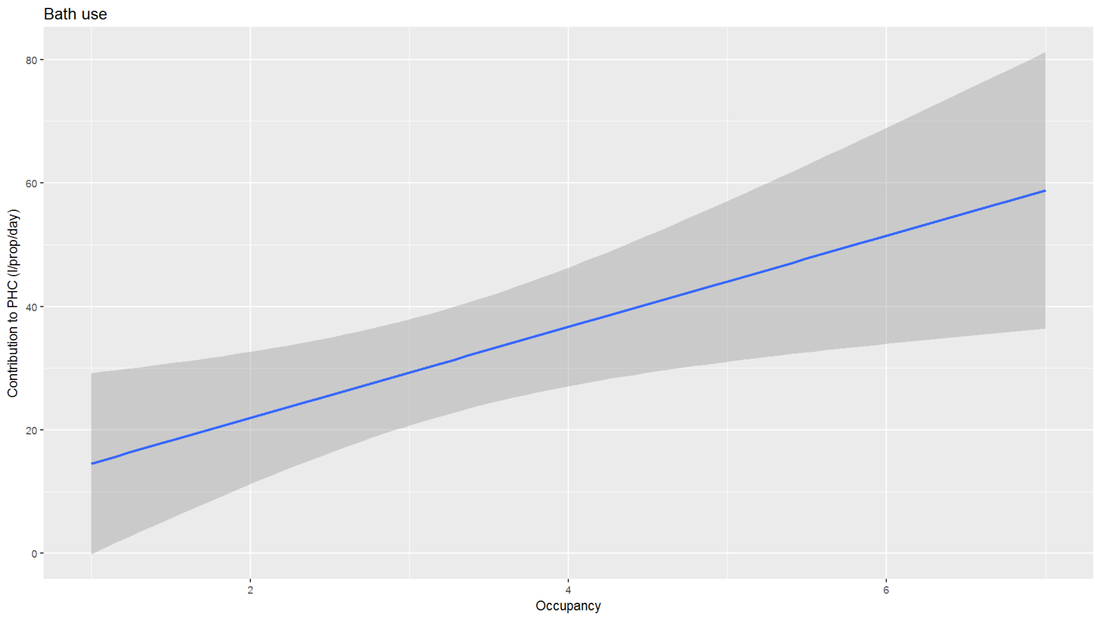


Figure B2.15 shows the variation of the water used for tap use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a log relationship of volume used per day against occupancy with the following equation:

Tap volume used per day = 27.92 + 62.89 * ln(occupancy) *Equation 4*

Figure B2.15: Variation of tap volume used per day with occupancy

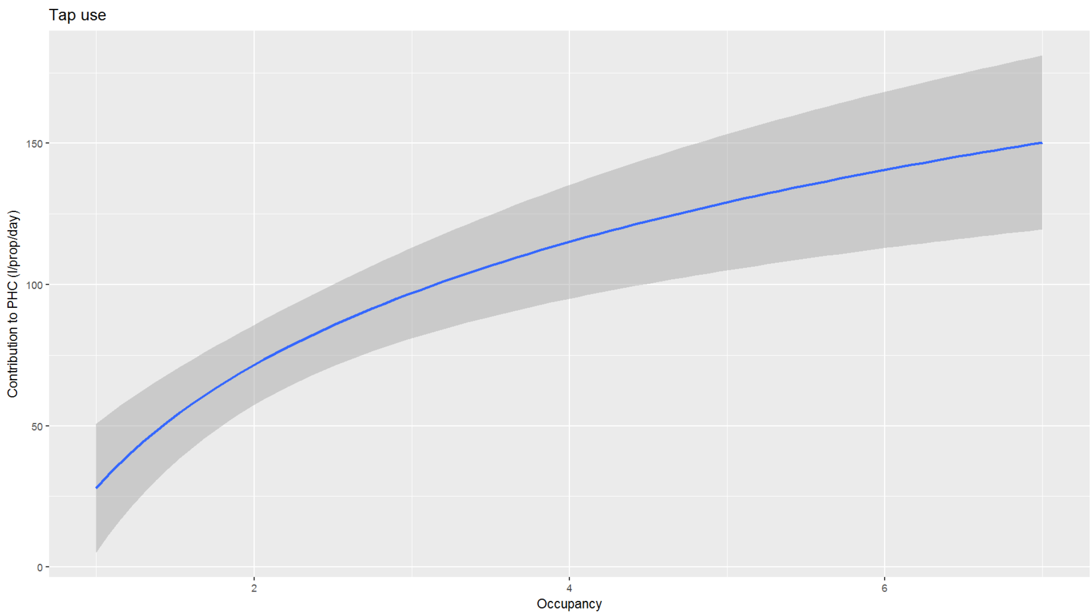
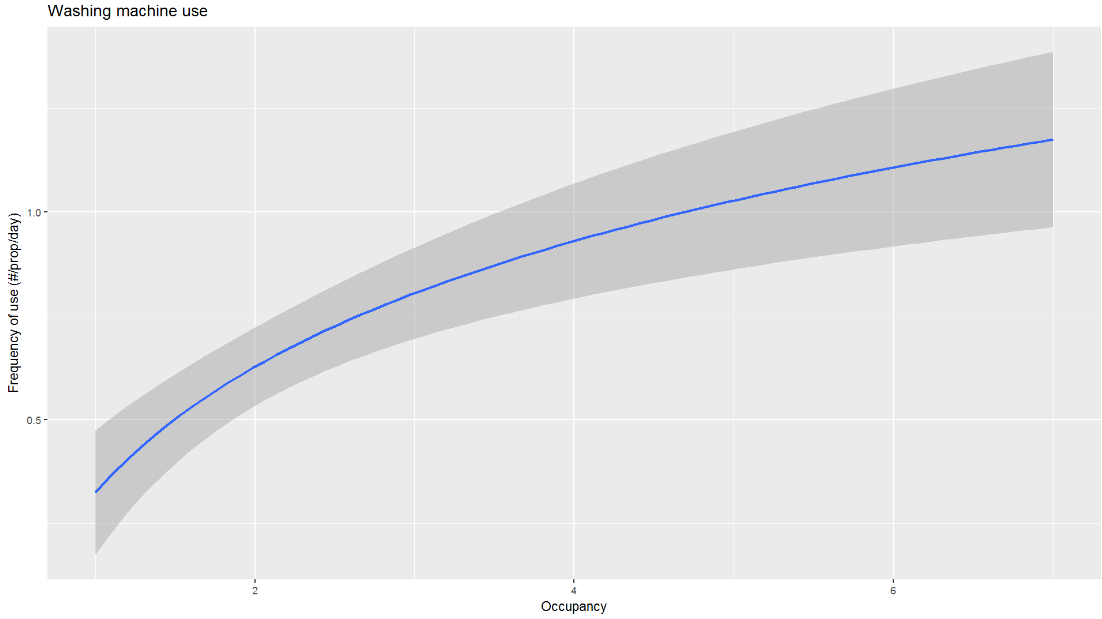


Figure B2.16shows the variation of the water used for washing machine use each day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use per day against occupancy with the following equation:

Frequency of use (uses/day) = 0.3242+ 0.43705 * ln(occupancy) *Equation 5*

Figure B2.16: Variation of washing machine frequency of use with occupancy



For each property type the model variables shown in Table B2.8 are also changed depending on the meter status of the property.

Table B2.8 Micro-component variables that change with meter status

Property type	WC flush volume (mean l/flush)	Washing machine volume/use (mean l/use)	Dish washer volume/use (mean l/use)	Wastage / plumbing losses (frequency of occurrence)
RV billed household (HH)	7.58	54.19	16.7	1.5*1.55
Existing measured HH	7.29	54.19	16.7	1.55
Optant measured HH	6.0	54.19	16.7	0.5*1.55
New build measured HH	5.5	50.0	15.0	0.5*1.55
Selective metered HH	7.58	54.19	16.7	0.5*1.55

Combining all the relationships and variables, the micro-component occupancy model is defined in Table B2.9.

Table B2.9 Micro-component occupancy model parameters

Micro-component	Weighted Ownership 'O'	Volume per use 'V' (l/use)	Frequency of use 'F' (uses/day)	Daily use (l/prop/day)
WC flushing	1	See Table B2.8	See Equation 1	O*V*F
Shower use				See Equation 2
Bath use				See Equation 3
Tap use				See Equation 4
Dish washer	0.42	See Table B2.8	0.5	O*V*F
Washing machine	0.95	See Table B2.8	See Equation 5	O*V*F
Water softener	0.02	52.06	0.97	O*V*F
External use	0.18	285.18	0.07	O*V*F
Plumbing losses	0.22	37.2	See Table B2.8	O*V*F
Miscellaneous	0.95	1.63	3.74	O*V*F

The model can then be used to calculate the micro-component daily use (and hence the per household consumption 'PHC') for the following property types based on the occupancy of assigned to each property type, in the base year and in the final year of the forecast:

- RV billed households
- Existing metered billed households
- Optant metered billed households
- New build metered households
- Selective (or compulsory) metered billed households.

Application of the occupancy model in the base year and final year are shown in Table B2.10 and Table B2.11. It should be noted that the relationships described in this section are for occupied households and therefore this analysis assumes a non-zero occupancy rate. This is not likely to be an issue, given that these equations are intended to be applied at a zonal level, where average occupancy will always be greater than zero.

Table B2.10 Micro-component occupancy model parameters – Base year (adjusted to NYAA)

Household types	WRZ	Occupancy	PHC (modelled)	PCC (modelled)	BY calibrated PHC	BY calibrated PCC
RV billed	Bishops Castle	2.22	299.67	135.05	289.82	130.61
HH	Forest & Stroud	2.49	321.25	129.12	328.13	131.89
	Kinsall	2.38	312.99	131.42	319.39	134.11
	Mardy	2.56	326.45	127.67	346.25	135.41
	Newark	2.37	311.68	131.78	314.45	132.95
	North Staffs	2.49	321.14	129.15	344.72	138.64
	Nottingham	2.46	319.41	129.64	327.59	132.95
	Rutland	2.52	323.39	128.53	326.93	129.93
	Ruyton	2.52	323.97	128.37	323.58	128.21
	Shelton (old STW	2.50	322.35	128.82	335.18	133.95
	WRZ)	2.55	325.60	127.91	298.29	117.18
	Stafford	2.55	325.68	127.89	341.79	134.21
	Strategic grid	2.47	320.21	129.42	331.33	133.91
	Whitchurch & Wem	2.61	330.33	126.58	345.63	132.44
	Wolverhampton					

Household types	WRZ	Occupancy	PHC (modelled)	PCC (modelled)	BY calibrated PHC	BY calibrated PCC
Existing	Bishops Castle	2.21	289.30	131.08	277.38	125.68
metered	Forest & Stroud	2.24	292.03	130.40	252.94	112.94
billed HH	Kinsall	2.33	299.76	128.43	257.18	110.18
	Mardy	2.31	297.99	128.88	276.94	119.78
	Newark	2.10	280.16	133.34	241.82	115.09
	North Staffs	2.20	288.98	131.16	232.29	105.44
	Nottingham	2.16	285.26	132.09	242.58	112.32
	Rutland	2.31	298.08	128.86	321.52	139.00
	Ruyton	2.77	331.95	119.94	315.62	114.03
	Shelton (old STW	2.24	292.37	130.31	245.56	109.45
	WRZ)	2.27	294.56	129.76	244.09	107.52
	Stafford	2.23	291.51	130.53	250.39	112.11
	Strategic grid	2.22	290.06	130.89	255.71	115.40
	Whitchurch & Wem	2.14	283.72	132.47	236.72	110.52
	Wolverhampton					
New build	Bishops Castle	2.21	263.85	119.55	252.98	114.62
metered	Forest & Stroud	2.40	278.66	116.22	241.36	100.66
HH	Kinsall	2.35	275.24	117.01	236.14	100.38
	Mardy	2.44	281.60	115.54	261.70	107.37
	Newark	2.23	266.06	119.06	229.65	102.77
	North Staffs	2.36	275.78	116.88	221.69	93.95
	Nottingham	2.34	274.23	117.24	233.20	99.70
	Rutland	2.40	279.04	116.13	300.99	125.27
	Ruyton	2.64	296.21	112.09	281.64	106.57
	Shelton (old STW	2.38	277.52	116.48	233.09	97.83
	WRZ)	2.39	277.74	116.43	230.15	96.48
	Stafford	2.21	264.09	119.50	240.16	108.67
	Strategic grid	2.33	273.89	117.31	241.46	103.42
	Whitchurch & Wem	2.42	280.46	115.81	234.00	96.62
	Wolverhampton					
Optant	Bishops Castle	1.47	198.79	135.23	190.60	129.66
metered	Forest & Stroud	1.47	198.79	135.23	172.18	117.13
HH	Kinsall	1.47	198.79	135.23	170.55	116.02
	Mardy	1.47	198.79	135.23	184.74	125.67
	Newark	1.47	198.79	135.23	171.59	116.73
	North Staffs	1.47	198.79	135.23	159.79	108.70
	Nottingham	1.47	198.79	135.23	169.04	115.00
	Rutland	1.47	198.79	135.23	214.42	145.87
	Ruyton	1.47	198.79	135.23	189.01	128.58
	Shelton (old STW	1.47	198.79	135.23	166.96	113.58
	WRZ)	1.47	198.79	135.23	164.72	112.06
	Stafford	1.47	198.79	135.23	170.74	116.15
	Strategic grid	1.47	198.79	135.23	175.25	119.22
	Whitchurch & Wem	1.47	198.79	135.23	165.86	112.83
	Wolverhampton					

Table B2.11 shows the modelled PHC and PCC figures based on the final year occupancies. These figures are without the forecast trends applied so is to demonstrate the impact of the changing occupancy over time of each of the household segments. RV billed occupancy increases with a resulting increase in PHC and decrease in PCC. The measured properties have a decreasing occupancy over the forecast period with a resulting reduction in PHC and small increase in PCC.

Table B2.11 Micro-component occupancy model parameters – Final year (free optant scenario)

Household types	WRZ	Occupancy	PHC (OVF modelled)	PCC (OVF modelled)
RV billed HH	Bishops Castle	2.11	297.81	135.55
	Forest & Stroud	2.81	326.99	127.52
	Kinsall	2.44	314.36	131.04
	Mardy	2.64	327.90	127.56
	Newark	2.66	318.40	129.92
	North Staffs	2.74	325.53	127.93
	Nottingham	2.75	322.66	128.73
	Rutland	2.66	325.38	127.97
	Ruyton	2.57	325.27	128.00
	Shelton (old STW WRZ)	2.68	323.21	128.58
	Stafford	2.74	326.68	127.61
	Strategic Grid	2.93	336.19	124.93
	Whitchurch & Wem	2.52	320.43	129.35
	Wolverhampton	3.10	336.13	124.95
Existing metered billed HH	Bishops Castle	1.36	201.24	147.53
	Forest & Stroud	1.85	256.79	138.70
	Kinsall	1.75	246.96	140.74
	Mardy	1.69	240.24	142.03
	Newark	1.86	257.57	138.53
	North Staffs	1.85	256.35	138.80
	Nottingham	1.82	253.62	139.38
	Rutland	1.79	250.43	140.04
	Ruyton	2.02	273.29	134.98
	Shelton (old STW WRZ)	1.79	250.63	140.00
	Stafford	1.86	257.48	138.48
	Strategic grid	1.98	268.76	136.04
	Whitchurch & Wem	1.64	234.61	143.05
	Wolverhampton	2.00	270.77	135.57
New build metered HH	Bishops Castle	1.99	245.53	123.36
	Forest & Stroud	2.30	271.19	117.92
	Kinsall	2.18	261.68	120.02
	Mardy	2.24	266.74	118.92
	Newark	2.17	260.56	120.26
	North Staffs	2.24	266.75	118.91
	Nottingham	2.23	265.89	119.10
	Rutland	2.24	266.33	119.01
	Ruyton	2.42	280.38	115.82
	Shelton (old STW WRZ)	2.24	266.17	119.04
	Stafford	2.24	266.56	118.96
	Strategic grid	2.32	272.88	117.54

Household types	WRZ	Occupancy	PHC (OVF modelled)	PCC (OVF modelled)
	Whitchurch & Wem	2.15	258.93	120.61
	Wolverhampton	2.35	275.03	117.05
Optant metered HH	Bishops Castle	1.46	197.13	135.37
	Forest & Stroud	1.57	210.26	134.04
	Kinsall	1.50	202.76	134.86
	Mardy	1.51	203.44	134.79
	Newark	1.57	210.40	134.02
	North Staffs	1.55	208.07	134.29
	Nottingham	1.55	208.42	134.25
	Rutland	1.52	205.16	134.61
	Ruyton	1.51	203.04	134.83
	Shelton (old STW WRZ)	1.52	205.09	134.62
	Stafford	1.52	205.24	134.60
	Strategic grid	1.57	210.73	133.98
	Whitchurch & Wem	1.50	202.37	134.90
	Wolverhampton	1.59	212.11	133.81

Using the base year and final year PHC values, a rate of change in PHC due to occupancy change can be calculated for each household metered status. This is in addition to the technology and behaviour trends described in the following section.

Micro-component trend model- baseline scenario

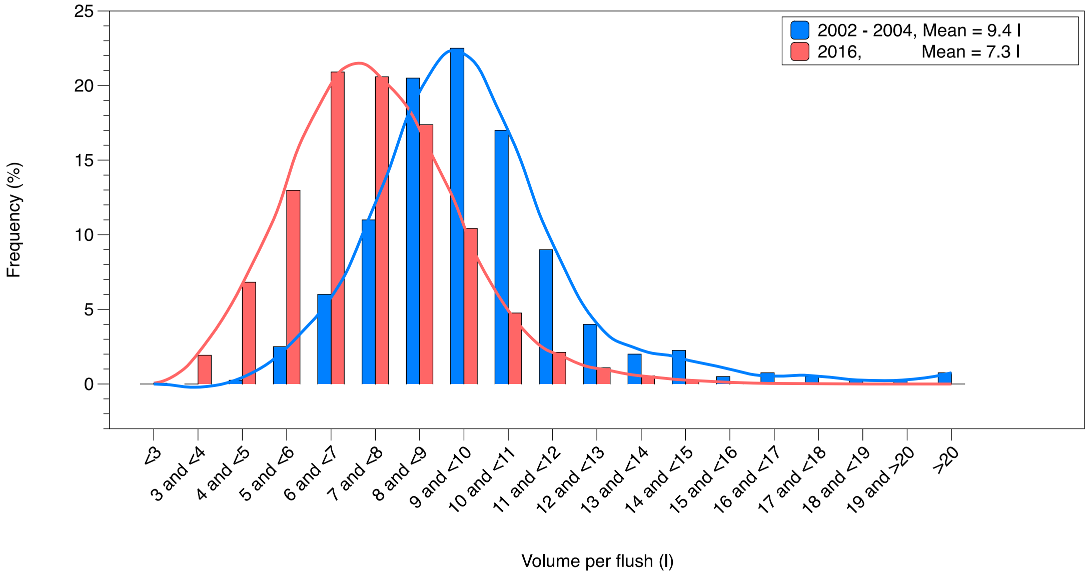
To investigate trends in individual micro-components due to technology change, policies and regulation, and behaviour change, we have used the data set from 2002/04 (Table 2.7) and the 2015/16 datasets (B2.5 and Table B2.6). For future projections of trends we have generally used the forecast water use values from Defra's Market Transformation Programme.

WC Flushing

For the trend we assume that ownership and frequency of use for WC flushing remains constant, with the volume per use changing due to market transformation.

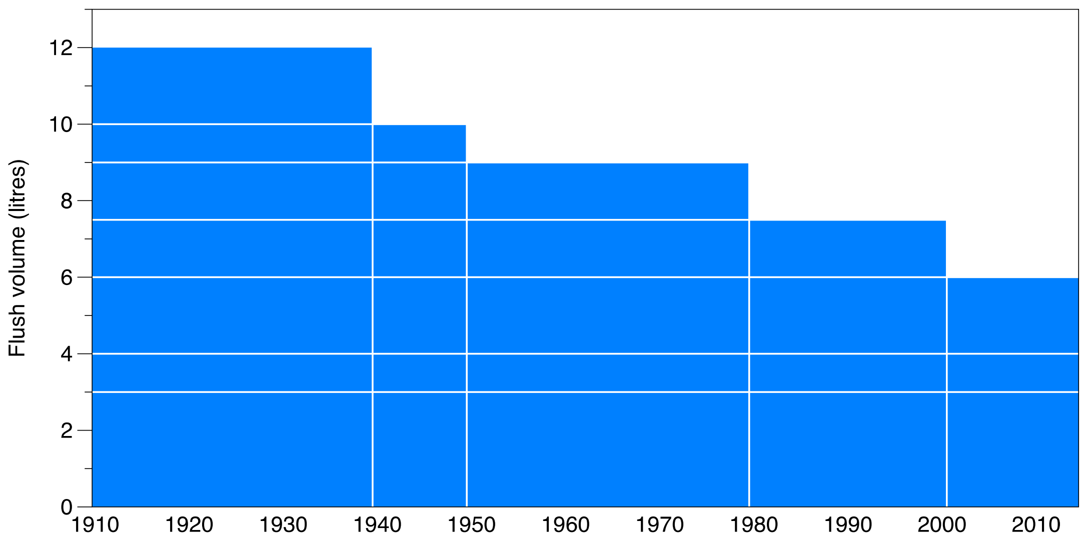
Using data from the WRc micro-component report CP187 and data from the UKWIR 2016 study, we can create a histogram of the volumes per flush from 2002/04 and 2015/16. These are shown in Figure B2.17. This shows that for 2002/04 the mean flush volume was 9.4 l/flush, with a range of flush volumes from 5 litres to > 15 litres. In 2015/16 the mean flush volume had reduced to around 7.3 litres with a range from 3 litres to about 13 litres per flush.

Figure B2.17: Histogram of WC flush volumes from 2002/04 and 2015/16



The reason for the reduction in flush volumes from 2002/04 to 2015/16 is due to the replacement of larger volume WC cisterns with smaller volume cisterns, due to market transformation based on regulatory policies. The schematic in Figure B2.18 shows the change in maximum flush volumes over time due to changes in regulation. From 12 litres in 1910 to 6 litre single flush or 6/4 or 6/3 litre dual flush in 2000 to date. The reason why we see larger flush volumes in the histogram is due to incorrect setting up of the fill height or over filling during the flush period.

Figure B2.18 Regulatory changes in flush volumes

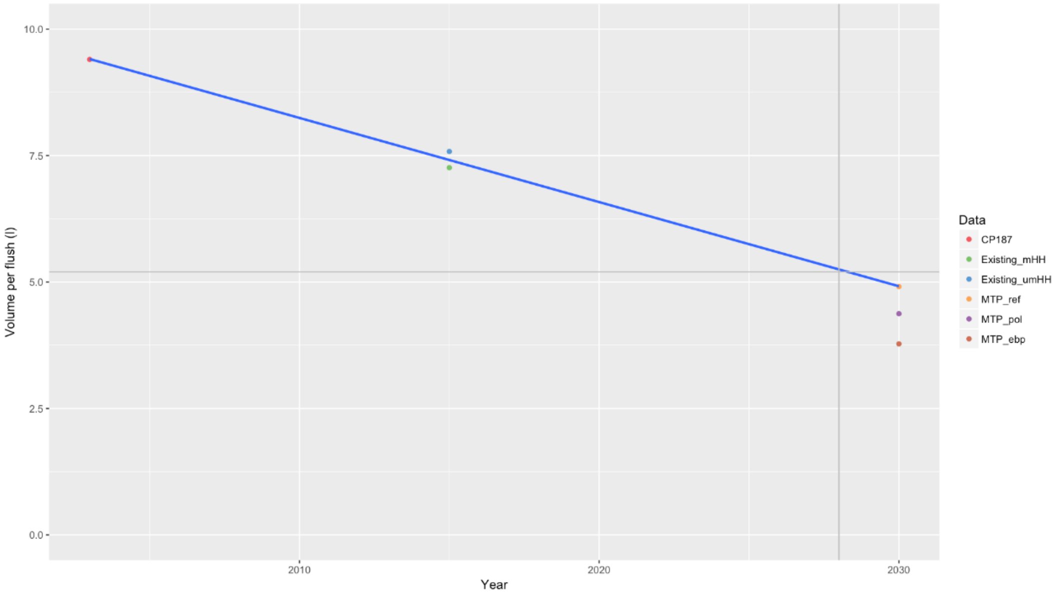


The latest MTP projections for WC flushing volumes[5] in 2030 for the reference scenario is 4.8 litres/flush. Figure B2.19 shows the mean 2002/04 (CP187), the 2015/16 flush volumes (Existing_mHH and Existing_umHH), and the flush volume from the MTP scenarios in 2030. The blue line shows the linear fit from the 2002/04, 2015/16 and MTP Reference scenarios.

[5] Source: http://efficient-products.ghkint.eu/spm/download/document/id/954.pdf

If we assume that the market transformation continues at the current rate (a reasonable assumption for baseline forecasts, as there are no planned regulatory changes in WC flush volumes), then the flush volume in 2028 will be approximately 5.1 litres (shown by the intersect of the lines in Figure B2.20). This provides some confidence in the MTP Reference scenario for WC flush volumes.

Figure B2.19: Historic, current and future flush volumes

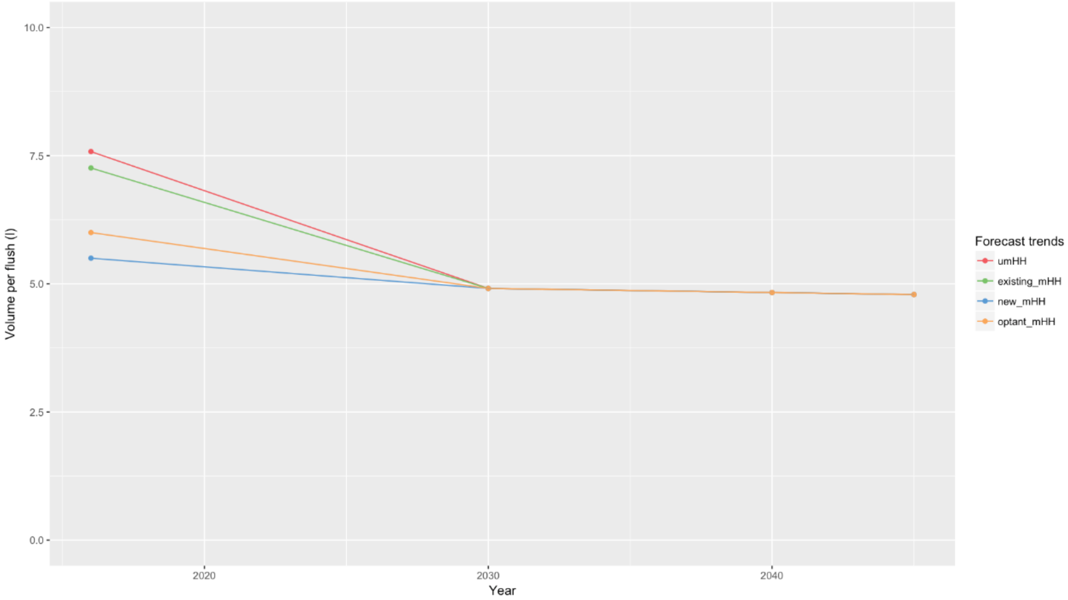


We have created future trends for WC volume per flush (see Figure B2.20) using:

- the base year volumes per flush in Table B2.8 for different property types,
- the 2030 projection for WC flush volume from the MTP reference scenario,
- an assumption that all property types will have achieved the MTP Reference scenario between the forecast base year and 2030 (for the baseline forecast assuming no change to current WC flush regulations)[6],
- and an assumption that the volume per use will then remain relatively constant until 2045.

[6] This is a reasonable assumption given the rate of change in actual data presented in Figure 2B.18 and discussed elsewhere in this section.

Figure B2.20: Trends for WC flush volumes



From these trends, annual rates of change have been produced for each of the property types. The rates of change are then incorporated into the model.

Showering

To investigate showering trends, we have used the overall daily water use (per household) from shower data. This is because shower use is a complex mix of behaviour (showering time), technology (shower flows), as well as frequency of use and occupancy.

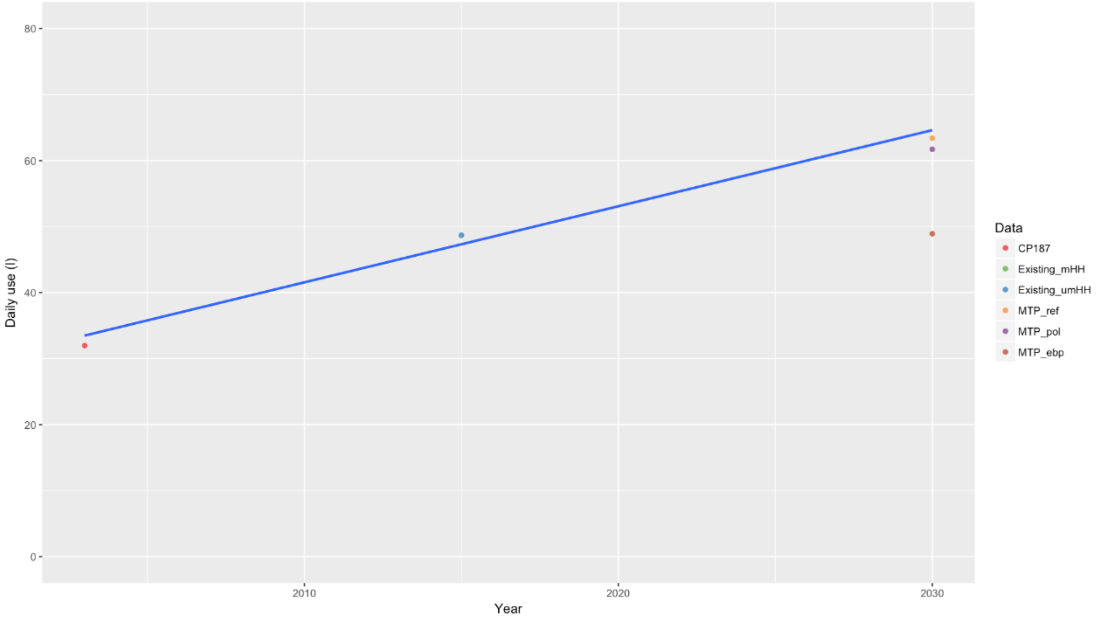
Figure 2.21 shows the following data points on daily shower volumes (l/day):

- 2003 from WRc CP187 report,
- 2016 from Table B2.5 (Existing_mHH) and Table B2.6 (Existing_umHH), both are approximately 49 l/day,
- 2030 from the MTP reference, policy and early best practice scenarios.

These data points assume an average occupancy for households in their specific years. The blue line shows a linear fit from the 2003, 2015/16 and MTP reference scenario. This shows a rising trend, which is consistent with the observations that shower use is increasing (in terms of ownership, frequency and flow rate).

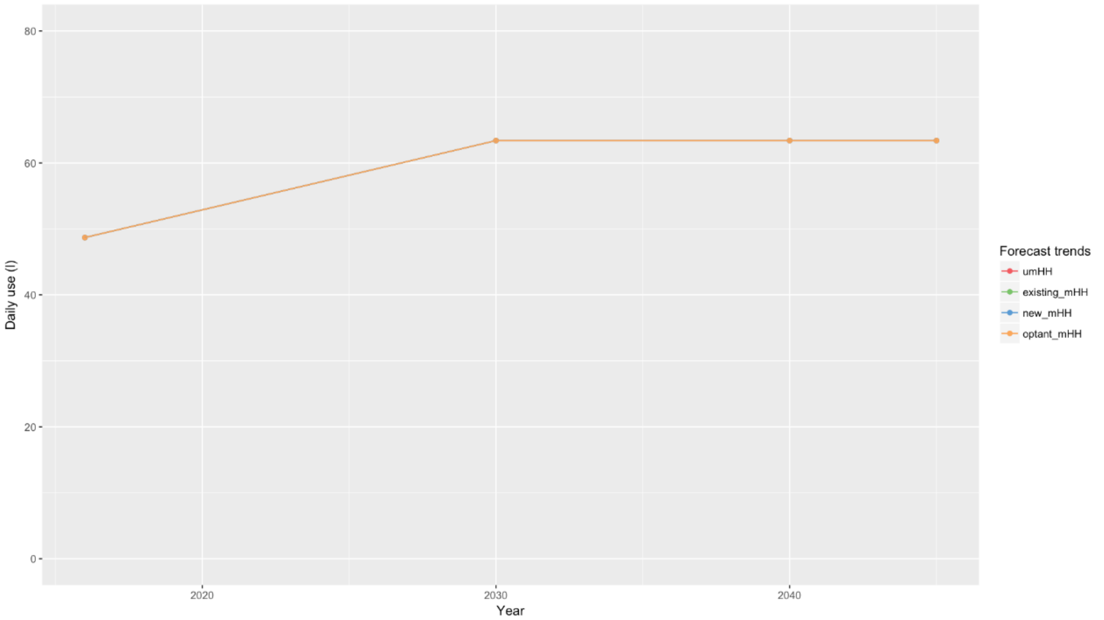
We have chosen not to fit trend line through the MTP Early Best Practice point as this assumes a very high proportion of water efficient showers being installed in new and existing households (which is not evident in current practice). This is used in the development of the lower PCC trend discussed in the alternative scenarios in Section 3.6.

Figure B2.21: Trend of daily volume of water used for showering



Using the trend line from Figure B2.21 and assuming that shower volumes per day plateau at the MTP reference scenario in 2030 and remain flat over the rest of the planning period, we have produced a predicted trend for shower use as shown in Figure B2.22. There is no evidence for different house types having different trends, so the same trend is used for all house types.

Figure B2.22: Future trend for daily volume of water used for showering



From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

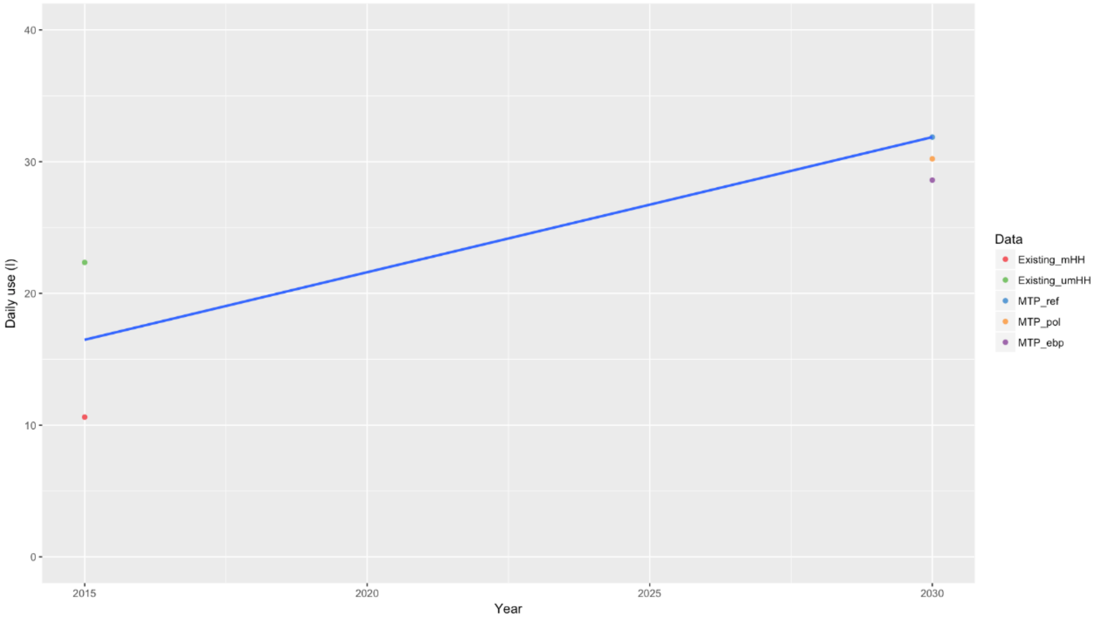
Bath use

For bath use trends, we have used the overall household daily water use from baths. Like showering, bath use is mix of behaviour, frequency of use and volume per use.

Figure B2.23 shows the evidence for daily volume of bath use from the following data points (l/day):

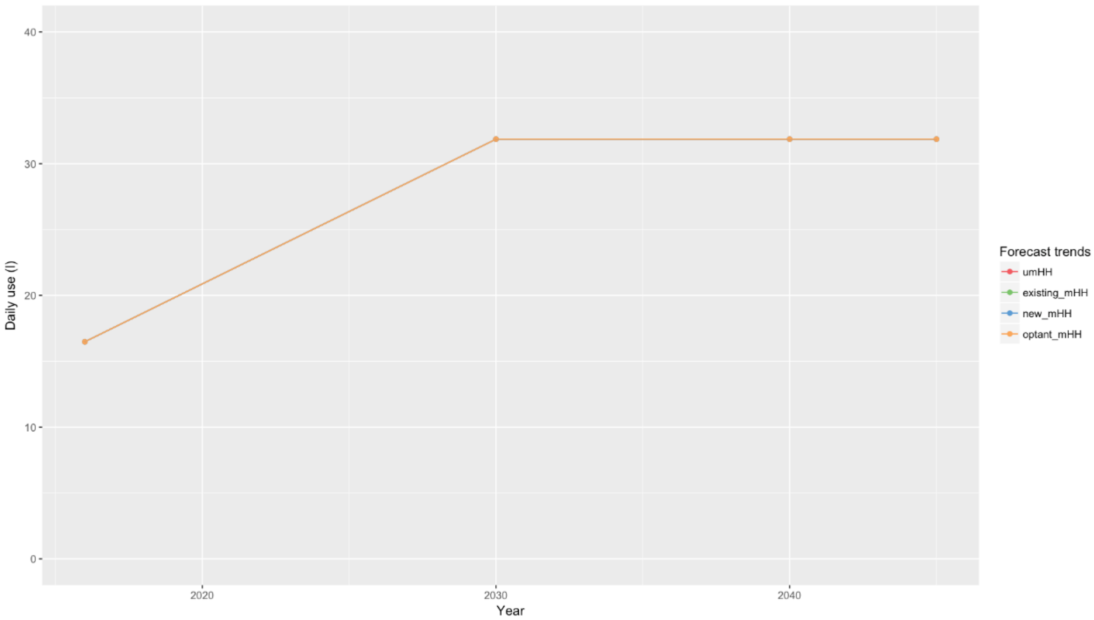
- 2016 from the bath use in Table B2.5 and Table B2.6.
- 2030 from the MTP reference, policy and early best practice scenarios.

Figure B2.23: Trend of daily volume of water used for bath use



The blue line in Figure B2.23 is a linear fit of the 2016 and 203 data. Using this trend, and assuming that bath use then levels off at 2030 to the end of the planning period, we have created the future trend shown in Figure B2.24.We have assumed that all household types show the same trend. From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

Figure B2.24: Predicted trends of daily volume of water used for bath use



Washing machine use

For washing machine use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table B2.6

This data was used to produce a linear trend over time shown in Figure B2.25 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

For the future trend in washing machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 50 l/use in 2016. The resulting future trends are shown in Figure B2.26. Rates of change are then computed from these trends and incorporated in the model.

Figure B2.25: Historic trend in washing machine volume per use

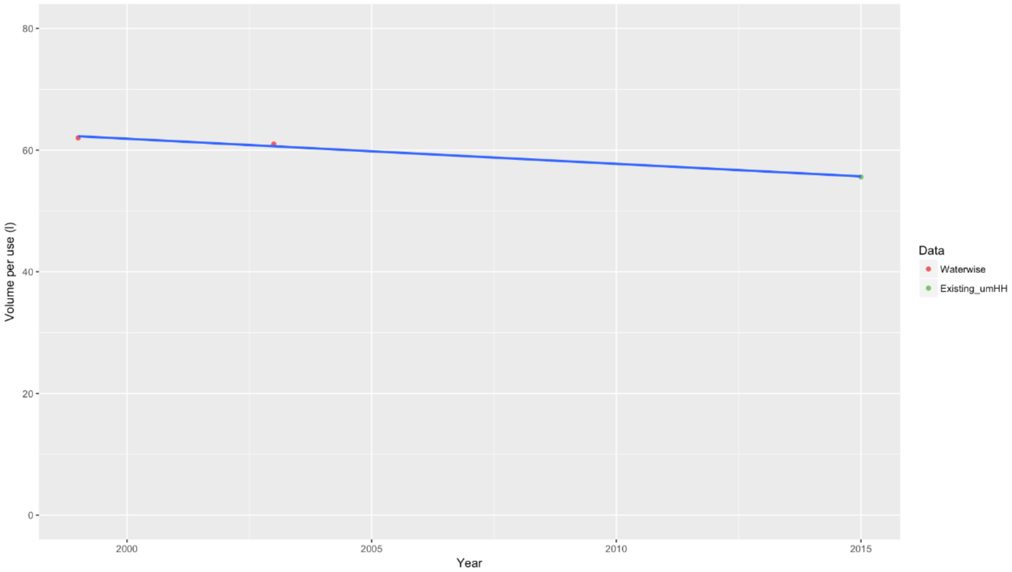
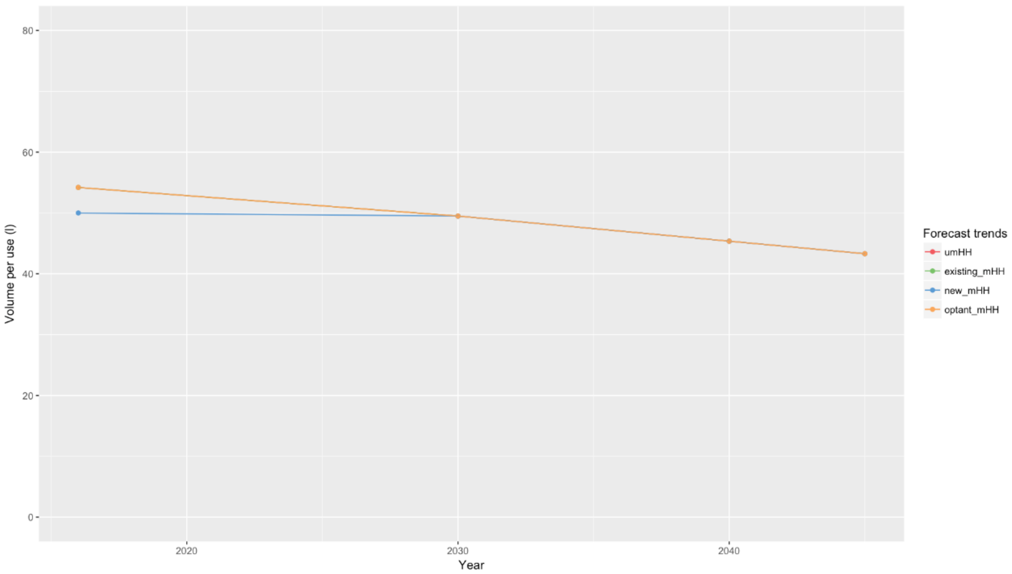


Figure B2.26: Future trend of washing machine volume per use



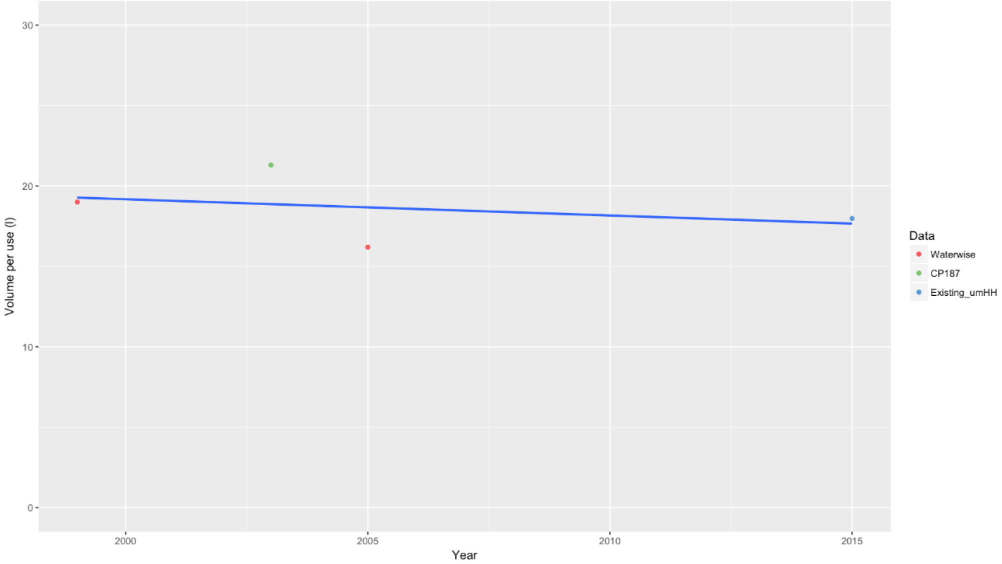
Dish washer use

For dishwasher use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table B2.6

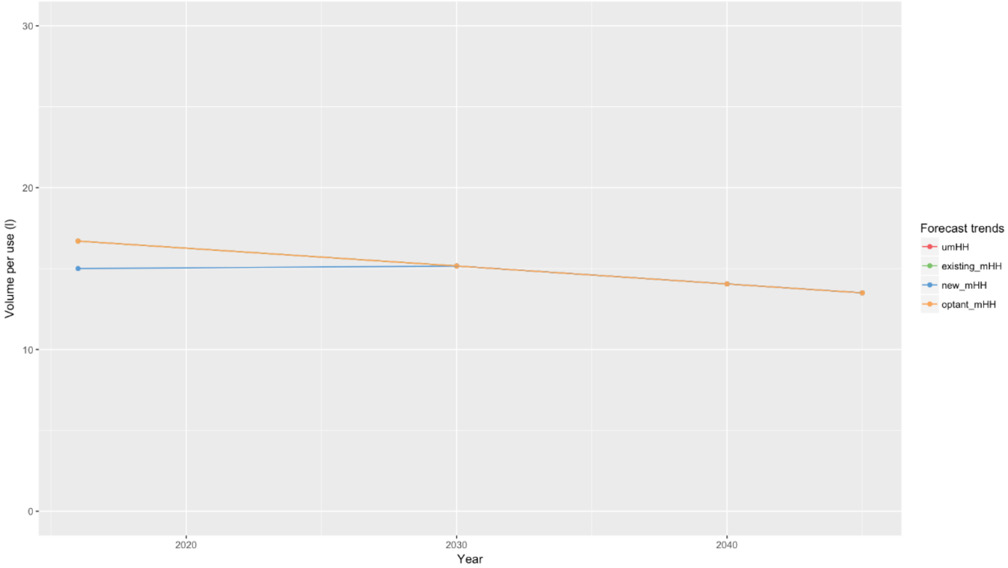
This data was used to produce a linear fit over time shown in Figure B2.27 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

Figure B2.27: Historic trend in dish washer volume per use



For the future trend in dish washer machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 15 l/use in 2016. The resulting future trends are shown in Figure B2.28. Rates of change are then computed from these trends and incorporated in the model.

Figure B2.28: Future trends of dish washer volume per use



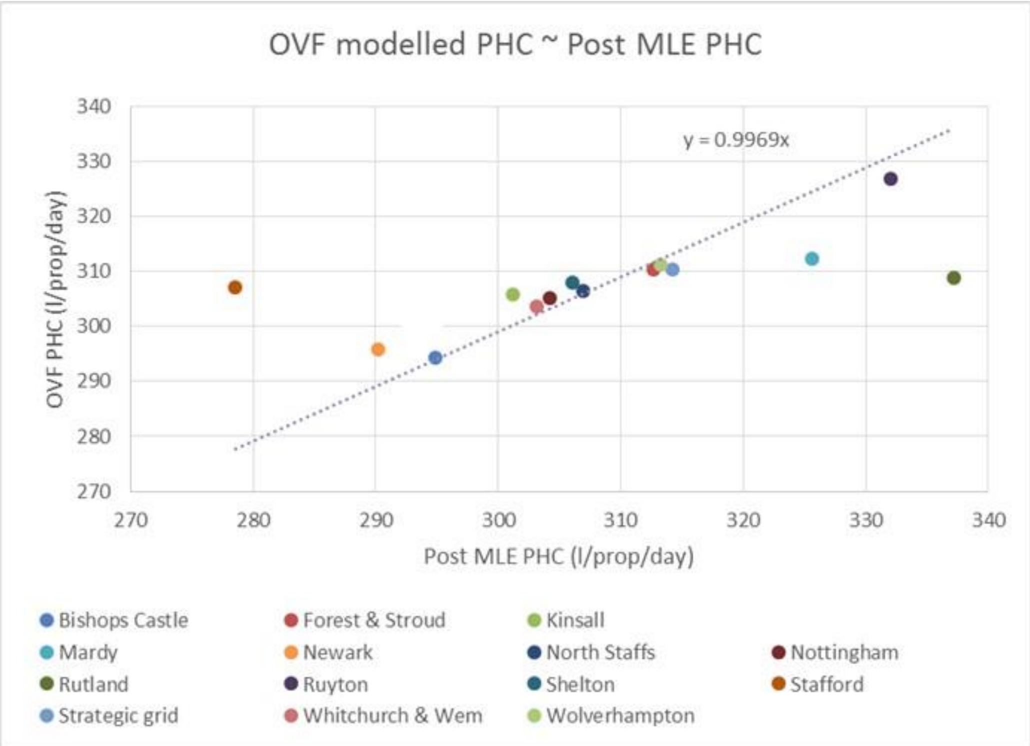
B2.4.5 Base Year Calibration

For each of the household segments, the OVF models are applied using the base year occupancy values. The OVF calculated PHC is then calibrated to the normal year annual average (NYAA) value. Further details of the NYAA calculations are described in section 4, however it is important to note that the normal year factor is applied within the base year (BY) calibration to ensure that the rate of change over time for each component is not affected by annual variation that might by contained within the BY. The zonal reported measured and unmeasured BYAA are factored to NYAA. The zonal PHC values for the non-reported figures; existing measured, new properties measured, optant measured and selective/compulsory measured are calculated proportionally based on the NYAA measured value using the OVF calculated PHC in each segment.

B2.4.6 Spatial validation

In order to validate the OVF PHC procedure, an analysis of the concordance between modelled OVF PHC and reported post-MLE (maximum likelihood estimation) PHC values has been conducted by WRZ. Figure B2.29 plots the OVF modelled PHC against the report post-MLE PHC for all households.

Figure B2.29: OVF modelled PHC versus Post MLE PHC



The chart (Figure B2.29) shows that the modelled OVF PHC values are quite similar to the reported ones and only deviate by a small degree for most zones; with only Rutland and Stafford that appear to diverge more.

This is evident in the following Table B2.12, where red-coloured cells highlight values that depart ±10% from the reported ones.

Table B2.12: OVF modelled PHC ~ Post MLE PHC Error

WRZ	Post MLE			OVF modelled			Error %		
	mHH	umHH	allHH	mHH	umHH	allHH	mHH	umHH	allHH
Bishops Castle	291.45	297.15	294.86	286.50	299.67	294.38	-1.73%	0.84%	-0.16%
Forest & Stroud	265.38	336.42	312.64	288.78	321.25	310.38	8.10%	-4.72%	-0.73%
Kinsall	270.74	327.46	301.24	297.43	312.99	305.80	8.97%	-4.63%	1.49%
Mardy	291.71	355.00	325.65	295.85	326.45	312.26	1.40%	-8.74%	-4.29%
Newark	255.08	322.39	290.23	278.53	311.68	295.84	8.42%	-3.44%	1.90%
North Staffs	244.64	353.43	306.90	286.85	321.14	306.48	14.71%	-10.05%	-0.14%
Nottingham	255.25	335.86	304.20	282.90	319.41	305.08	9.78%	-5.15%	0.29%
Rutland	338.97	335.19	337.21	296.19	323.39	308.87	-14.44%	-3.65%	-9.17%
Ruyton	332.34	331.76	332.07	329.44	323.97	326.88	-0.88%	-2.41%	-1.59%
Shelton (old STW WRZ)	258.55	343.65	306.03	290.14	322.35	308.11	10.89%	-6.61%	0.67%
Stafford	257.64	305.82	278.55	293.05	325.60	307.18	12.08%	6.08%	9.32%
Strategic grid	263.56	350.42	314.25	288.92	325.68	310.37	8.78%	-7.60%	-1.25%
Whitchurch & Wem	269.77	339.70	303.17	288.42	320.21	303.60	6.46%	-6.09%	0.14%
Wolverhampton	249.23	354.36	313.23	281.54	330.33	311.24	11.48%	-7.28%	-0.64%

When considering metered segments (measured and unmeasured) the number of OVF PHC values that deviate ±10% from the reported ones appears somewhat high. However, the number falls to none when measured and unmeasured PHC values are combined at total households' level. Additionally, this means that the OVF procedure underestimates by only 0.68% when considering all households at company level.

Because the forecast is built upon NYAA, we have also run the analysis on normal year adjusted PHC values. This is shown in Table B2.13 and Figure B2.30.

Figure B2.30 OVF modelled PHC versus NYAA PHC

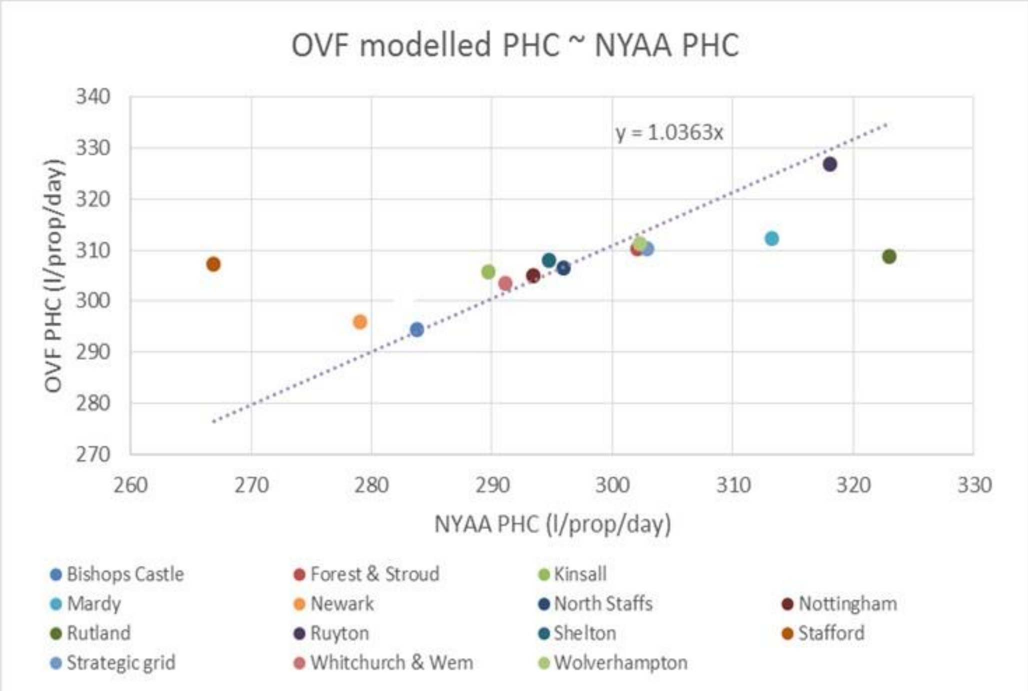


Table B2.13 OVF modelled PHC ~ NYAA PHC Error

WRZ	NY adjusted			OVF modelled			Error %		
	mHH	umHH	allHH	mHH	umHH	allHH	mHH	umHH	allHH
Bishops Castle	274.69	289.82	283.75	286.50	299.67	294.38	4.12%	3.29%	3.61%
Forest & Stroud	250.12	328.13	302.02	288.78	321.25	310.38	13.39%	-2.14%	2.69%
Kinsall	255.18	319.39	289.70	297.43	312.99	305.80	14.21%	-2.05%	5.26%
Mardy	274.94	346.25	313.18	295.85	326.45	312.26	7.07%	-6.06%	-0.29%
Newark	240.42	314.45	279.07	278.53	311.68	295.84	13.68%	-0.89%	5.67%
North Staffs	230.58	344.72	295.90	286.85	321.14	306.48	19.62%	-7.34%	3.45%
Nottingham	240.58	327.59	293.42	282.90	319.41	305.08	14.96%	-2.56%	3.82%
Rutland	319.49	326.93	322.96	296.19	323.39	308.87	-7.87%	-1.09%	-4.56%
Ruyton	313.23	323.58	318.07	329.44	323.97	326.88	4.92%	0.12%	2.69%
Shelton (old STW WRZ)	243.68	335.18	294.74	290.14	322.35	308.11	16.01%	-3.98%	4.34%
Stafford	242.83	298.29	266.90	293.05	325.60	307.18	17.14%	8.39%	13.11%
Strategic grid	248.41	341.79	302.90	288.92	325.68	310.37	14.02%	-4.95%	2.41%
Whitchurch & Wem	254.27	331.33	291.08	288.42	320.21	303.60	11.84%	-3.47%	4.13%
Wolverhampton	234.91	345.63	302.31	281.54	330.33	311.24	16.57%	-4.63%	2.87%

In this case, the error about measured households increase; however, the unmeasured prediction becomes better. Again, at total households' level the error is not high, with only Stafford showing an error greater than 10%.

B2.4.7 Climate Change

Climate change impacts on consumption have been calculated in accordance to UKWIR 13/CL/04/12 Impact of Climate Change on water demand. Median percentage climate change impacts on household demand at 2040, relative to 2012 are published for each river basin within the UK. The Severn and South Humber basins are used for Severn Trent. The annual average forecasts use the average of the factors for these basins, therefore have a 0.905% increase in consumption over that period. As the base year is now 2015/16 and the final forecast year is 2044/45 the percentage change is shifted along as there has been no further evidence since this report. However, as the forecast period with the base year set at 2015/16 is one year longer the final percentage is slightly larger than the figure printed in the guidance. If the forecast were to be run under a critical period scenario the percentage affected by climate increases from 0.91% to 2.38%. When critical period is selected the appropriate climate change factor is applied in a linear fashion across the forecast period.
The additional demand from climate change is added to the external use micro-component only. The volume attributed to climate change is displayed in a separate row in the top section of the outputs. The model includes functionality to output forecasts with and without climate change factors.

B2.4.8 Trends, scenarios and uncertainty

Further work was carried out using a Monte Carlo approach, which has been applied at company (Ml/d) and at property level (PHC) split by measured and unmeasured to give an idea of the statistical variance and error calculations throughout the modelling procedure.
Population and property errors; for the population and properties we apply the UKWIR guideline[7] errors to a normal distribution (which we note is truncated at zero for the unmetered figures). The groups within the overall population and property figures are varied (where the figure is not fixed) and then normalised to sum to an overall population and property figure varied with the UKWIR errors. Note that the precise implementation requires a re-normalisation process at each time-step; as this process is somewhat complex we merely summarise the process here.

Modelling error has been derived from the standard statistical outputs from the micro-component linear modelling. It combines error within the predictor variables, modelling error and errors in the trends.

B2.4.9 Normal year and dry year adjustments

The application of NYAA was touched on in section 3.7. In this section the full methodology and application is explained. The methodology for the NYAA and DYAA factors comes from the UKWIR household consumption forecasting guidance[8] report number 15/WR/02/9 –and the UKWIR peak demand forecasting guidance[9].

Stage one is to assess the weather data, more specifically temperature and rainfall. Total summer rainfall is plotted against mean summer temperature, with the mean of all years for the two factors plotted as ablines and presented in Figure B2.33. Data from four Met Office weather stations were reviewed for this analysis – these stations are:

- Pershore: South-east of Worcester (top left in Figure B2.31);
- Shawbury: North-east of Shrewsbury (top right in Figure B2.31);
- Watnall: North-west of Nottingham (bottom left in Figure B2.31); and
- Coleshill: North-east of Birmingham (bottom right in Figure B2.31).

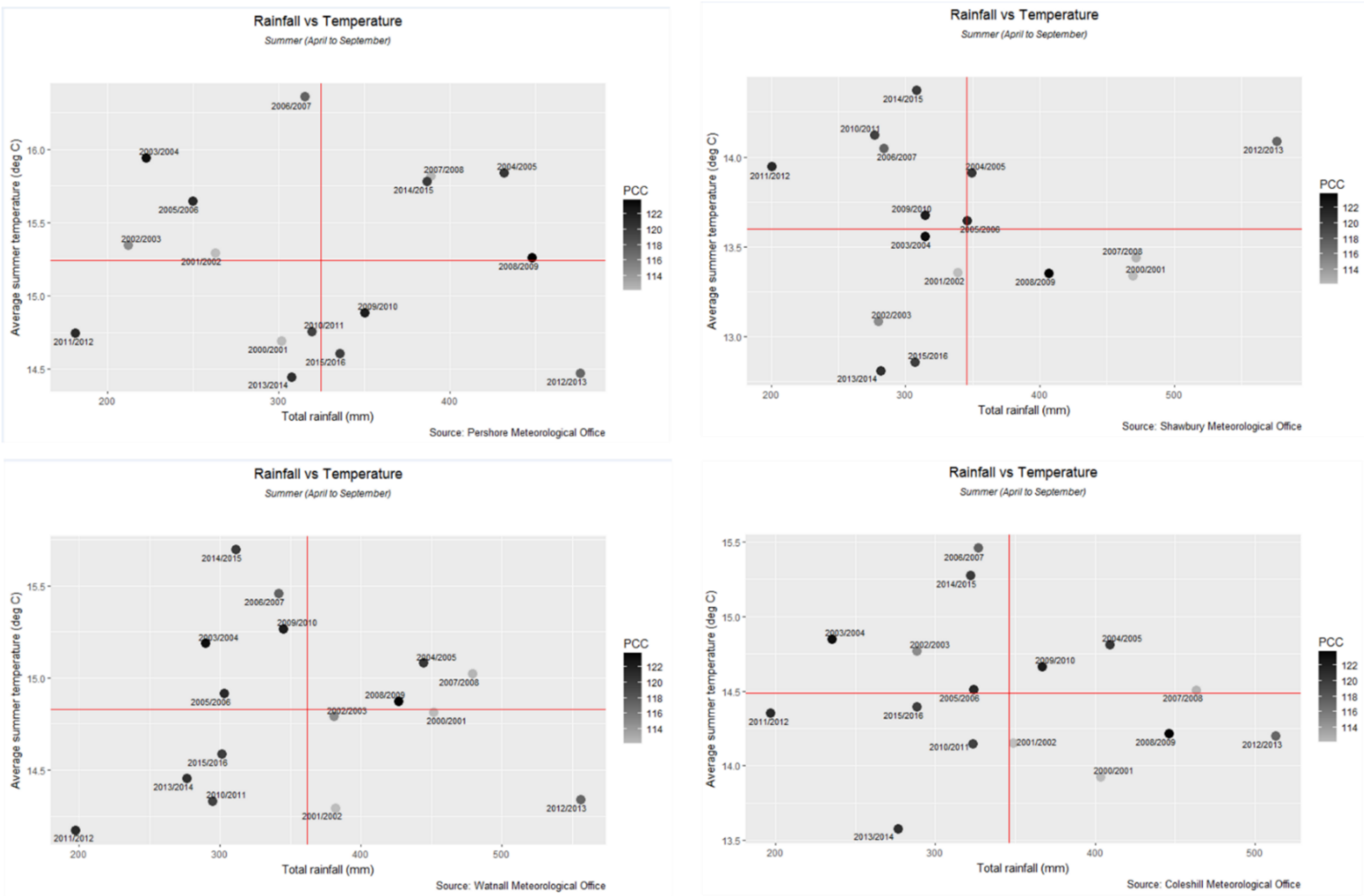
[7] UKWIR 15/WR/02/8 WRMP19 methods – population, household property and occupancy forecasting
[8] UKWIR (2015) WRMP19 Methods – Household Consumption Forecasting Guidance manual. Report Ref. No. 15/WR/02/9
[9] UKWIR (2006) Peak Water Demand Forecasting Methodology. Report Ref. No. 06/WR/01/7

Figure B2.31 also presents annual average unmeasured per capita consumption data for each of the years plotted, illustrated by the shading of the annual ‘dot’. These data are from the Severn Trent Domestic Consumption Monitor (DCM). This DCM includes approximately 1,000 properties from across the Severn Trent region.

The results presented in Figure B2.31 show that 2003/04 is placed relatively highly in the top left quadrant (i.e. dry and warm) for three out of the four weather stations (i.e. all except Shawbury, where it is just below the mean temperature abline but still relatively warm dry). The years 2006/07 and 2014/15 are consistently warmer than 2003/04, but generally not as dry. Importantly, the consumption in both these years is less than in 2003/04. Also, 2003/04 was identified as the dry year for WRMP14, using a different method.

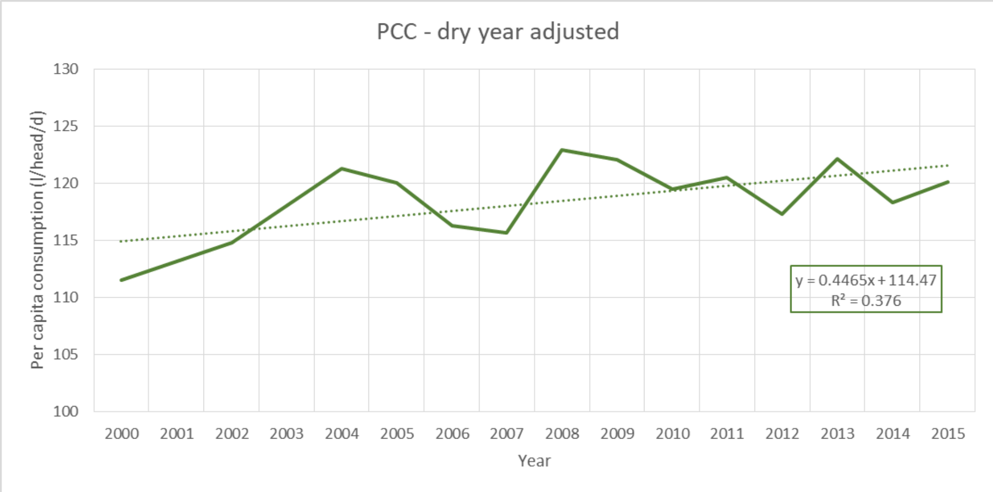
Therefore, 2003/04 is selected as the representative dry year for our region, using the best quality data available, including inter-station weather data.

Figure B2.31: Quadrant plot for determining the dry year



Stage two is to analyse the PCC trends for the DCM unmeasured annual average consumption data set, as presented in Figure B2.32

Figure B2.32: Average annual unmeasured per capita consumption for previous Severn Trent DCM properties



The dry year factor is calculated by removing the dry year, then calculating a trend line through the remaining points. The dry year factor is the actual consumption divided by the modelled consumption for 2003/04 – that is 124.26 l/head/day divided by 116.26 l/head/day. This results in a dry year factor of 1.0688. The WRMP14 forecast used a 1.052 dry year factor. Normal year factor calculations are calculated in a similar way, using the same trend line which excludes the dry year point. The normal year factor is the modelled figure divided by the actual figure for 2015/16 – that is 121.61 l/head/d divided by 120.12 l/head/d. This results in a normal year factor of 1.0124.

It is interesting to note the slight upward trend in per capita consumption (PCC) in Figure B2.32. This may due to a range of reasons including the relative dryness of the last three years in the data set (2013/14 – 2015/16), as illustrated in Figure B2.31; or the composition of the DCM itself, which is typical of many consumption monitors in that it will tend to lose relatively low consumption households who opt for a meter.

The option to define different normal years and dry years for each of the company's WRZs (or groups of WRZs) was considered in this study, however this was not pursued for three reasons:

- This method of analysis provides broadly consistent results for the four Met Office weather stations used – not only for 2003/04 but also for other potential dry years such as 2006/07 or 2014/15.
- Other methods for forecasting consumption and dry year factors could provide zonal results but were not implemented due to lack of data. For example normalising for weather is an intrinsic part of regression modelling for consumption forecasting. However we would need to have household-level data on a range of explanatory variables such as occupancy, household type/size and socio-demographic data and these data are not available for the DCM properties.
- The DCM data provides a good sized sample at the company level of around 1,000 properties. However this reduces significantly in size at the WRZ level, thus reducing the accuracy of the consumption estimate at this level of detail.

Application of the NY factor is different to the DY. The base year to normal year is applied before the calibration of the OVF calculated PHC, the reported figures are adjusted prior to this step so that the forecast is run from the normal year. Once the normal year forecasts are calculated the DY and CP factors are applied. These factors are independent of each other in that they are both applied to the NY forecast. Either option can be selected within the model. The baseline forecast for Severn Trent is as a DYAA.

B3 Forecasting non-household demand for water

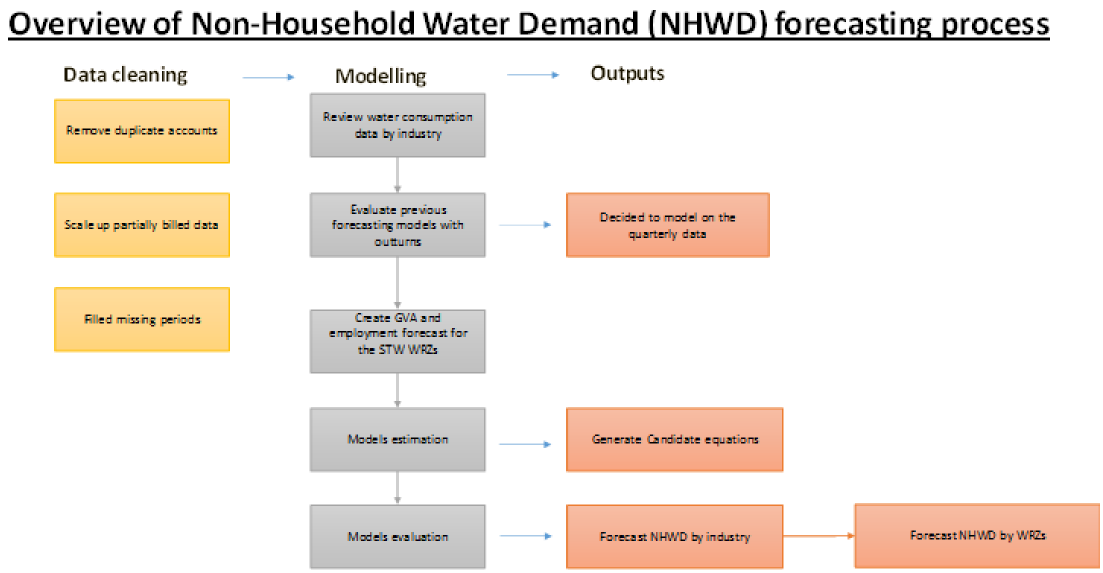
We have worked with Experian, a leading economic information and analytical services provider, to produce forecasts of non-household water demand (NHWD) to 2040. The forecasts have been derived econometric analysis to identify the historical relationship between NHWD and explanatory factors such as industrial output and employment and trends in efficiency of water use. The results of this statistical analysis were combined with Experian forecasts of output and employment by industry within the Severn Trent Supply Area to provide NHWD forecasts disaggregated by broad sector. In addition, plausible economic scenarios were constructed to provide a range of possible outcomes. These involved variations in the macro assumptions to create alternative water demand forecasts.

B3.1 The non-household demand modelling approach

The 25 year non-household water demand forecasts have been constructed using econometric models that relate non-household water demand to measures of economic activity (output and employment) in our region. We also take account of trends in water demand that are unrelated to economic conditions and reflect secular trends in the efficiency of water use by non-household consumers. These models follow the best practice guidelines laid out by the Environment Agency in developing water demand forecast for the next twenty five years.

The econometric models are constructed on an industry sector basis for which we classify industries by a Standard Industry Classification (SIC) code, a code classification for categorising business activity. We relate historical trends in non-household water demand for each of 30 SIC- based industries to local economic conditions in those sectors. This approach maximises the ability of the forecast models to incorporate industry-specific relationships between economic activity and non-household water demand. We vary the economic measures used (output or employment) and the coefficients relating economic measures to water consumption for each industry to reflect differences in the sensitivity of industry water consumption to economic conditions. An industry-by-industry approach also allows for different trends in water use efficiency for each industry sector. The chart below (Figure B3.1) summarises the approach and is followed by a detailed explanation of the analysis:

Figure B3.1 Overview of Non-Household Water Demand (NHWD) forecasting process



B3.2 Methodology

NHWD Data

In order to develop the non-household water demand forecasting model, a set of historical water demand data from Severn Trent was required. For this purpose, account level data for non-household customers on a financial year basis between 2005/06 – 2015/16 was provided for the old Severn Trent region. Experian analysed the quarterly year consumption data in order to identify the most appropriate basis for model estimation and forecasting NHWD.

The data consisted of individual customer records showing water demand for each quarterly billing period. For each account, Experian received the following information:

- Unique ID
- Location (post code)
- Water usage (Ml/day)
- Industry (SIC)
- Consumption Band

B3.3 Data Cleaning Process

Water usage data

Experian undertook the task of processing this data to produce a consistent time-series of water demand using techniques developed for the previous study. Checks were applied to the dataset to ensure data quality is consistent and to ensure no duplicate records were included in compiling the water usage data for modelling. These included checking for consistency of samples between the billing records and for consistent SIC industry coding, and other characteristics (name and address details, location details, consumption and tariff details) of individual accounts.

In addition, Experian followed the Forecasting water demand components – Best Practice Manual (UWKIR, 1997) by aggregating individual account into appropriate industry groupings with similar economic characteristics to increase the robustness of the data. Aggregating the data on this basis helps to smooth out volatility in consumption patterns at an account level. The industry groupings used are based on aggregations of SIC industries to the broad sector industry classification. The results from these aggregations were checked for consistency then aligned to the aggregated industry-level annual return data provided by STW.

The historical estimates for the broad sector groupings[10] are presented, on a financial year basis, in Table B3.1 below.

[10] The industry definitions are presented in Appendix A

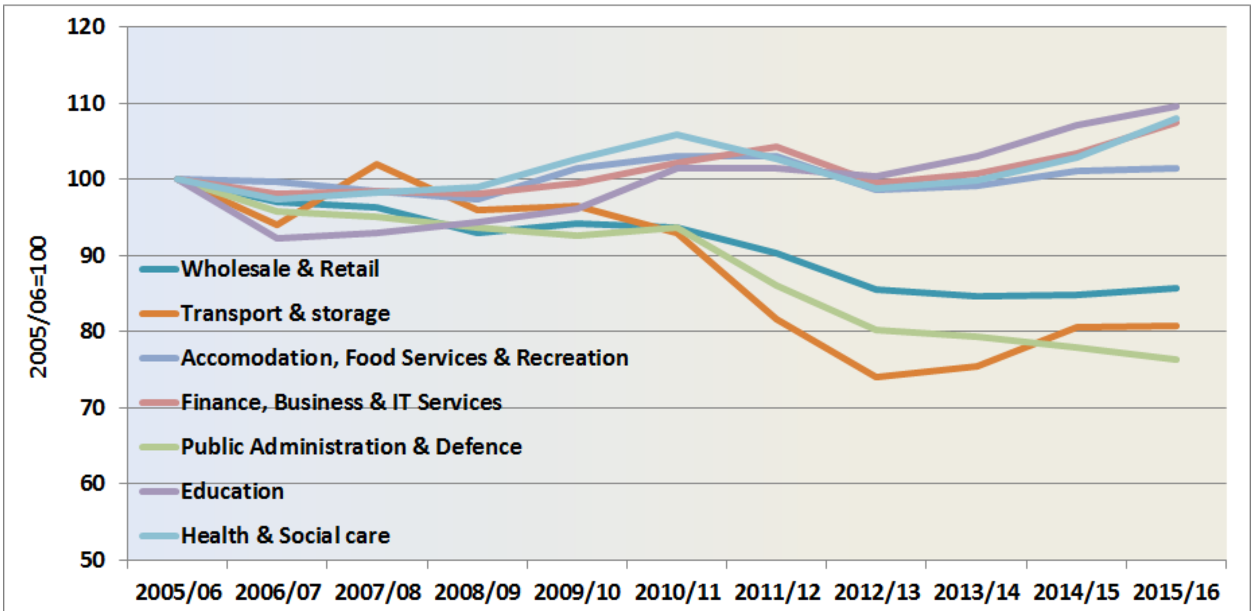
Table B3.1 Water consumption by broad industry sector

Industry (Ml/d)	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Primary industry	45.7	44.2	42.1	39.9	40.9	42.6	41.2	36.4	36.8	37.5	38.0
Manufacturing	110.8	99.7	95.2	87.7	84.9	86.2	84.4	78.7	79.5	81.5	84.3
Utilities	8.6	7.9	7.3	7.8	8.3	8.4	7.6	7.5	7.6	7.9	8.2
Construction	2.5	2.6	2.6	2.7	2.7	3.0	2.9	2.9	2.8	2.8	2.8
Wholesale & Retail	32.5	31.5	31.3	30.2	30.6	30.4	29.3	27.8	27.5	27.5	27.9
Transport & storage	8.3	7.8	8.5	8.0	8.0	7.7	6.8	6.2	6.3	6.7	6.7
Accomodation, Food Services & Recreation	48.7	48.5	47.9	47.4	49.4	50.2	50.2	48.0	48.3	49.2	49.3
Finance, Business & IT Services	37.4	36.7	36.8	36.6	37.1	38.2	39.0	37.2	37.7	38.6	40.1
Public Administration & Defence	18.6	17.8	17.7	17.4	17.2	17.4	16.0	14.9	14.7	14.5	14.2
Education	28.3	26.1	26.3	26.7	27.2	28.7	28.7	28.4	29.1	30.3	31.0
Health & Social care	22.8	22.2	22.4	22.6	23.5	24.2	23.4	22.6	22.8	23.5	24.7
Unallocated	27.2	23.9	21.1	16.4	12.2	9.5	8.2	8.9	10.4	10.3	13.3
Non-service	167.5	154.4	147.2	138.2	136.8	140.1	136.1	125.5	126.7	129.7	133.3
Service	196.6	190.7	190.8	188.9	193.0	196.7	193.4	184.9	186.4	190.4	193.9
Totals, all sectors:	**391.3**	**369.0**	**359.1**	**343.5**	**342.0**	**346.3**	**337.7**	**319.3**	**323.4**	**330.4**	**340.5**
Source: Severn Trent Water, Experian											

Most of non-service sectors showed declining water demand over the period 2005/06-2015/16 with the exception of the construction industry. Manufacturing accounted for the bulk of the decline which corresponded to the weakness observed in the GVA estimates and strong efficiency gains in the industry. The long term decline reversed in some industries since 2012/13, notably in the manufacturing industry where the water consumption rose from a decade low of 78.7 ml/day in 2012/13 to 84.3 ml/day in 2015/16. The recent increase in water usage corresponded to an increase in the industry's GVA, which may indicate that the water demand became more sensitive to changes to economic conditions and the water efficiency gain in the industry may be slowing.

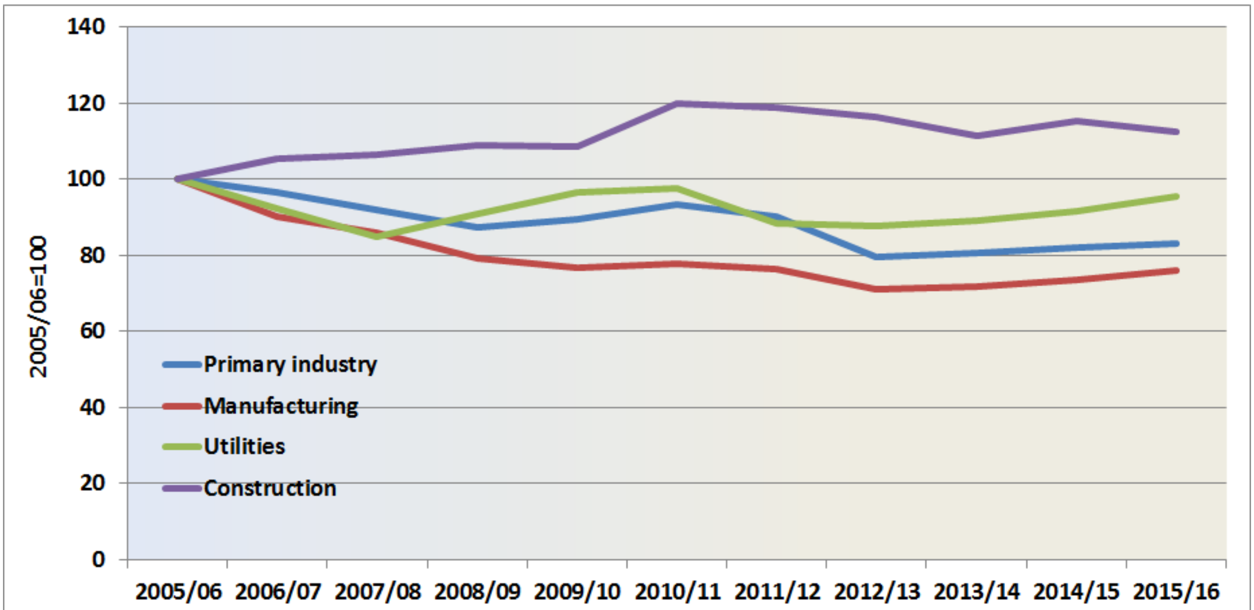
Figures B3.2 and B3.3 show the trends in water demand within the service sectors relative to 2005/06. Although water consumption in the service sectors has remained much more stable compare to the non-service sector as a whole, diverging trends can be seen at the individual industry level. Water demand in education, health & social care and finance, business and IT services increased whereas the water demand fell in transport & storage, wholesale & retail and public and administration & defence.

Figure B3.2: Water consumption by industry in the non-service sector



Source: Severn Trent Water, Experian

Figure B3.3: Water consumption by industry in the service sector



Source: Severn Trent Water, Experian

B3.4 Model Development

An econometric model is an analytical forecasting tool which operates by simplifying the real world into a set of variables, equations and identities. It produces forecasts to describe likely future outcomes based on the past interactions between variables under a set of pre-determined macroeconomic assumptions.

Experian followed the EA guidance and an established process of model development. The EA guidance states that the non-household demand model to be developed either using the main SIC categories published by the ONS or simply between service activities and non-service activities, identifying key sectors.

In the first instance, Experian began by exploring economic theories, available data and the desired forecast output. Once a model has been designed, candidate equations are estimated. The statistical properties of these equations are assessed. In particular, the following are considered:

- The fit of the equation (including the significance of individual estimated coefficients);
- The signs and magnitude of estimated coefficients;
- The dynamic properties of the equation;
- The suitability of the equation for forecasting or simulation (as may be required).

It is important to note that emphasis was placed on the forecasting and simulation properties of the model. In places, this meant that variables which were not statistically significant but which had the appropriate signs and magnitudes were included in equations to add explanatory power to the underlying forecast and to ensure that the model was appropriately responsive when used for simulation.

The economic rationale determines the demand for water is taken from the PR14 Non-household water demand report for Severn Trent. Furthermore the analysis of the accuracy of WRMP14 forecasts demonstrated that the demand for water in industry (non-services) is essentially derived demand. In that sense, water is demanded by industry because it is an important input into the productive process. Depending on the industry in question, water may be used directly in production as a raw material. Alternatively, water may be used indirectly in that it is consumed by people in the working environment. Accordingly, the demand for water in non-service industries should vary with output and demand for water in service industries should vary with employment. The relationship between NHWD and the explanatory variable have been re-examined across the broad industries (service and non-service) and more detailed industry groupings.

The factors explored were as follows:

- Sectoral output
- Sectoral employment
- Trends in the efficiency of water usage

The next section describes the estimation process in detail

Stage 1: Estimation of equations

Based on the procedure set out in the EA guidance, the NHWD forecasting methodology involved pooling the sectoral data into two main groups: non-services and services. The equations were specified in the form of difference in logarithms to remove the non-stationary elements of the time series data.

A water efficiency variable was estimated to capture the changes in water consumption which was not explained by changes in GVA or employment depending on the sector. As recent efficiency gain was exceptionally high - which would be unlikely to continue at past rates - slower efficiency gain was factored into the forecast.

The equations were modelled over the period 2005/06 to 2015/16. It was necessary to be pragmatic at times to estimate the equations where there were large fluctuations in the water consumption data and construct a forecasting model with sensible forecasting properties. The following two pooled equations were estimated:

For the non-service sectors:

$$Dlog(NHWD_{pt}) = \alpha_1 + \alpha_2\, Dlog(GVA_{pt}) + \varepsilon$$

and for services:

$$Dlog(NHWD_{st}) = \alpha_1 + \alpha_2\, Dlog(EMP_{st}) + \varepsilon$$

Where NHWD = measured non-household water demand (Ml/day)
GVA = Total output in non-service industries (Gross Value Added in 2012 VCM (Value Chained Measure))
EMP = Full-time equivalent employment in service industries
Subscript t refers to time period (2005/06 to 2015/16)
Subscript p refers to non-service industries
Subscript s refers to service industries

In these equations we - capture the relationship between growth of NHWD and growth in economic activity, while the 'constant' term, α, incorporates a constant trend growth rate for NHWD which is independent of economic conditions. So, in this specification, consumption in the relevant sector is tending to increase (or decline, since α is generally negative) at a constant exponential growth rate but this trend growth rate would increase or decrease depending on the strength of the local economy (measured by either output growth or employment growth).

Stage 2: Estimation results

The results from estimating the models on the quarterly data from 2005/06 to 2015/16 were as follows:

Non-services:

(i) $Dlog(NHWD_{pt}) = 0.43^{*}\, Dlog(GVA_{pt}) - 0.027$

Services:

(ii) $Dlog(NHWD_{st}) = 0.14^{*}\, Dlog(EMP_{st}) + 0.002$

The initial results indicated that the growth in output has a positive relationship with water consumption in the non-service industry, +0.43 for the (non-services) and employment is +0.14 for the services. In other words, the equation implies that a 1 per cent increase in output would increase water consumption by 0.43 per cent with everything else remaining unchanged, while a 1 per cent increase in employment would increase water consumption for service industries by 0.14 per cent.

The signs of the coefficients make intuitive sense for the equations for both the service and non-service sectors, since non-household water demand rises in response to increased activity in the sector. However, the magnitude of the employment in the service sector equation is deemed insignificant, therefore only the equation for non-service was accepted. In addition, the efficiency terms in the non-service equation is also considered insignificant to be included in the equation.

Stage 3: Estimation of detailed industry relationships

The broad sector approach produced sensible results for the non-service sector which can be used to estimate demand equations for detailed sectors. The second stage of the modelling phase was to impose the results from stage one on the sectors belong to the non-services industries. This involved running a regression for each category using fixed values for the coefficients of output, estimated in stage 1. These results were then imposed on the demand equations so that each category’s own intercept term can be estimated with these restrictions imposed. Therefore despite limitations with the data, the use of both time-series and pooled regression techniques enables each industry’s derived demand to depend upon the industry’s performance in terms of output or employment. Furthermore, efficiency variables were included in the equations but only retained if the sign and magnitude of the coefficient was sensible.

The pooling method did not produce satisfactory results for the service sector aggregate. For each service sector, one of following model specifications was used:

$$Dlog(NHWD_{st}) = \beta_1 + \beta_2 \, Dlog(EMP_s) + \varepsilon \qquad (1)$$

or

$$Log(NHWD_{st}) = \beta_1 + \beta_2 \, Log(EMP_{st}) + \varepsilon \quad (2)$$

In variant (1), above, the equation attempts to capture the relationship between growth of NHWD and growth in economic activity, while the ‘constant’ term, β_1, incorporates a constant trend growth rate for NHWD independent of economic conditions. In this specification, consumption in the relevant sector is tending to increase (or decline, since β_1 is generally negative) at a constant exponential growth rate but this trend growth rate is increased or decreased depending on the strength of the local economy (measured by either output growth or employment growth).

In variant (2), the *level* of NHWD is related to the level of local economic output or employment in the relevant industry sector. The log operator means that the coefficient, β_2, relating water consumption to economic activity is an ‘elasticity’. It measures the percentage change in water consumption by that industry consequent upon a 1 per cent increase in either output or employment. This specification was considered in cases where there was no evidence of a trend in NHWD unrelated to economic conditions.

The details of each equation can be found in Table B3.2.

It is important to point out at this stage that among the detailed industry level NHWD figures provided to Experian by Severn Trent, there were a number of commercial customers that could not be directly aligned to a SIC group. This meant that a small element of NHWD could not be attributed to either service or non-service economic drivers, so no equations could be estimated to forecast future demand. Therefore it was decided to assume the unallocated category constant at a level equivalent to the mean over the period 2005/06 to 2015/16.

Table B3.2: Model coefficients by broad sector

Industry	Coefficients			
	constant term	GVA	Employment	Model Specification
Primary industry	-0.001	0.4	0.0	
Manufacturing	-0.002	0.4	0.0	
Utilities	-0.001	0.4	0.0	
Construction	0.00	0.4	0.0	
Wholesale & Retail	-0.01	0.0	0.1	1
Transport & storage	0.00	0.2	0.0	1
Accomodation, Food Services & Recreation	-0.01	0.2	0.0	1
Finance, Business & IT Services	12.69	0.3	0.0	2
Public Administration & Defence	9.76	0.0	1.0	2
Education	-0.01	0.0	0.6	1
Health & Social care	-0.02	0.6	0.0	1
Source: Experian				

Stage 4: Water Resource Zone forecasts

The final stage of the forecast process was to provide non-household water consumption forecasts for each of the Water Resource Zone (WRZ) areas within the STW catchment. The method used was to allocate water demand forecasts across the WRZs using the WRZs share of economic activity in that industry. This means that the WRZ area forecasts reflect the most recent composition of water demand in those areas by industry sector, and the industry sector demand forecasts for the STW catchment region as a whole. No attempt was made to adjust WRZ area forecasts for local economic conditions in the WRZ relative to those for the STW catchment. A further step is taken to calculate the results of the post-Maximum Likelihood Estimation (MLE).

A scale factor has been derived by averaging the scaling factors between the water consumption from the billing data and the post-MLE data from the Annual return every year between 2011-12 and 2015-16.The non-household water demand does not factor in any explicit assumption regarding to customers swapping from non-public supply. However, it is assumed implicitly in that if a customer had swapped water supply from non-public supply then the water consumption would be higher for a given amount of economic output, and as the constant term in the equation captures water demand that is not explained by either employment or output growth, the demand forecast assumes the customers' behaviour in the past (including swapping from non-public supply) will be a reflection of the future.

B3.5 Summary Results

Total non-household water demand

Table B3.3 and figure B3.4 show the total non-household water demand in the Severn Trent supply area declined steadily from 391 ml/day from 2005/6 to 319ml/day in 2012/13 before rising to 341ml/day in 2015/16 as shown in Figure B3.4. We expect the water consumption to be relatively stable in the next few years as the UK economy faces major political and economic uncertainties. By the early 2020s water demand is forecast to increase steadily until the end of the forecast period. The forecast reflects the increasing economic dominance of services activities with more stable water demand relative to manufacturing activities for which demand is expected to decline. By the end of the forecast period, we expect the water consumption from the non-services sectors to be 9% below the 2015/16 level, but the water demand from the service sector will be 8% higher during the same period.

The WRZ forecasts are based on allocating the industry-level water demand forecasts to WRZs based on the most recent share of WRZ demand within total demand for the STW region within that industry.

Figure B3.4: Total non-household water demand, 2005/06 – 2044/45

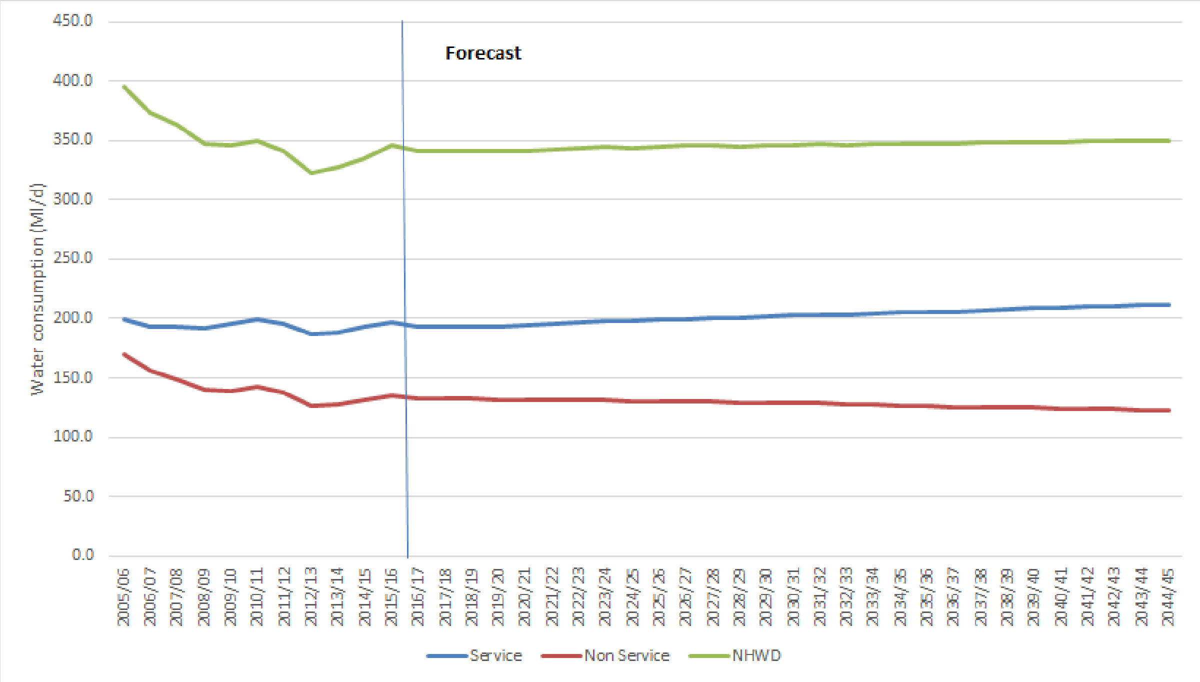


Table B3.3: Total non-household water demand (Ml/d) by water resource zone (selected years)

Water resource zone	2016/17	2025/26	2035/36	2044/45
Bishops Castle	0.5	0.5	0.5	0.5
Forest & Stroud	11.8	11.4	11.0	10.6
Kinsall	1.3	1.4	1.4	1.4
Chester	6.9	6.9	6.8	6.8
Mardy	0.4	0.4	0.4	0.4
Newark	2.8	2.8	2.8	2.7
Nottingham	42.4	43.2	43.7	44.1
North Staffs	19.8	20.1	20.3	20.4
Rutland	1.9	1.9	2.0	2.1
Ruyton	0.9	0.9	0.9	0.9
Strategic grid	215.3	218.5	220.4	221.5
Shelton	20.7	21.1	21.3	21.5
Stafford	4.6	4.7	4.8	4.8
Wolverhampton	9.3	9.5	9.7	9.9
Whitchurch & Wem	2.0	2.0	2.0	2.0

B4 Leakage

The key elements of our future Active Leakage Control (ALC) policy are as follows:

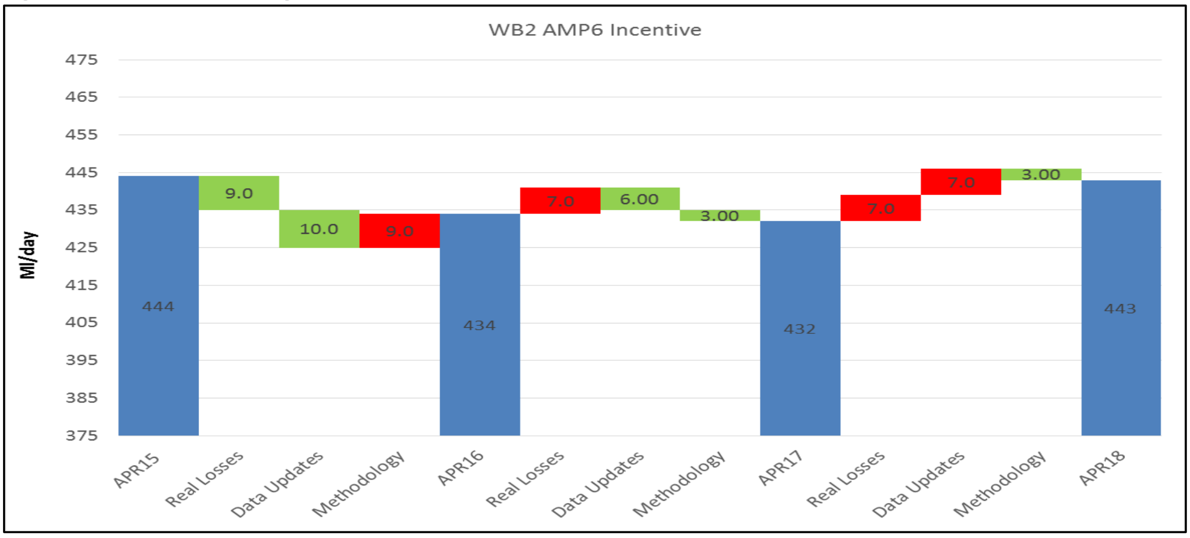
- Active leakage detection will continue to be the mainstay of delivering lower leakage levels in AMP6.
- We will maintain and upgrade an increasing number of pressure control valves, recognising that proactive maintenance prolongs asset life, and reduces network deterioration and burst rates.
- We will widen the scope of pressure control to trunk mains and pumped networks.
- We will proactively replace obsolete DMA meters as we recognise we have an ageing asset that degrades in accuracy over long periods. This includes optimising the DMA network that promotes effective leakage management. We will look for new opportunities to promote sub DMA monitoring.
- Separating demand from leakage will play an increasingly important part in our activities going forward as we look to account for consumption on the network.
- We will continue to refine our approach to measuring and reporting trunk main and service reservoir losses, and are committed to undertaking more maintenance and surveys of trunk main assets.
- We have established 60 Accountability Zones and are starting to undertaken water balance calculations to understand trunk main leakage in these zones. We will progressively move to a programme of periodic water balance assessment of Accountability zones.
- We will continue to have a rolling programme of water balance improvement initiatives.

B4.1 AMP6 performance so far for Severn Trent

We are on target to achieve the Severn Trent commitment of delivering a 6% leakage reduction over AMP6. We outperformed commitment levels by 10Ml/d in year one and 7Ml/d in year two. However we saw a rise in leakage in year 3, mainly as a result of the 'Beast from the East' in March 2018. This came late in the year and as we carried minimal headroom against target, meant that we were unable to recover sufficiently enough to achieve the target. We out-turned 9Ml/d above target in year 3. Leakage remains 23% of Water into Supply, which we know is not good enough, and we are working hard to reduce this. Our PR19 target setting will reflect our ambition to reduce this.

Annual reported leakage is broken down in to method, data and real loss changes. Like most companies in the industry, in AMP6 we are not claiming method changes in our annual return. We will talk about changes to methodologies and leakage measurement later in this chapter. Although data updates and improvements are made annually the incentive is only made on real loss change. See the waterfall diagram in Figure B4.1 below for these changes.

Figure B4.1: AMP6 Leakage Data



Active leakage detection

As part of our Upper Quartile performance improvement programme we have undertaken a number of leakage experiments to assess different approaches to improving performance. Historically, focus has tended to be on seeking to improve our 'find and fix' process through better detection equipment, scheduling and so on. However, our recent work has shown clearly that achievement of a step-change in performance is dependent upon us improving our measurement and data. This will enable us to identify unaccounted for usage, reduce uncertainty in our water flow balance, reduce estimations and increase confidence grades in our top down calculation. Not only is there more to be gained in the short-term from this approach, we believe it is essential to provide the basis for better targeting and an improvement in our 'find and fix' efficiency.

We have also restructured our leakage detection organisation and will be rolling out a new operating model in 2018. We have created a new Water Engineer role that will take greater ownership of a 'patch' of DMAs within their traditional county boundaries. This will drive a greater understanding of the issues and working of these zones in order to more effectively control leakage activities.

Pressure Management

In our AMP6 business plan Severn Trent set out a number of commitments to optimise many Pressure Relief Valves (PRVs), we have 4200 on our network, and have also installed more sophisticated PRV controllers (Pegasus Units). We are ahead of our planned installation targets and have further opportunities built into our current plans. Table B4.1 summarises the actual and projected performance compared to our Business Plan commitments. This is supplemented by planned maintenance activity on our current asset base.

To date, 600 PRVs (against our Business Pan 'BP' target of 1200) have been replaced through a combination of proactive and reactive replacements.

Table B4.1: Actual and projected leakage compared to our Business Plan commitments

AMP6 commitment		Yr1 & Yr2 (Ml/d)	Yr3 (Ml/d)	Yr4 (Ml/d)	Yr5 (Ml/d)
3.5 Ml/d	500 PRV optimisations	6.8 Ml/d 490 optimisations	3.0 Ml/d 240 optimisations	5.0Ml/d 329 optimisations	-
5.0 Ml/d	200 PRVs	1.9 Ml/d Target = 3.0 Ml/d	2.0 Ml/d	1.1 Ml/d	-
3.5 Ml/d	190 PRV Controller installations	Target = 5.8Ml/d Yr1 – Yr5 total (211 installations) Yr1 – Yr5 total			
1.0 Ml/d	74 Trunk main PRV controllers	-	0.5 Ml/d	- Transferred to year 5	0.5
AMP6 BP Total:		13 Ml/d Yr1 – Yr5 total			
	AMP6 Actual:	**26.6 Ml/d (Projected) Yr1 – Yr5 total**			

Trunk Mains Leakage

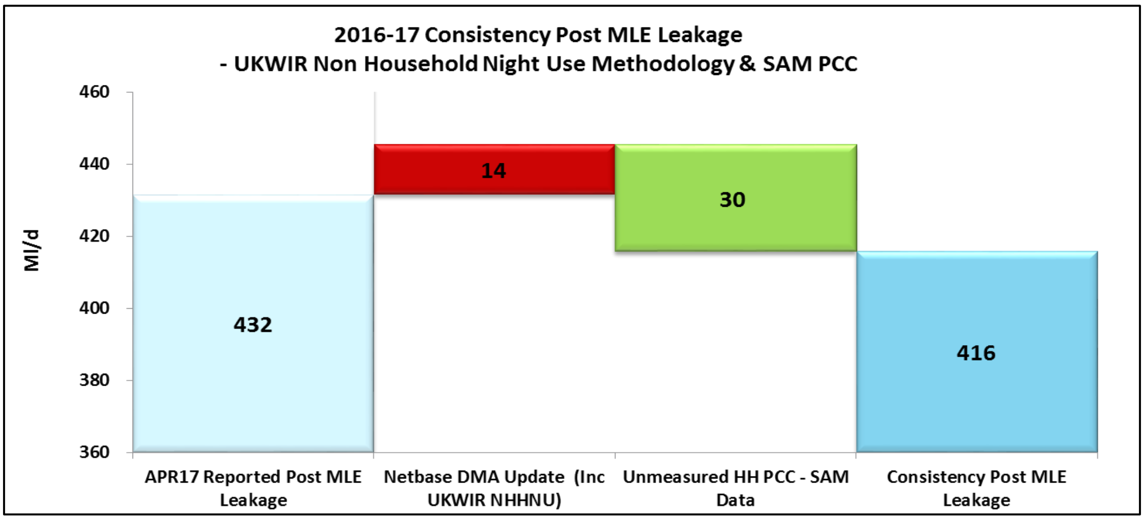
We have moved forward the mass balance assessment approach of the trunk mains and service reservoir network by rolling out a programme across our 60 Accountability Zones. These zones sit below Water Resource Zones and allow us to carry out a wide reaching mass balance assessment but also the ability to drill down in to issues in DMAs. We have a programme to the end of the AMP to monitor and assess 70% of Water Accountability zones. We have accounted for 69Ml/d of water into supply, through issues such as monitoring errors, network configuration and connectivity issues as well as genuine leakage. We are using the outputs of the tile analysis to drive new leak detection activity as well as alignment with existing trunk mains walking programme. This activity is allowing us to target stressed areas of the network and better focus our activity and investment alongside future ALC activities.

Leakage Consistency

Water companies have been working together, co-ordinated by Water UK, to improve the consistency of reporting of definitions of key measures of performance, so that performance can be compared between companies more easily. This work is supported by Ofwat, the Environment Agency, Natural Resources Wales and the Consumer Council for Water.

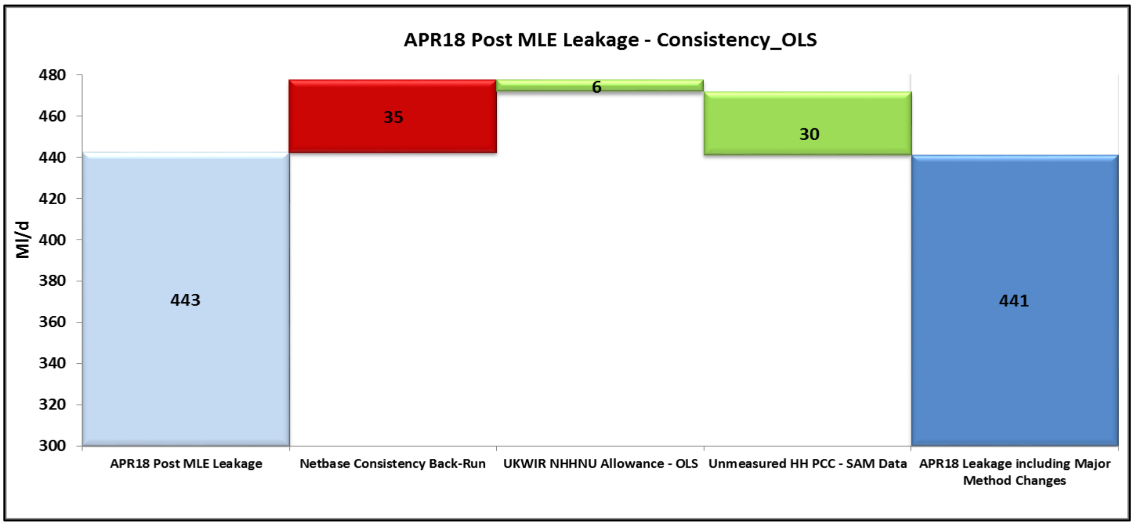
One of the measures of performance this applies to is leakage. The change in measuring leakage performance is purely a change in reporting; it does not affect the actual amount of water lost through leakage. The Water UK consistency project on leakage outlined 72 recommendations in its final report. For our leakage reporting purposes, 12 of those recommendations will require significant system, Netbase modelling, and platform changes, the others are linked to improvements in monitoring and process. We have a plan to make these improvements, and to achieve full compliance with the recommendations by the end of AMP6. In August 2017 we completed a back run of APR17 and applied where we could, recommended consistency approach to our leakage calculation to test the implications. The results gave us a net leakage reduction of 16Ml/d to 416Ml/d when compared to our previously reported 2016-17 leakage performance (Figure B4.2).

Figure B4.2: 2016-17 Consistency Post MLE Leakage



We have now completed this analysis for 2017-18 and the post consistency change is -2Ml/d from the APR18 position. The change from APR17 is driven by new compliant activity delivered in 2018 – a new estimate of NHH night use and operational performance in 2017-18 affecting DMA shadow performance (Netbase).

Figure B4.3: 2016-17 Consistency Post MLE Leakage



These changes do not affect the fundamental supply demand challenge we have in AMP7. Consistency is not impacting total distribution input, it is merely changing our understanding of real unmeasured consumption and reported leakage. Our AMP7 WRMP priority is still to focus on reducing distribution input using leakage reduction, water efficiency and more metering. As a result of the work done to date we plan to build the leakage consistency results into our PR19 investment modelling and start position for AMP7. We have taken Ofwat through these key changes and signalled that these will be included in our base level of performance for target setting.

Moving to full compliance

Where we do not have full compliance to best practise we have a delivery plan to be fully compliant by the end of the AMP. The tables below (Tables B4.2 and B4.3) shows our current compliance and the plan to get to full compliance.

Table B4.2 Our current compliance status

Sub Component	APR19 R/A/G
Coverage	*Green*
Availability	*Amber*
Properties	*Green*
Night flow period and analysis	*Red*
Household night use	*Green*
Non-household night use	*Green*
Hour to day conversion	*Green*
Annual distribution leakage	*Green*
Trunk main losses	*Amber*
Service reservoir losses	*Red*
Distribution input	*Amber*
Measured consumption	*Green*
Unmeasured consumption	*Amber*
Company own water use	*Amber*
Other water use	*Amber*
Water balance and MLE	*Green*

Table B4.3: Compliance Plan - Expected dates of when components will turn to green

	Availability	Night Flow Period	Trunk Main Losses	Service Res Losses	Dist Input	Unmeasured Cons	Company Own Use	Other Use
18/19 Q1	*Amber*	*Red*	*Amber*	*Red*	*Amber*	*Amber*	*Amber*	*Amber*
18/19 Q2	*Amber*	*Red*	*Amber*	*Red*	*Amber*	*Amber*	*Amber*	*Amber*
18/19 Q3	*Amber*	*Red*	*Amber*	*Amber*	*Amber*	*Green*	*Amber*	*Amber*
18/19 Q4	*Amber*	*Red*	*Amber*	*Amber*	*Amber*	*Green*	*Amber*	*Amber*
19/20 Q1	*Amber*	*Red*	*Amber*	*Amber*	*Amber*	*Green*	*Amber*	*Amber*
19/20 Q2	*Green*	*Red*	*Amber*	*Amber*	*Amber*	*Green*	*Amber*	*Amber*
19/20 Q3	*Green*	*Red*	*Green*	*Green*	*Amber*	*Green*	*Green*	*Green*
19/20 Q4	*Green*	*Green*	*Green*	*Green*	*Green*	*Green*	*Green*	*Green*

We will dual report Consistency internally through the remainder of the AMP and externally as part of APR. As work is completed and components become compliant we will include the impact in shadow reporting so that we are fully compliant by APR20. The majority of the remaining work is collection of company specific data in order to estimate these components. We are confident of delivery as any new metering and monitoring in order to establish these estimates is now in place.

B4.2 Long term leakage targets

Our approach to setting out our long term (2020-2045) leakage targets formulated and considered three different options. These were:

- Option 1: Implement an economic approach to leakage targets
- Option 2: Extend AMP8 / AMP9 leakage reduction into zones with no SDB deficit.
- Option 3: Beyond AMP8 we adopt the NIC 50% target, and use it to set our innovation ambition

The long term leakage targets in the Severn Trent draft WRMP were aligned with Option 1, however for our final WRMP we have realigned our leakage targets to reflect a more ambitious long term leakage target as provided by Option 3.

We have changed our approach in direct response to the outcomes of the draft WRMP consultation process, where customers and stakeholders challenged our long term leakage ambition and pressed us to continue with significant multi-AMP leakage reduction strategies. Also, since we published the draft WRMP we have compared our leakage ambitions with the long term leakage profiles proposed in other companies' draft WRMPs. Separately, the National Infrastructure Commission (NIC) has set out a challenge that the industry should reduce leakage by 50% over the next 25 years.

In response to these challenges, we have considered potential options for setting more ambitious long term leakage targets for inclusion in our final WRMP. The three options considered, and our chosen approach are explained in the following sections.

Option 1: Implement an economic approach to leakage targets

The leakage approach described in the Severn Trent draft WRMP was based on a least whole-life cost economic appraisal of supply and demand needs and the available intervention options. This approach produced the long term leakage reduction profile illustrated in Figure A2.1 and A2.2, demonstrating a 15% reduction in AMP7 followed by modest reductions in subsequent AMPs. This has been termed Option 1a.

The long term profile of Option 1a reflects our projected supply and demand outlook and the costs of our different investment options. Note that while the AMP7 overall leakage reduction target is 15%, the reductions are only targeted in the Water Resource Zones (WRZs) with supply / demand shortfalls (these being our Strategic Grid WRZ and Nottinghamshire WRZ and Forest and Stroud WRZ), with leakage rates maintained at their current rate in all other WRZs. The Chester WRZ target for this option is a reduction target of 7.5% in line with the Dee Valley draft WRMP.

Since the published Severn Trent draft WRMP in December 2017, we have made some minor updates to our overall supply / demand appraisal using the latest information. The main areas of update to our supply / demand assessment have been:

- The final list of sustainability reductions confirmed in the Environment Agency's WINEP3 in April 2018.
- Revised water resource option capex / opex estimates which reflect our ongoing engineering appraisal of supply-side and demand-side options.

The updates have caused some small changes to the supply / demand profiles for WRZs that are affected by long term sustainable abstraction pressures and there is a rebalancing of the costs and benefits of our different options. As a result of these changes, our assessment is that further AMP8 and AMP9 leakage reduction would become more cost effective than was modelled at the time of our draft WRMP. This gives rise to a least whole-life cost leakage approach that has been amended since we published our draft WRMP and this has been termed Option 1b.

Our latest assessment for Option 1b is that the updated 'least whole-life cost' approach would mean no changes to the AMP7 company wide reduction of 15%, but would increase the AMP8 leakage reduction rate to 0.6% and the AMP9 leakage reduction rate to 11.5%. However, the longer term supply / demand outlook would mean no further leakage reductions in subsequent AMP periods. The resulting long term leakage profile generated by Option 1a and 1b is illustrated in Figures B4.4 and Figures B4.5.

Figure B4.4 Long term leakage profile (Company wide): Economic Approach

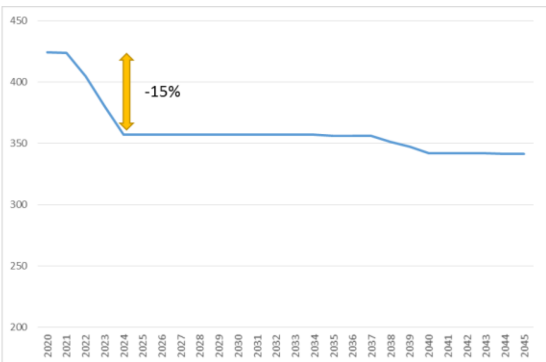
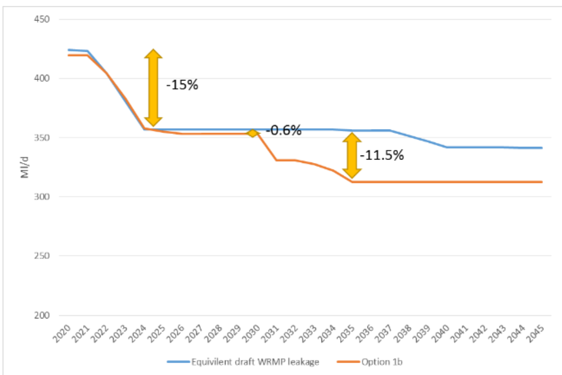
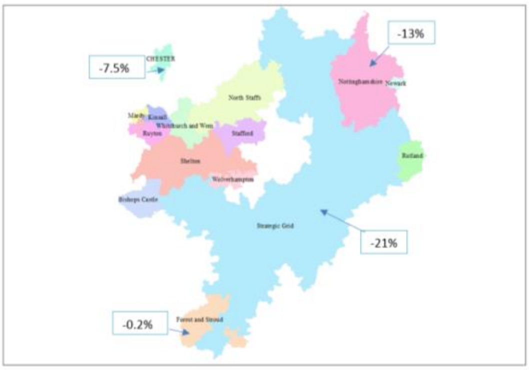
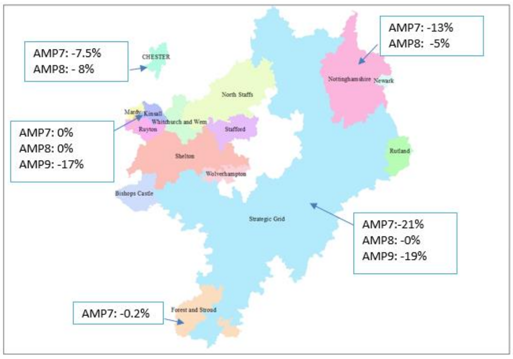
Option 1a: Economic approach leakage target	Option 1b: Adjusted economic approach
	

Figure B4.5 Long term leakage profile (by WRZ): Economic Approach

<table>
<tr><th>Option 1a: Economic approach leakage target</th><th>Option 1b: Adjusted economic approach</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

We recognise that using the Option 1b approach, reductions would still only be targeted in a few of WRZs with a supply / demand balance deficit, with no reductions in the remaining WRZs. The long term profile also implies that our leakage targets become less challenging in the long term. Therefore, we have explored further options to go beyond the least whole life cost approach.

<u>Option 2: Extend AMP8 / AMP9 leakage reduction into zones with no SDB deficit</u>

Option 2 builds on the revised supply / demand economic appraisal described in Option 1b. The approach for Option 2 involves continuing to deliver the least whole-life cost leakage reductions targeted in the two zones with a supply / demand balance deficit. However, we would also extend AMP8 / AMP9 leakage reduction into the remaining zones to maintain an overall AMP by AMP target reduction of 15%. The additional AMP8 and AMP9 reduction zonal targets would not be set based on supply / demand balance need, but would be distributed across all WRZs based on short-run costs and ease of finding and fixing leaks.

This approach means that we prioritise leakage reduction activities to benefit customers in the WRZs with the greatest needs to meet the supply / demand balance, but longer term we will extend our ambition into WRZs with a lower supply / demand risk. Beyond AMP9, once the supply / demand balance deficit has been addressed, the least whole-life cost approach would mean no further leakage reductions are required as demonstrated in Figures B4.6 and B4.7.

Figure B4.6 Long term leakage profile (Company wide): Option 2 Extending the least whole life cost approach to achieve an overall 15% AMP reduction target for AMP7-9.

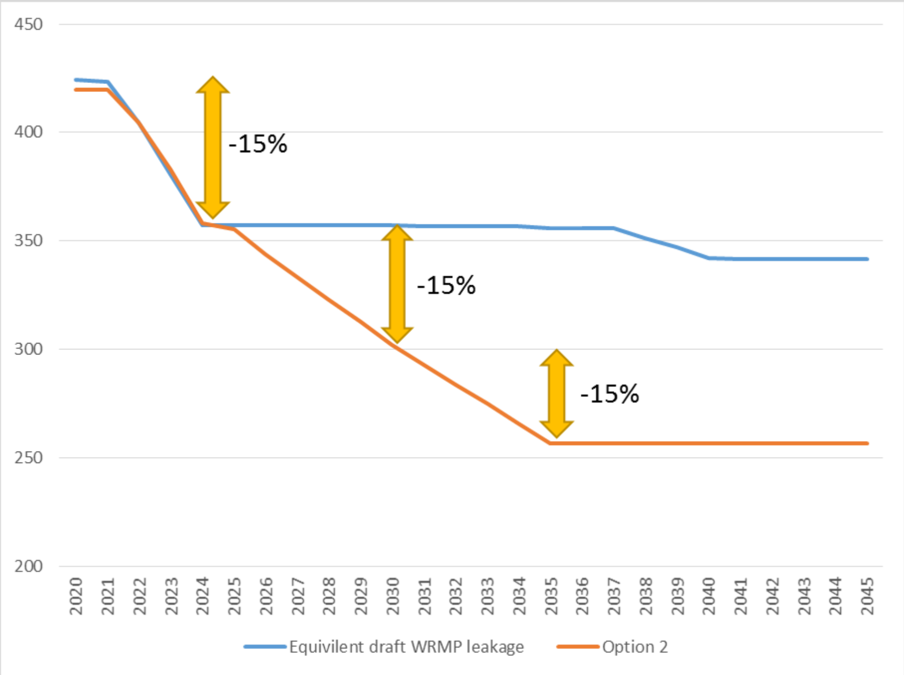
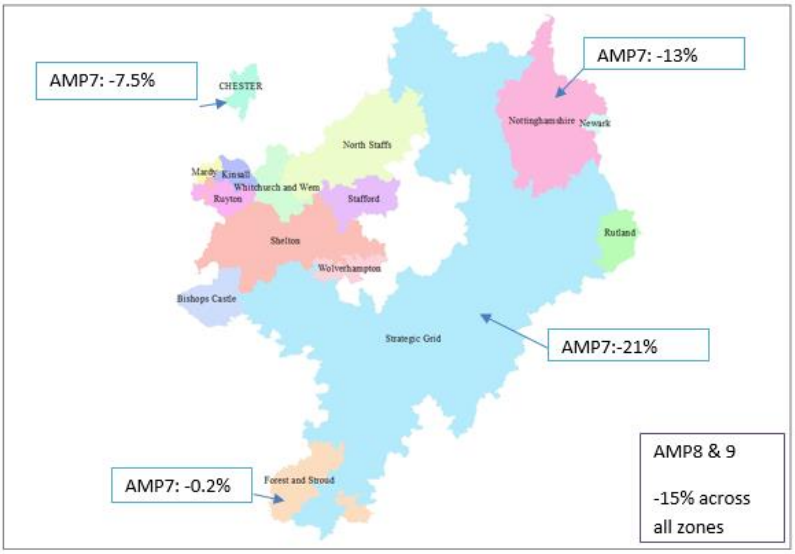


Figure B4.7 Long term leakage profile (by WRZ): Option 2 Extending the least whole life cost approach to achieve an overall 15% AMP reduction target for AMP7-9.



Option 2 seeks to balance overall leakage ambition with bill impacts, security of supply and meeting customers' priorities. However, Option 2 does not address the long term leakage reduction challenge that was set by the National Infrastructure Commission (NIC).

<u>Option 3: Beyond AMP8 we adopt the NIC 50% target, and use it to set our innovation ambition</u>
<u>This builds on the expanded leakage reduction targets described in Option 2.</u>

Option 3 is the approach we are adopting in our final WRMP. Option 3 sets top down AMP8, AMP9, AMP10 and AMP11 reduction targets based on achieving the 50% leakage reduction challenge set by NIC. Our current least whole-life cost modelling suggests that based on existing leakage reduction technology, costs and performance it would not be cost effective to reduce to these levels. However, we recognise that stakeholders and regulators expect us to prioritise long term leakage reduction and to find innovative ways to drive future performance. Option 3 will require us to increase investment in the leakage technology and innovation required to achieve these levels of performance. Beyond AMP7, these longer term reductions would be distributed across all zones regardless of supply / demand balance needs as demonstrated in Figure B4.8 and B4.9.

Figure B4.8 Long term leakage profile (Company wide): Option 3 – Achieving the NIC's 50% leakage reduction target over 25 years.

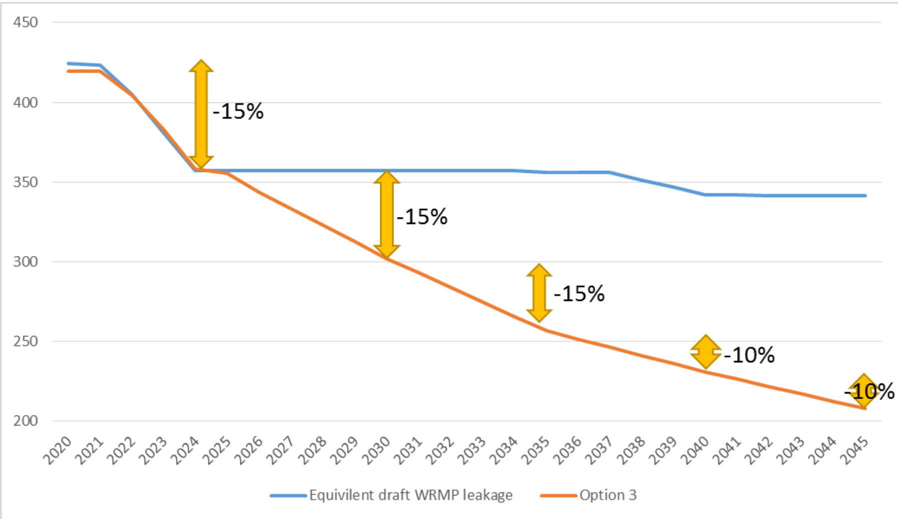
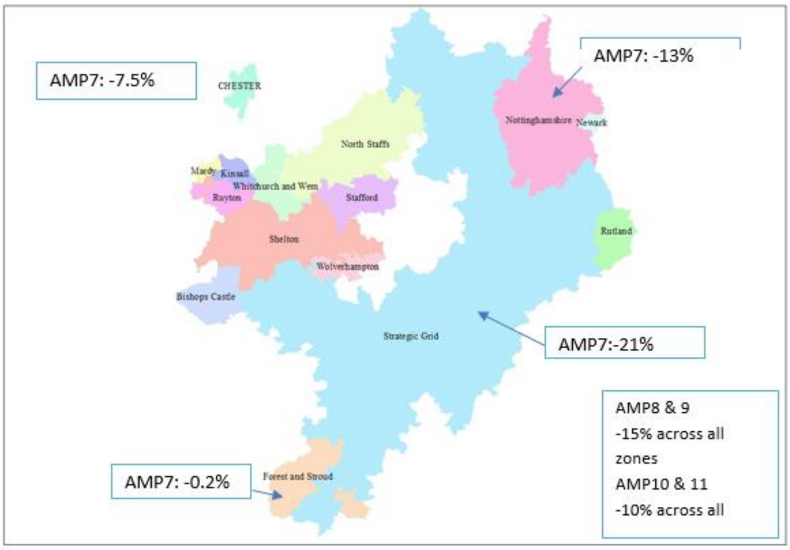


Figure B4.9 Long term leakage profile (by WRZ): Option 3 – Achieving the NIC's 50% leakage reduction target over 25 years.



Option 3 presents an ambitious approach to leakage reduction that is not limited to WRZs with a projects supply / demand balance deficit.

Option Selection Process

Based on the feedback from stakeholders and our ongoing engagement with regulators, Option 3 is our new recommended long term leakage reduction profile and will be included in our final WRMP. These leakage reduction targets will drive our leakage innovation thinking and mean we need to find new ways of delivering a step change in leakage performance. Our new AMP by AMP leakage reduction numbers are shown in Table B4.4. Note these numbers are pre-leakage convergence data changes, and are annual average targets.

Table B4.4 Recommended leakage targets for our final WRMP & PR19 performance commitment.

	2020	2025	2030	2035	2040	2045
Total Leakage (Ml/d)	420	355	302	257	234	207
Percentage Reduction	-	15%	15%	15%	10%	10%

B4.3 Our future approach to leakage management

Our long term leakage ambitions and our customers' wider expectations mean that innovation in leakage reduction will be crucial to our ability to deliver these reductions. We believe that in a world of rapid change and increasing uncertainty, innovation is critical if we are to drive better outcomes for our customers, our people, our investors and society. In AMP6 we've embraced new opportunities from an outcomes based regulatory framework and made a step change in our approach to innovation – the model we use, the resources we dedicate to it, and a culture that inspires our people to innovate every day.

We understand that challenges posed by such stretching leakage targets mean that traditional leakage management techniques are unlikely to offer cost effective ways of delivering the required reductions. We also understand that with any new innovation there is an inherent risk involved in the new approach being able to deliver the expected benefits. We have, therefore, developed a balanced approach to leakage reduction in the future that embraces new technologies whilst maintaining some more traditional leakage management approaches.

We will continue to prioritise proactive renewals of the asset base, pressure management and network optimisation as ways to prevent increases in leakage. We will use a combination of more traditional activities such as Pressure Management Valve (PMV) installation and optimisation along more innovative activities, such as addressing transient pressure waves.

The biggest contributor to our current leakage performance is our ability to prevent and become aware of network failure. We have developed initiatives that will focus on reducing network bursts and improve our awareness time to allow for faster intervention on the network before customer are impacted. To address this challenge we are planning to adjust our current operational model and techniques through a combination of increasing our operational effectiveness by introducing new technology (such as fixed acoustic networks and high density pressure logging) and continuous improvement in our processes.

Both fixed acoustic networks and high density pressure logging technology are being implemented to reduce the time for us to become aware of a leak and improve the localisation of the leak – thereby reducing both the lifespan of a leak and the time needed to pinpoint before remedial interventions can be implemented. We believe that a combination of both of these approaches will allow us to gain these benefits across our mixed material pipe network in both urban and rural areas by exploiting the strengths of each technology. The Case Study described in Figure B4.10 demonstrates one of our proactive initiatives to research and mitigate leakage at the root cause level.

We are continually running trials on new leakage technologies such as satellite leak detection and in-pipe detection and repair technology. We assess each technology for both potential benefits and any associated risks. Our openness and experience of evaluating new technologies will allow us to quickly implement new leakage reduction technologies into our leakage reduction strategy in a controlled and measured way. This will ensure our customers are protected alongside delivering our ambitious leakage reduction program.

Figure B4.10 Case Study: Reducing Transient Pressure Waves

Case Study: Reducing Transient Pressure Waves

Pressure transient waves are short-lived pressure spikes on water companies' networks. They can cause bursts, asset damage and risk contamination from ingress - resulting in water quality issues. Pressure transients are generated by sudden, significant changes in the velocity of flow in the network. They are usually caused by the operation of valves and pumps or large surges in customer demand of water. Research has indicated that 15-20% of bursts on our network are caused by pressure transients. These waves have until relatively recently gone unquantified within the network.

This work was instigated via an Eng.D funding programme with Imperial College and has evolved from the development of a model to prove that a relationship between transient waves and bursts could be established. Now, with a start-up company rolled out from Imperial College, we aim to develop a metric to enable even better quantification and understanding of the relationship between dynamic pressure variability and bursts. This will allow us to assess the risk at each site and the predicted reduction in burst rates.

We have already seen significant benefits of our approach at one of our pumping stations since 2015. Following a £15,000 investment in pump improvements at this station, pressure transient occurrences have been eliminated, resulting in approximately 70% reduction in burst rate. The avoidance of repairs in this case translates to an opex saving of £60,000 per year, providing a three month return on investment as well as reduced risk and a positive impact on customers.

Leakage modelling assumptions

Four our latest WRMP, we have followed a similar leakage modelling process to our previous WRMP14 and previous business plan PR14, albeit with updated base data and updated best practice methodology where appropriate. Between publishing our draft WRMP and the publication of our final WRMP our Active Leakage Control (ALC) cost curves have been further updated. While these represent the base costs for achieving our targets, through our PR19 process the final unit costs that we have used in the plan have had further efficiencies applied to them as a result of benchmarking against the industry and PR19 cost efficiency. This will be assessed by Ofwat, the economic regulator, as part of our PR19 Business Planning submission.

A range of options for leakage reduction were considered as part of the WRMP planning process, including:

- Active leakage control (ALC)
- Mains renewal
- Pressure management
- Supply pipe leakage reduction as a result of metering

The costs within the ALC cost curves includes:

- Detection costs
- Detected repair costs
- Leakage savings

We used our Water infrastructure Supply Demand Model (WiSDM) to select the most beneficial programme as described in Appendix E. When WiSDM was operated, the tool had free ability to select a combination of active leakage control, mains renewal and supply-side options to solve any supply / demand balance deficits across our WRZs (after having accounted for the benefits of metering and water efficiency).

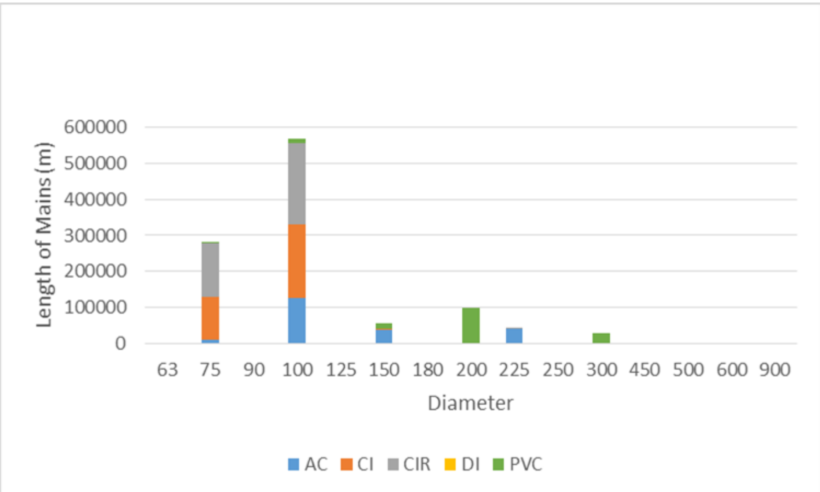
Our WiSDM tool selected a 15% leakage reduction target for AMP7 (pre convergence leakage definition), which was predominantly driven by ALC. Our WiSDM model also selected 1,122km of mains renewal for AMP7.

WiSDM creates an optimal solution to the problem it is presented with using a genetic algorithm; the problem being solved is non-linear. This makes it difficult to identify the driver for specific lengths of mains renewal. The minimum constraints that the WiSDM model must achieve include; maintaining the supply / demand balance; maintain supply interruptions rates, and; maintain burst rates. The burst rate to be maintained is modified to account for 1 in 10 year extreme weather events.

The 1,122km of main renewal selected by WiSDM will, as a minimum, offset the Natural Rate of Rise (NRR) in the network and contribute to maintaining supply interruptions and mains bursts performance commitments. The mains renewal program will prevent the deterioration of NRR, and other activities (Pressure management, ALC, metering) will deliver the leakage improvement, in combination with enhanced monitoring of the network and new technologies.

The WiSDM model was able to test a larger mains renewal program, for example to reduce leakage rather than using ALC, but this was not found to be a cost beneficial solution. The length of mains recommended for replacement is congruent with historic renewal length, giving confidence around deliverability. There is a small, long term risk that a top down decision to reduce the mains renewal program could lead to a growth in the NRR. Figure B4.11 shows the recommended blend of materials and diameters for replacement in AMP 7. Note that the specific mains to be replaced will be identified by our delivery teams using these parameters as a starting point, but with the ability to calibrate for up to date information.

Figure B4.11 AMP7 proposed mains renewal length by diameter and material



All costs that we used for mains repairs, mains renewal activity and additional repairs are based on our latest unit cost data. The same PR19 cost efficiency and benchmarking has been used on these interventions.

Environmental and social costs of leakage interventions have been included in the optimisation of our WRMP, and the specific values are reported in the WRMP data tables for each water resource zone (WRZ). These tables includes the AIC and AISC of the leakage interventions in each WRZ, and so the materiality can be assessed. These costs include:

- Congestion
- Additional repairs
- Ongoing costs
- Carbon ALC cost.

The methodology remains consistent with the work that we completed for PR14 and WRMP14.

Supply pipe leakage

Household metering is part of our demand management strategy, through which we expect to realise benefits in the form of reduced consumption and reductions to Underground Supply Pipe Losses (USPL). Our draft WRMP detailed the consumption benefits of household metering but not the USPL reduction benefits. For the final WRMP tables we have adopted and implemented the recently published Environment Agency data tables that contain corrections for capturing USPL benefits in WRMP data Table 6.

The USPL benefits are calculated based on our preferred meter location policy under which the majority of new meters will be externally fitted. Consistent with our annual water balance reporting, we expect to achieve, on average, a lower per property USPL for external meters. Table B4.5 and Table B4.6 demonstrate our expected metering locations and average 'per property' USPL assumptions.

Table B4.5 Metering location assumption:

Metering location split	
Internal	10%
External – existing boundary box	23%
External – without boundary box	67%

Table B4.6 USPL per property:

Metering type	
Externally Measured Household	24.09
Internally Measured Household	26.91
Unmeasured Household	26.91

Table B4.7 shows the reduction in household USPL from metering by water resource zone that are included in our final WRMP data tables. The WRZ saving aligns with the number of meters fitted in the WRZ each year.

Table B4.7 Forecast USPL Reduction by WRZ

ANNUAL USPL REDUCTION Ml/d	2020 -2021	2021 -2022	2022 -2023	2023 -2024	2024 -2025	2025 -2026	2026 -2027	2027 -2028	2028 -2029	2029 -2030	2030 -2031	2031 -2032	2032 -2033	2033 -2034
Bishops Castle										-0.01				
Forest & Stroud						-0.03	-0.03	-0.01						
Kinsall										-0.01				
Llandinam & Llanwrin											-0.02			
Mardy										-0.01				
Newark					-0.02									
North Staffs			-0.04	-0.11	-0.11									
Nottingham	-0.11	-0.15	-0.13	-0.09	-0.08									
Rutland						-0.01								
Ruyton										-0.01				
Shelton								-0.04	-0.09	-0.08				
Stafford						-0.03								
Strategic grid					-0.03	-0.24	-0.24	-0.25	-0.25	-0.25	-0.39	-0.28	-0.17	-0.07
Whitchurch & Wem										-0.01				
Bishops Castle							-0.05	-0.05	-0.02					
Company total	-0.11	-0.15	-0.17	-0.20	-0.24	-0.32	-0.32	-0.35	-0.35	-0.35	-0.40	-0.28	-0.17	-0.07

B5 Baseline demand projections

Chapter B1 to B4 explain how we build the components of our baseline projections of demand for water and total distribution input for the next 25 years. Chapter B5 summarises baseline projections used in our final WRMP.

B5.1 Water Resource Zone baseline demand projections

The general trends in the baseline demand projections across all WRZs are:

- Measured PCC and unmeasured PCC to modestly decline over the forecasting period
- Measured water delivered to rise as new household property consumption and meter optant customer consumption is added to this category
- Unmeasured water delivered to decline as customers opt to have a meter installed
- Leakage to remain flat to 2045 at the end of AMP6 level in each WRZ (this is what is required in a baseline forecast)

The following series of charts show the baseline PCC forecast and baseline dry year distribution input forecast with components of the demand forecast.

Bishops Castle zone

Figure B5.1: Bishops Castle baseline dry year PCC

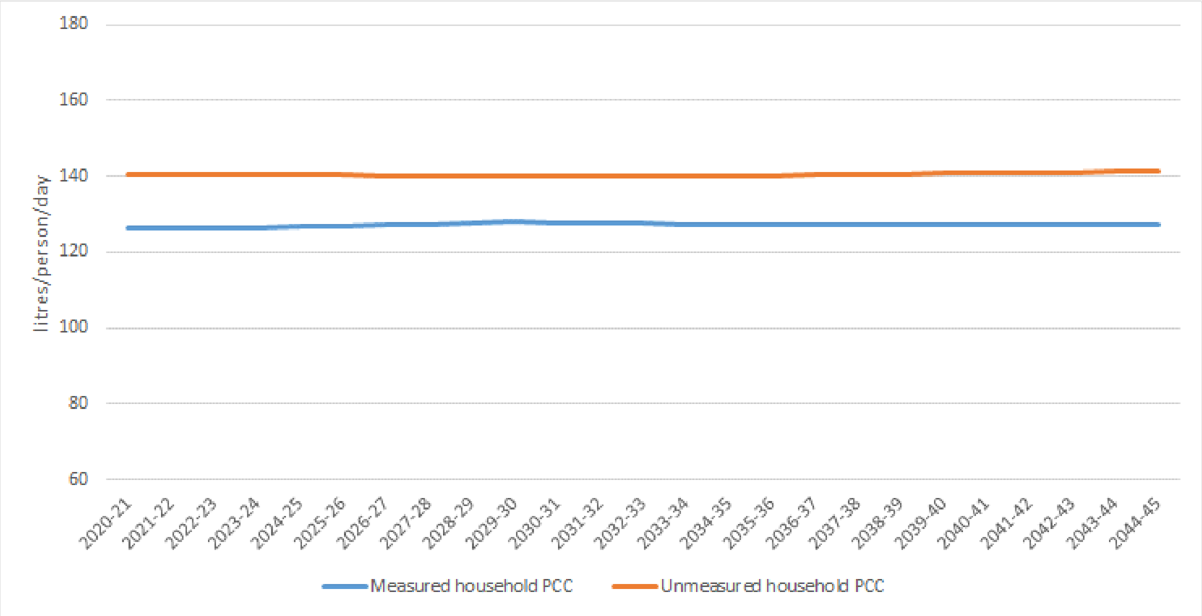
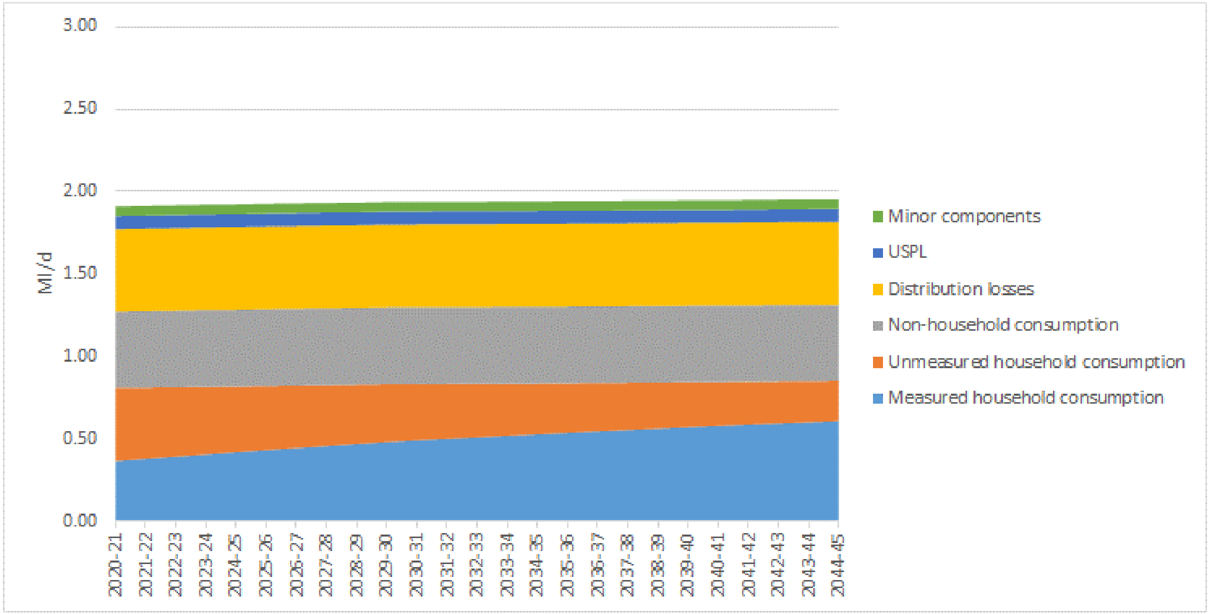


Figure B5.2: Bishops Castle baseline dry year DI



Forest & Stroud zone

Figure B5.3: Forest & Stroud baseline dry year PCC

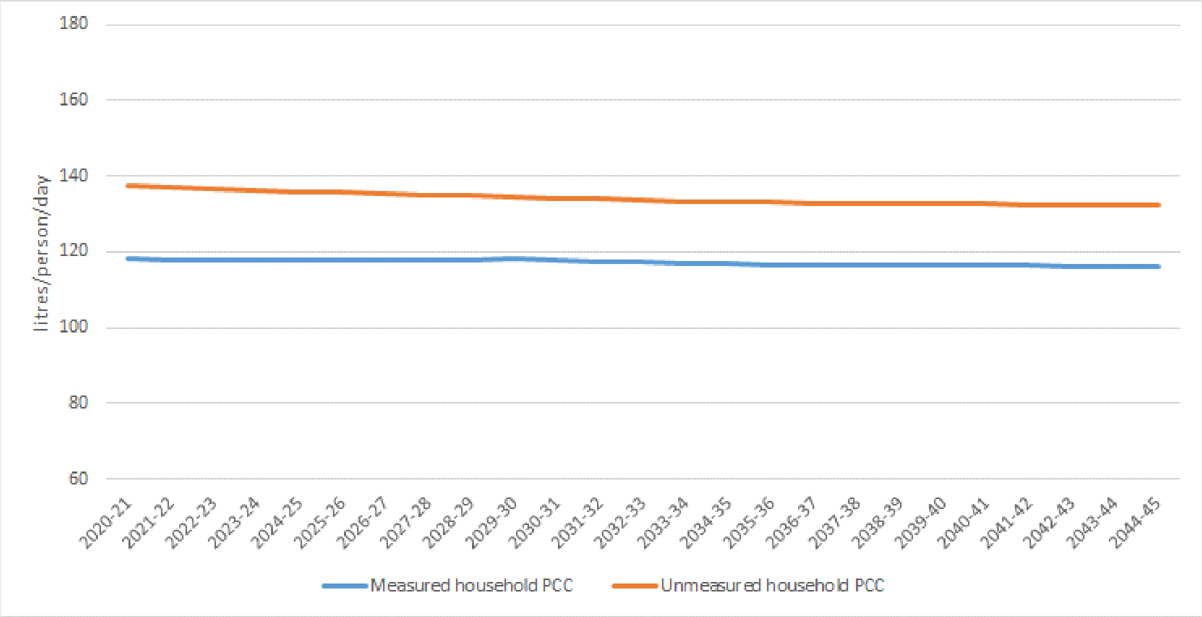
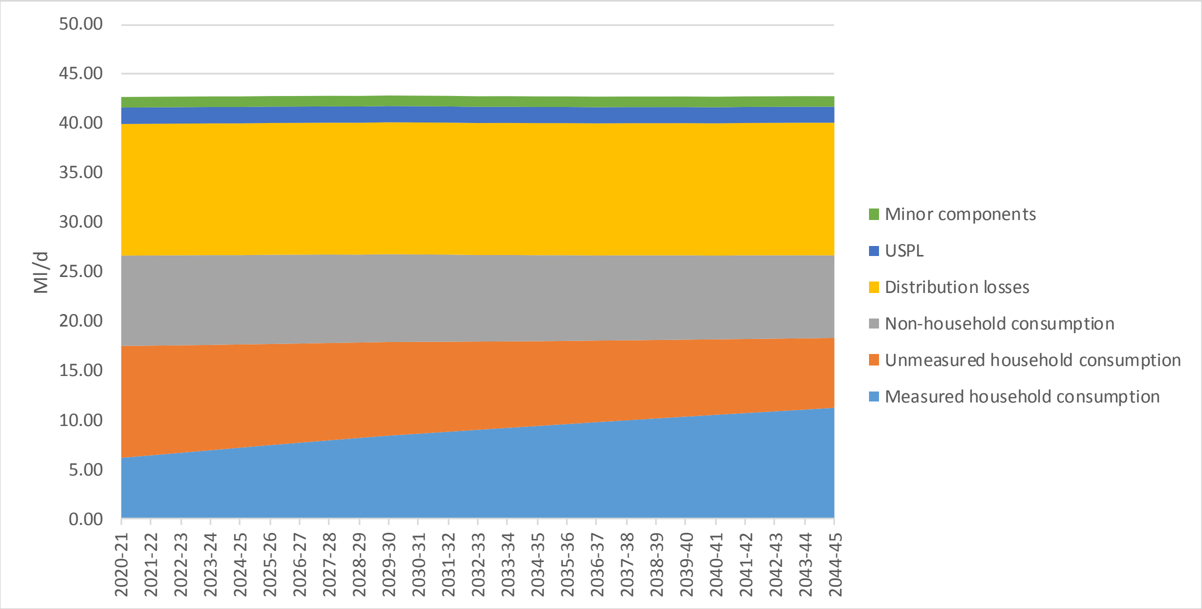


Figure B5.4: Forest & Stroud baseline dry year DI



Kinsall zone

Figure B5.5: Kinsall baseline dry year PCC

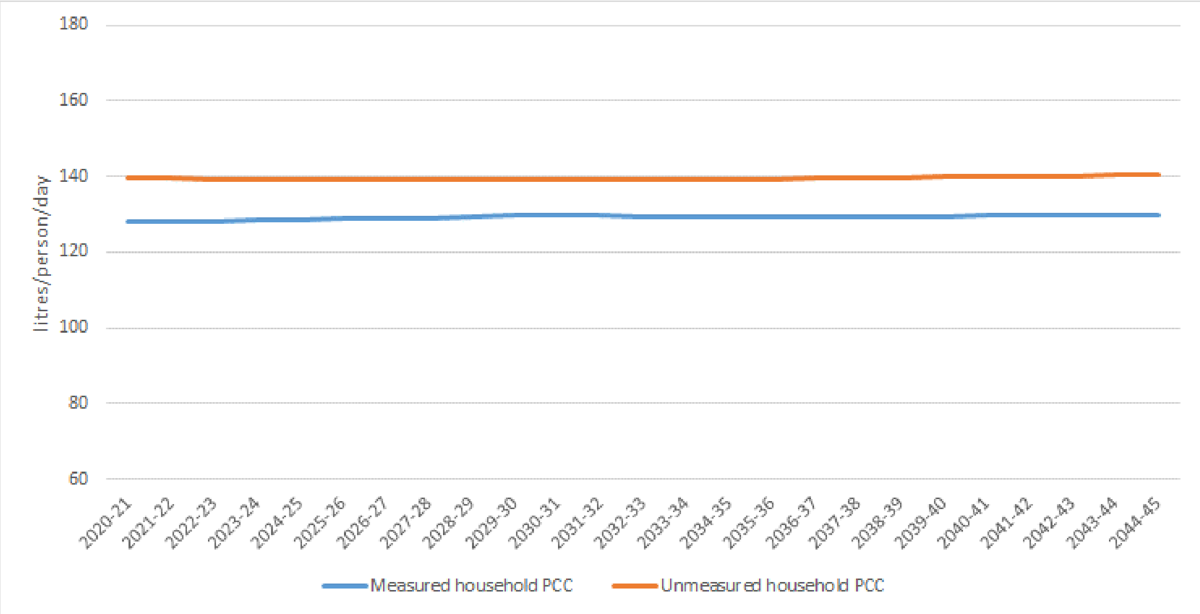
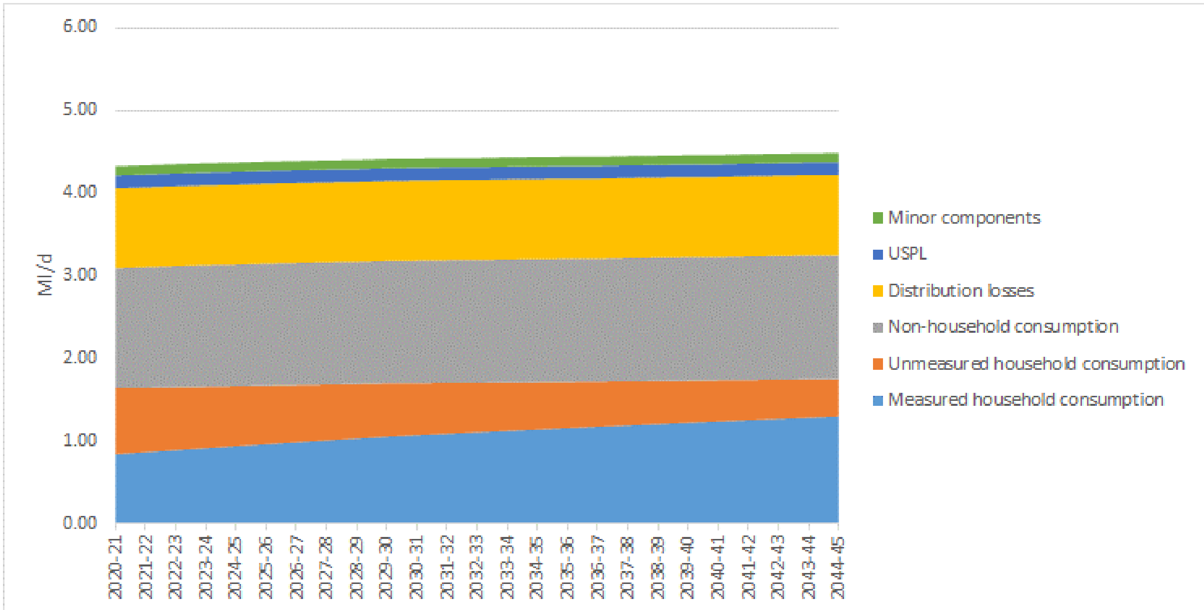


Figure B5.6: Kinsall baseline dry year DI



Mardy zone

Figure B5.7: Mardy baseline dry year PCC

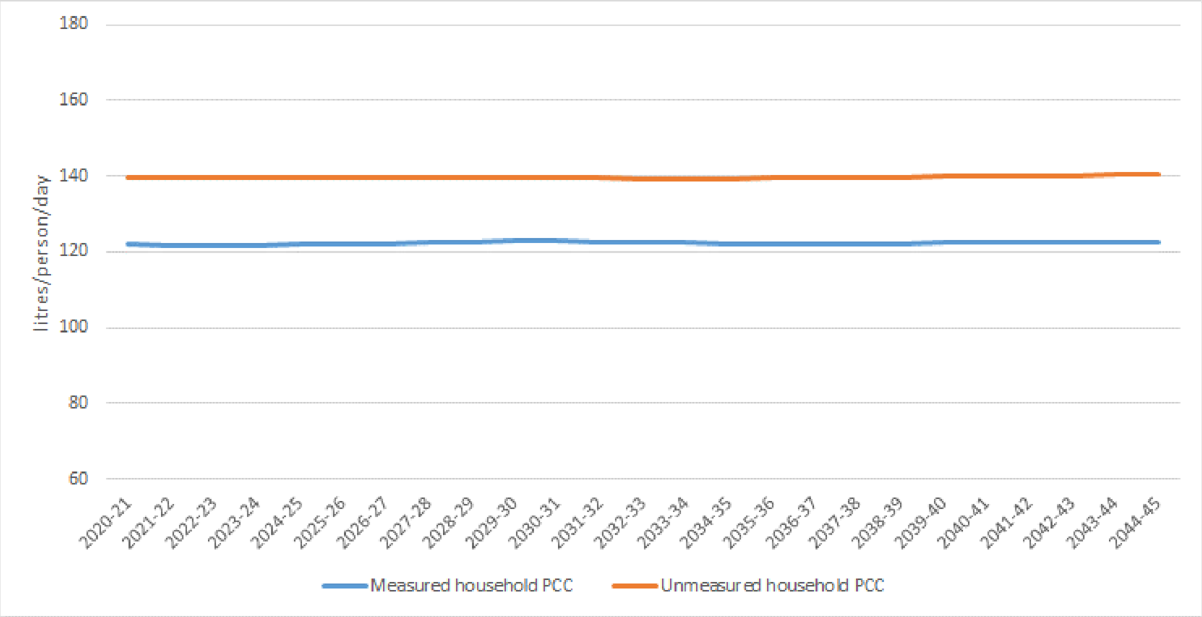
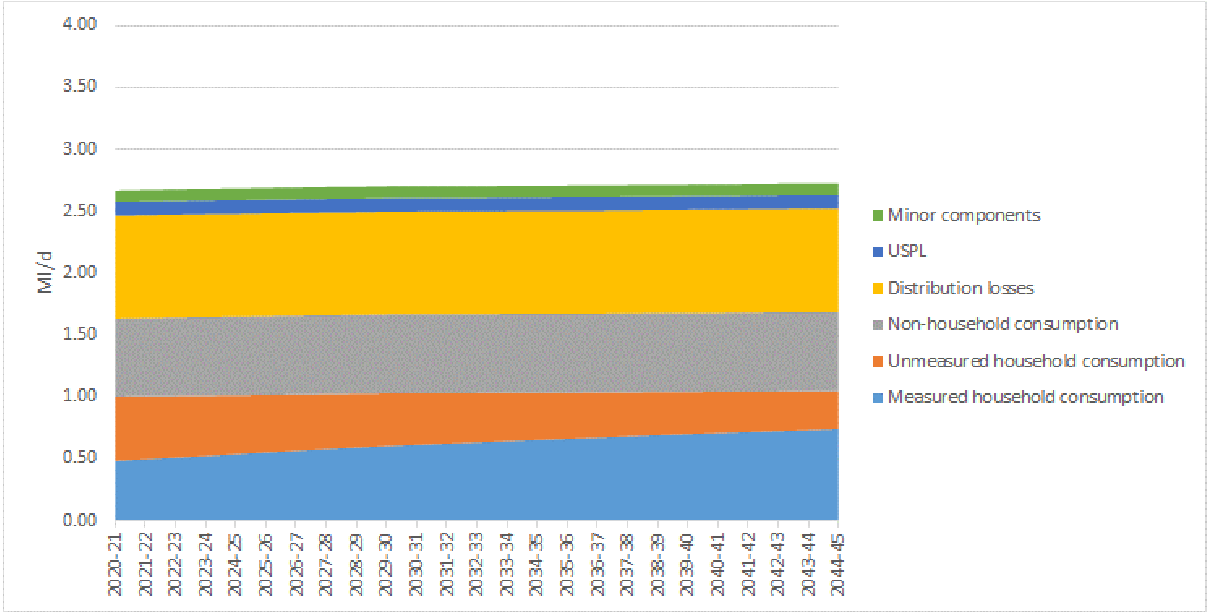


Figure B5.8: Mardy baseline dry year DI



Newark zone

Figure B5.9: Newark baseline dry year PCC

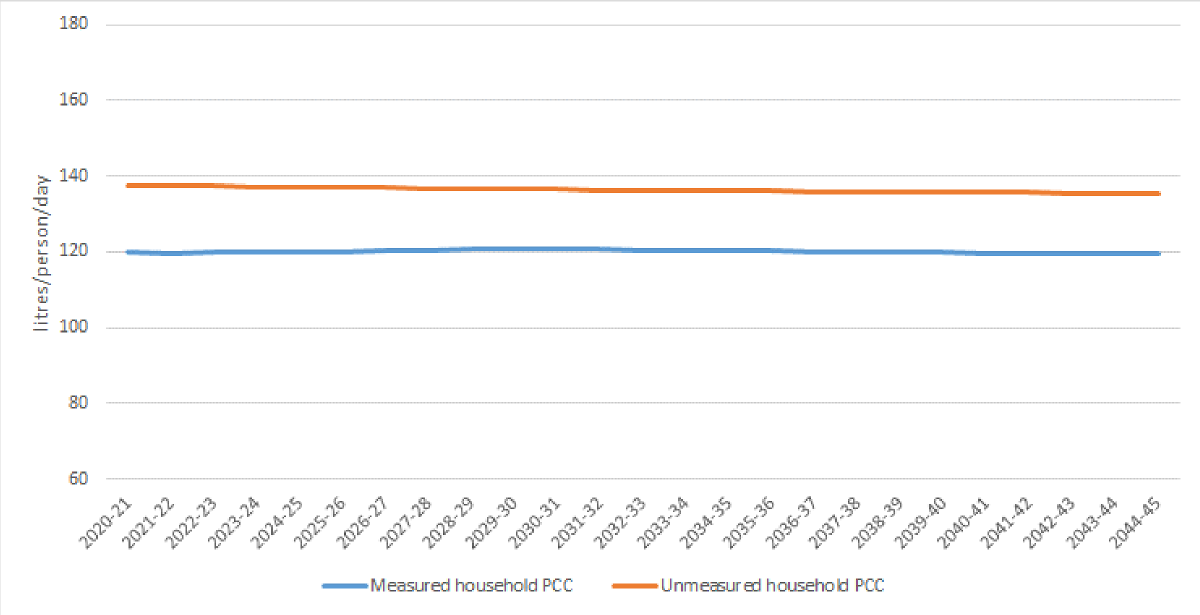
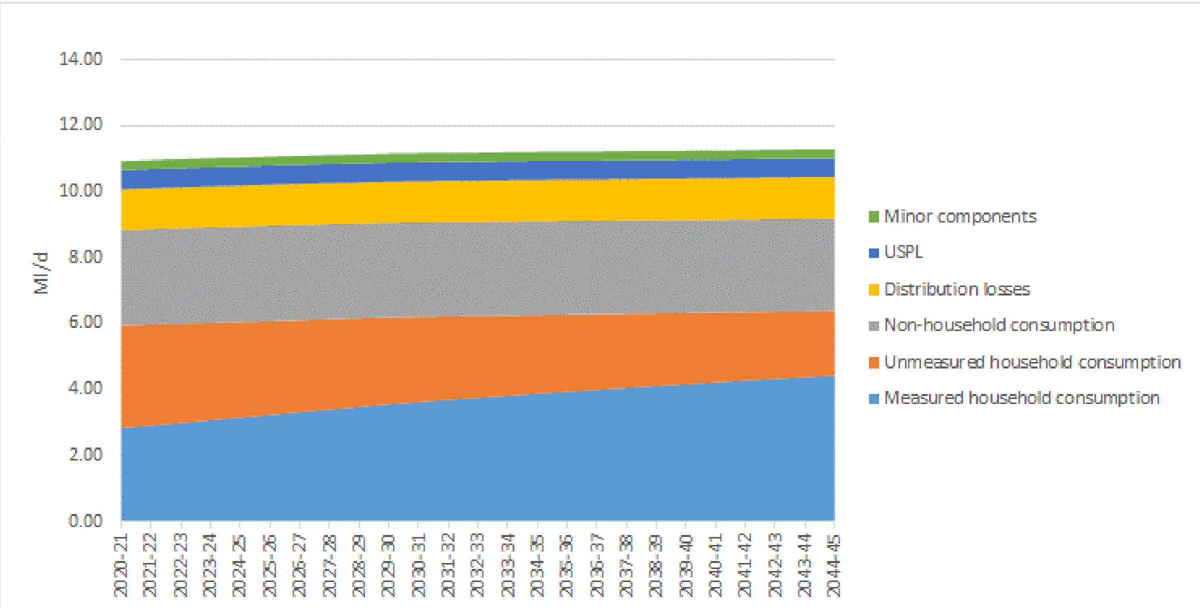


Figure B5.10: Newark baseline dry year DI



North Staffordshire zone

Figure B5.11: North Staffordshire baseline dry year PCC

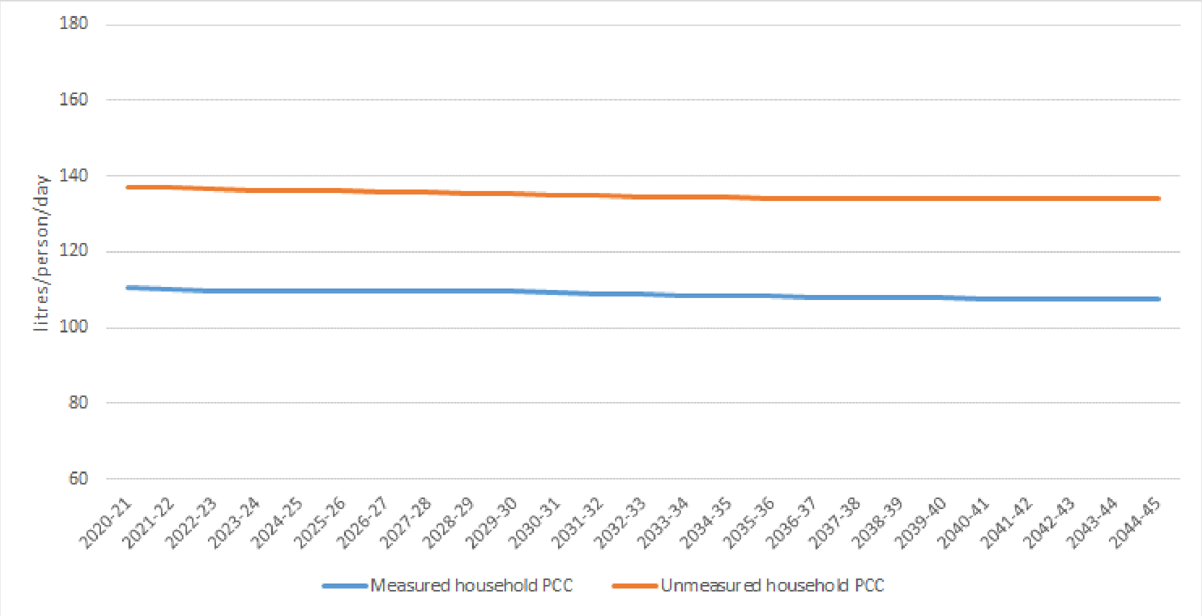
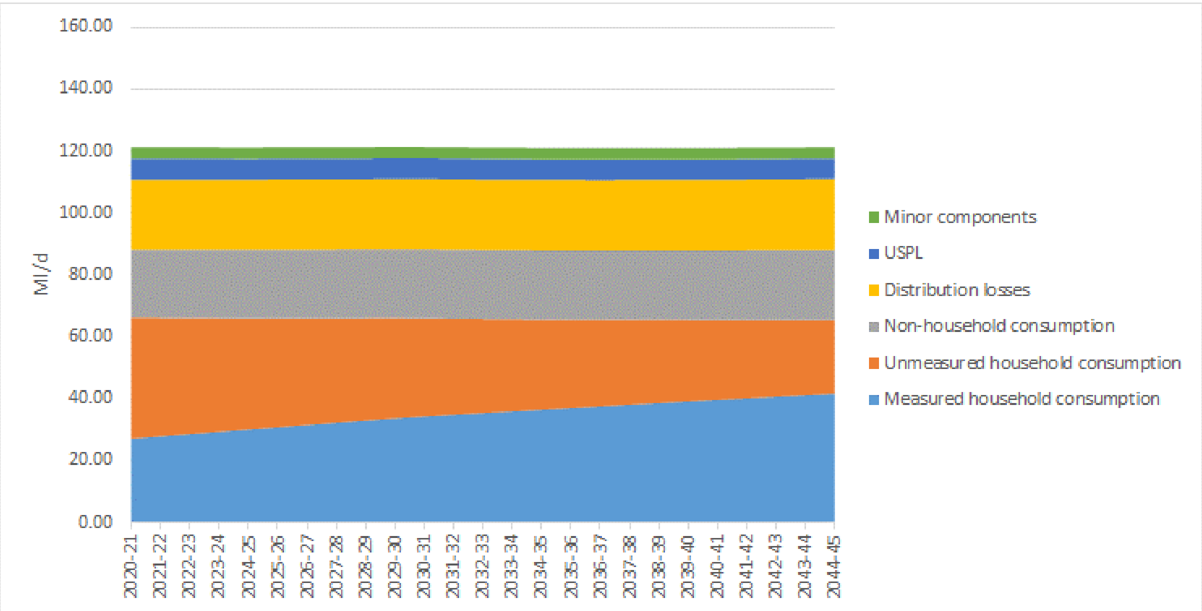


Figure B5.12: North Staffordshire baseline dry year DI



Nottinghamshire zone

Figure B5.13: Nottingham baseline dry year PCC

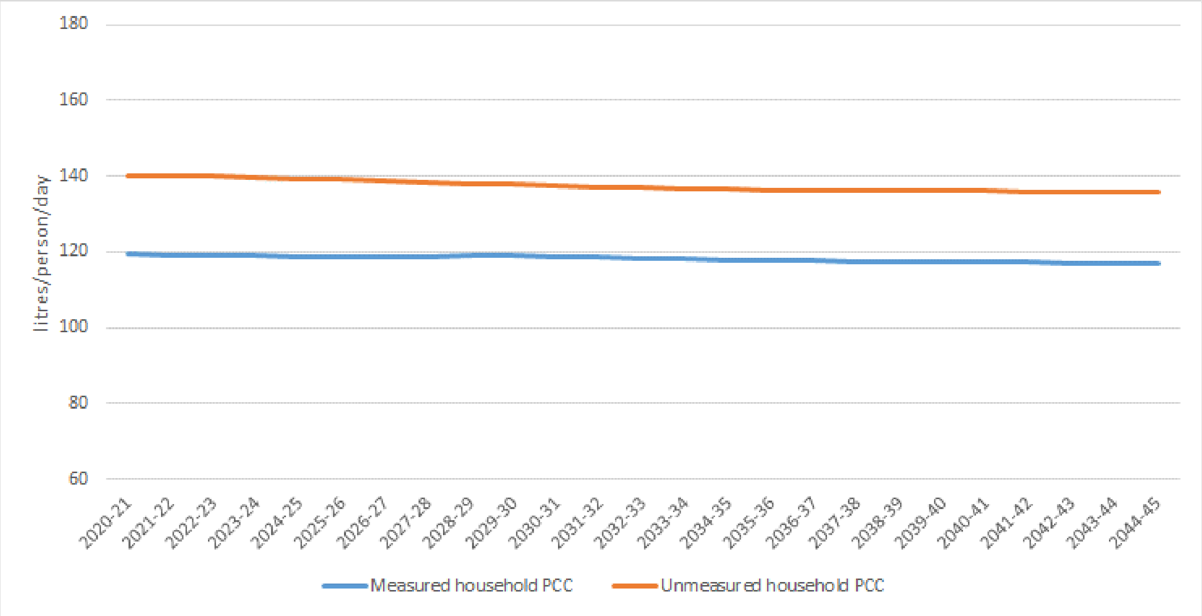
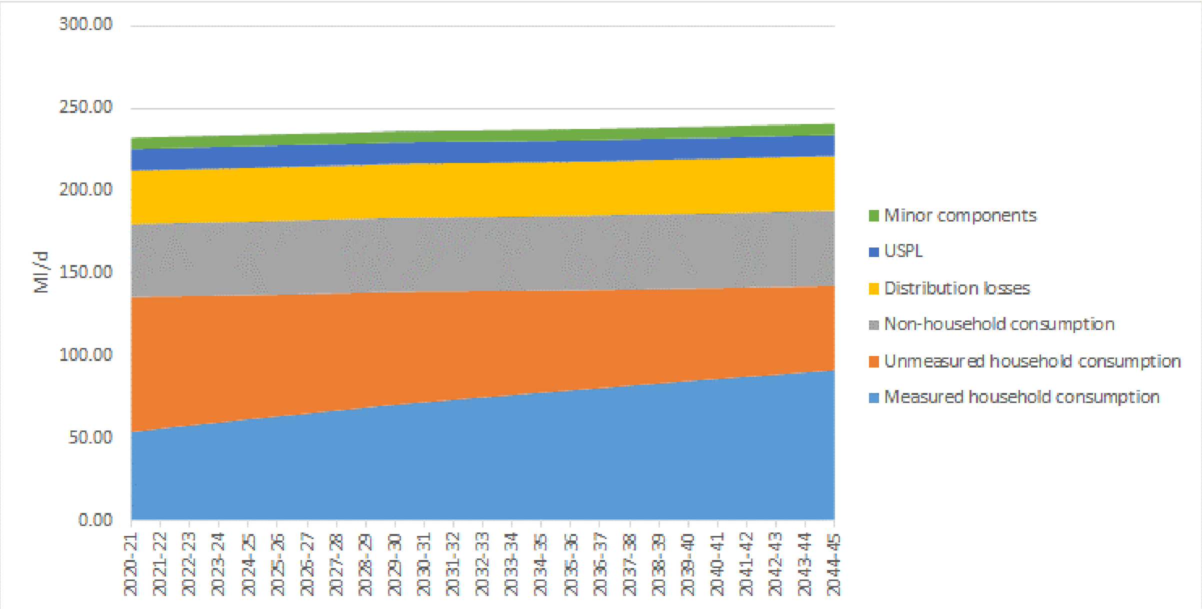


Figure B5.14: Nottingham baseline dry year DI



Rutland zone

Figure B5.15: Rutland baseline dry year PCC

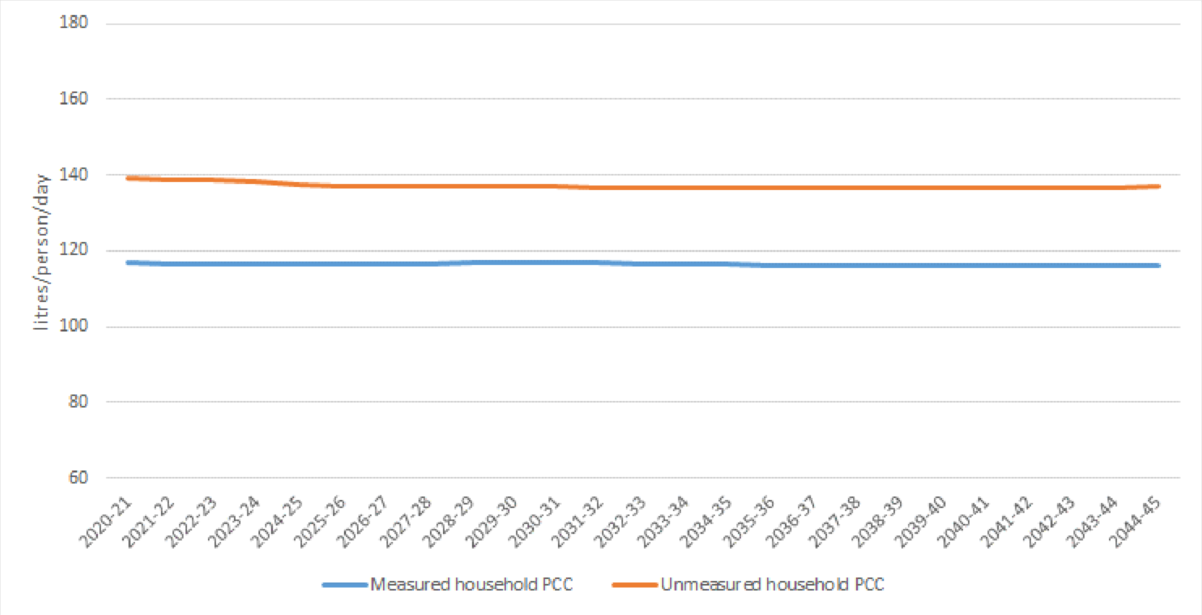
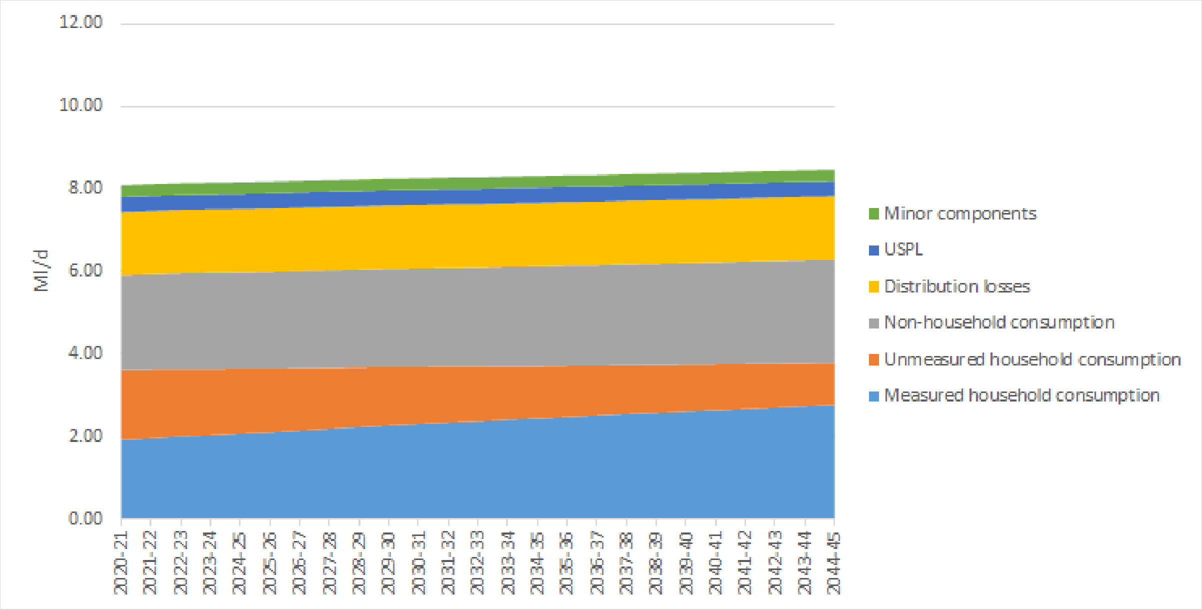


Figure B5.16: Rutland baseline dry year DI



Ruyton zone

Figure B5.17: Ruyton baseline dry year PCC

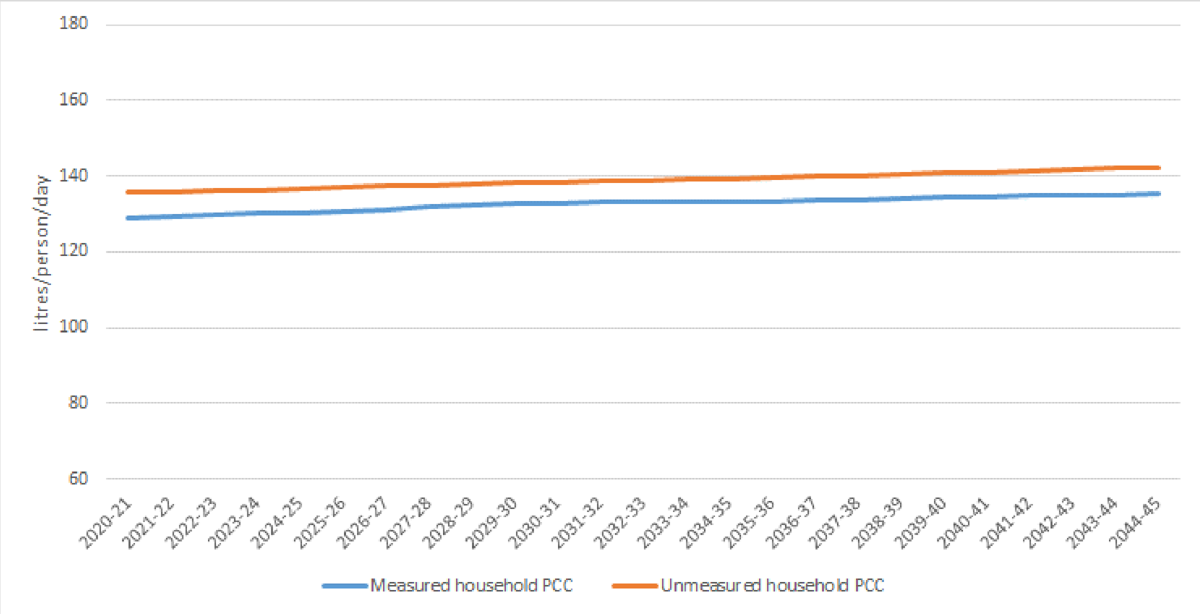
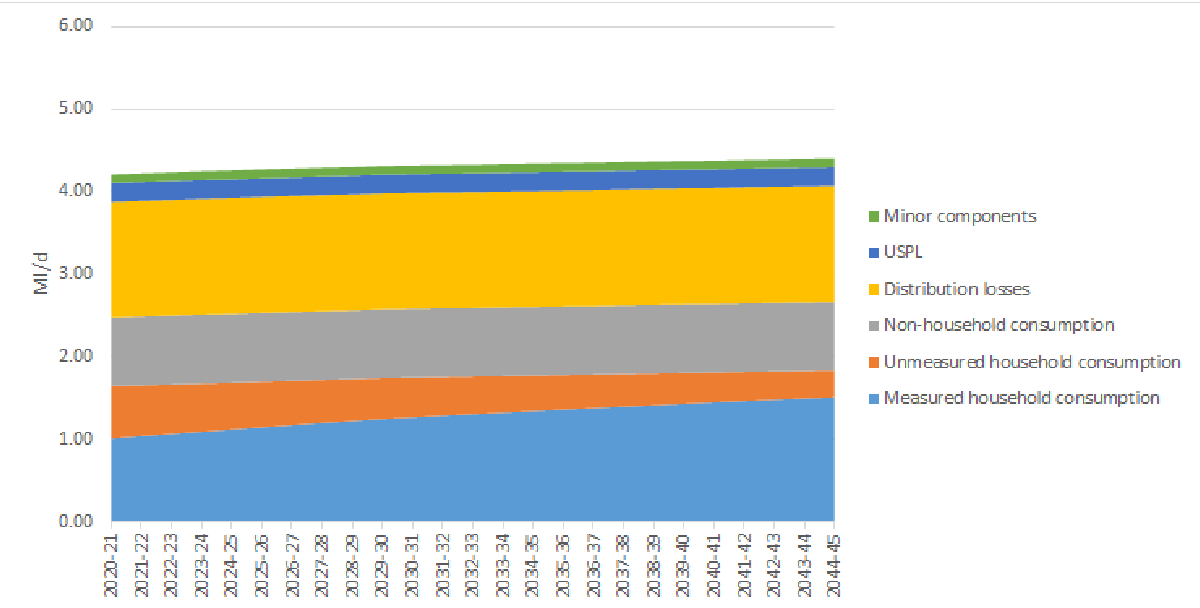


Figure B5.18: Ruyton baseline dry year DI



Shelton zone

Figure B5.19: Shelton baseline dry year PCC

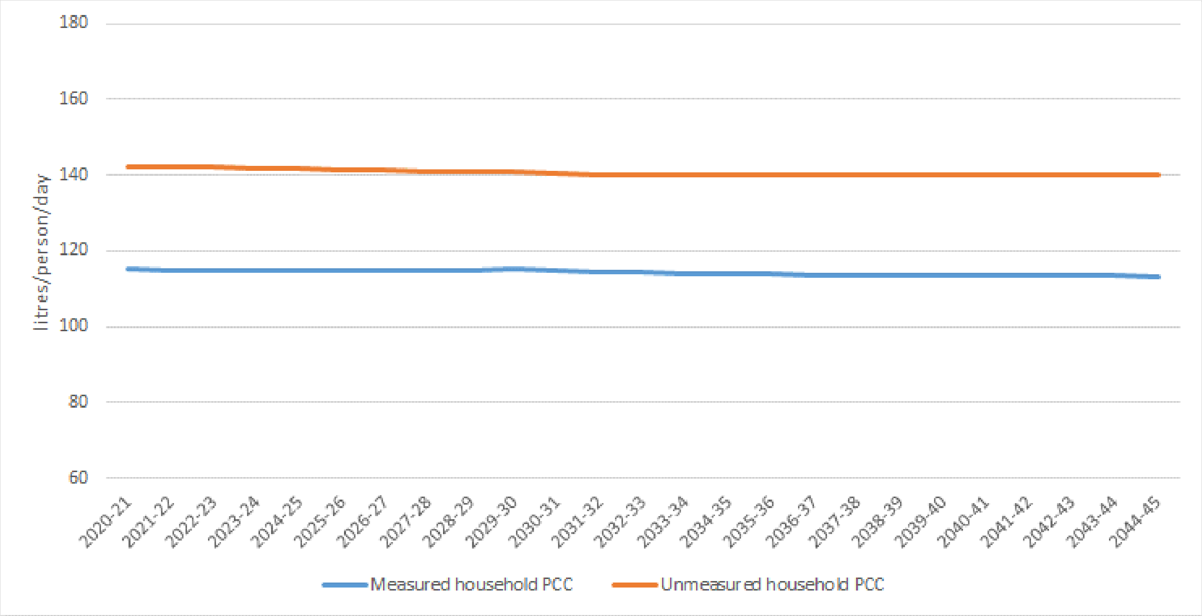
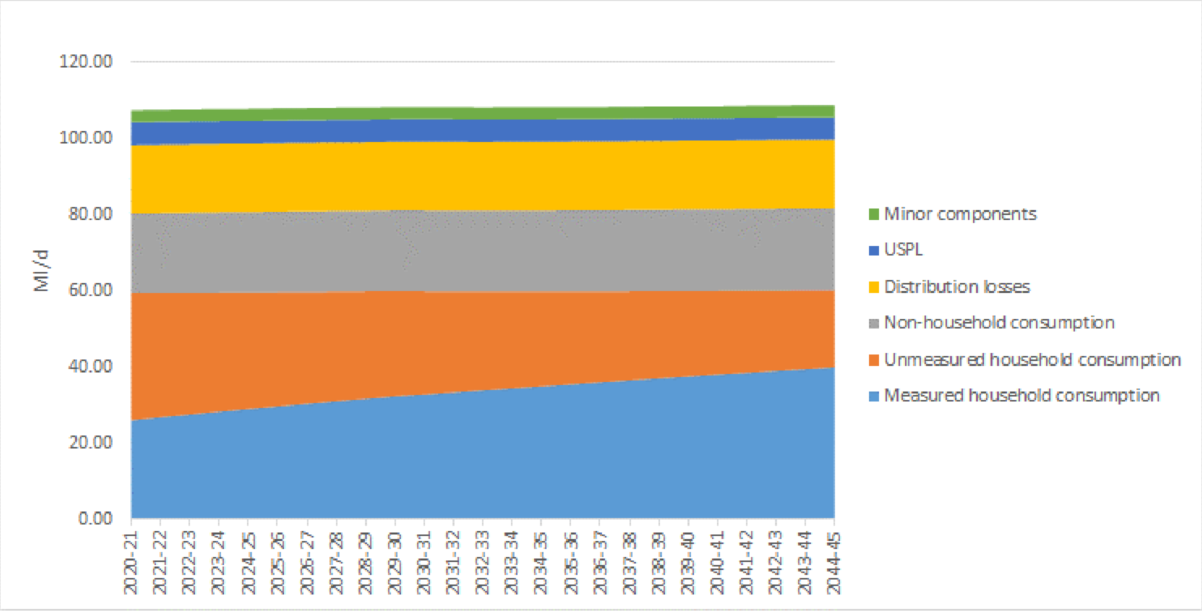


Figure B5.20: Shelton baseline dry year DI



Stafford zone

Figure B5.21: Stafford baseline dry year PCC

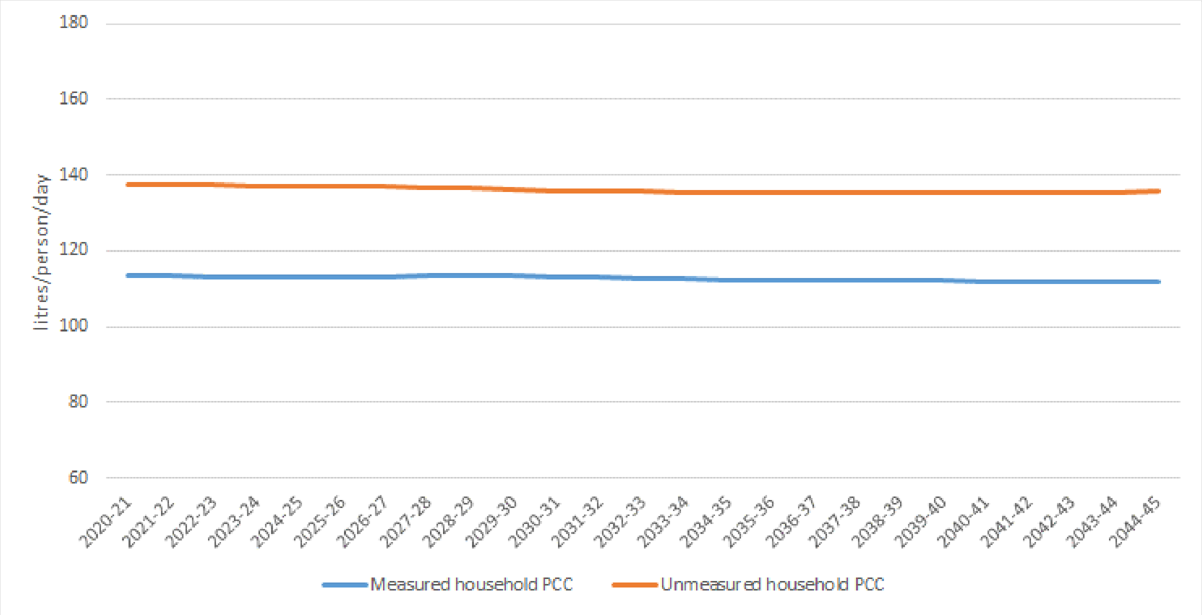
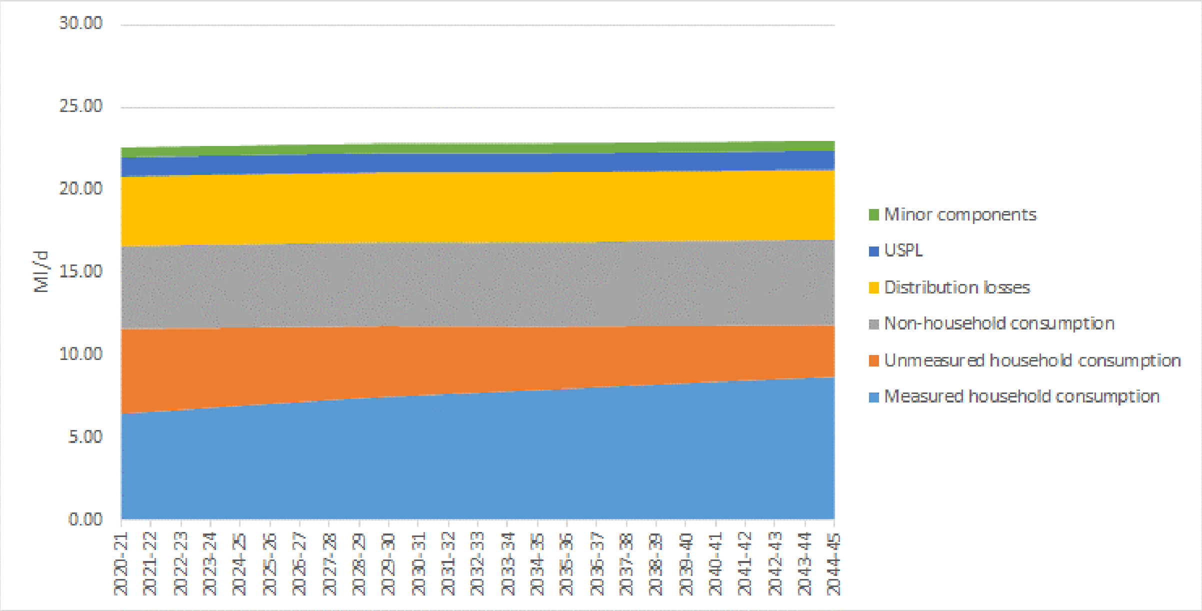


Figure B5.22: Stafford baseline dry year DI



Strategic Grid zone

Figure B5.23: Strategic Grid baseline dry year PCC

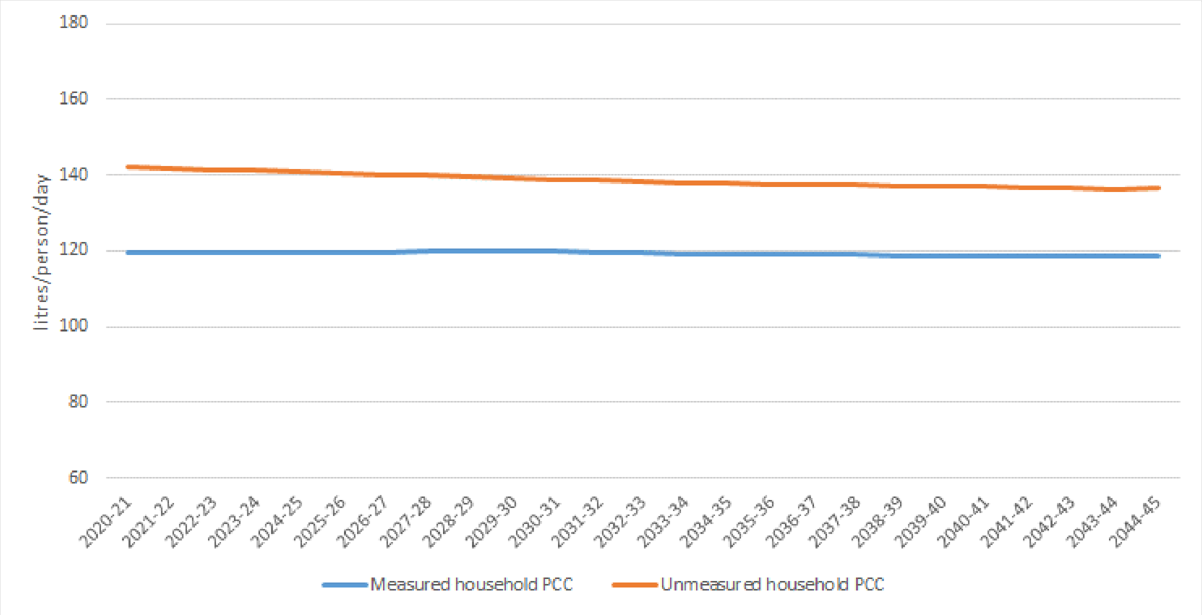
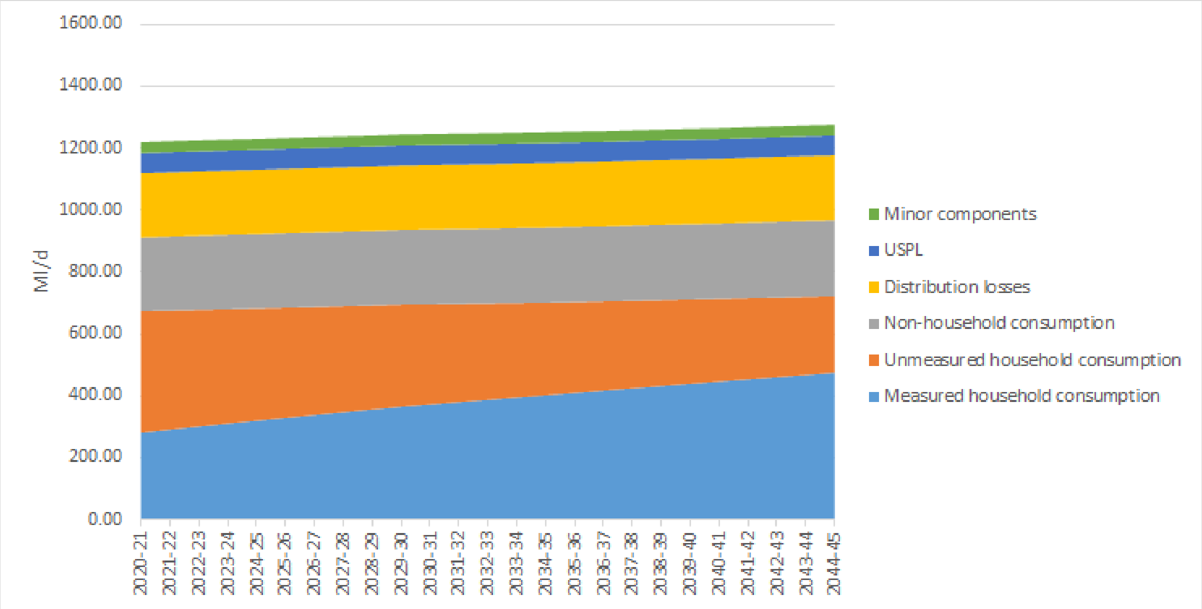


Figure B5.24: Strategic Grid baseline dry year DI



Whitchurch & Wem zone

Figure B5.25: Whitchurch & Wem baseline dry year PCC

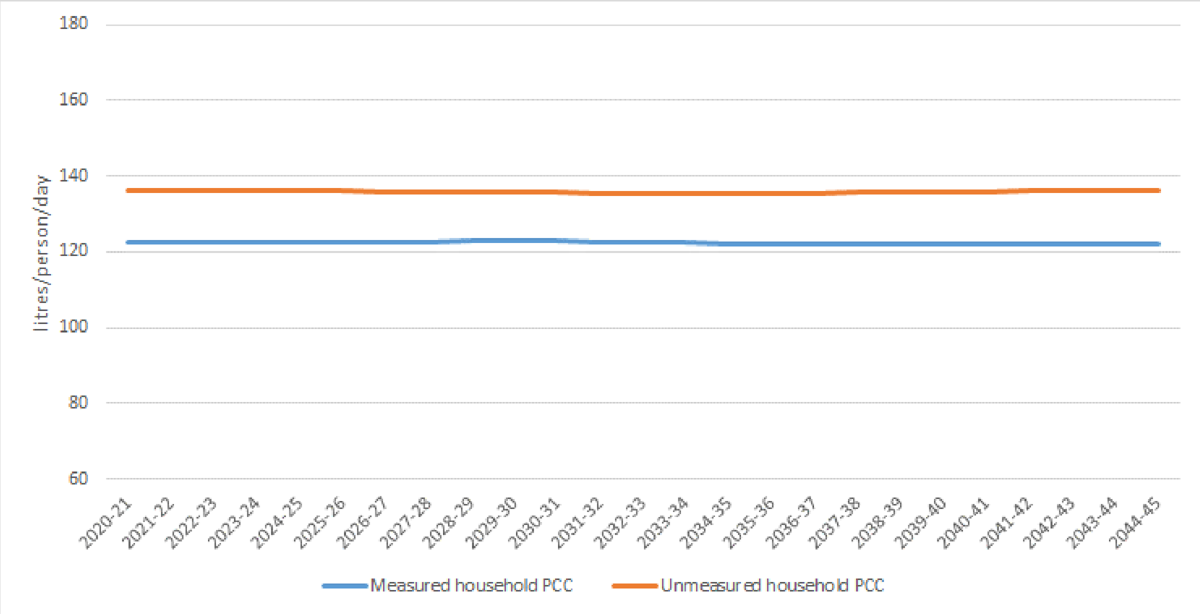
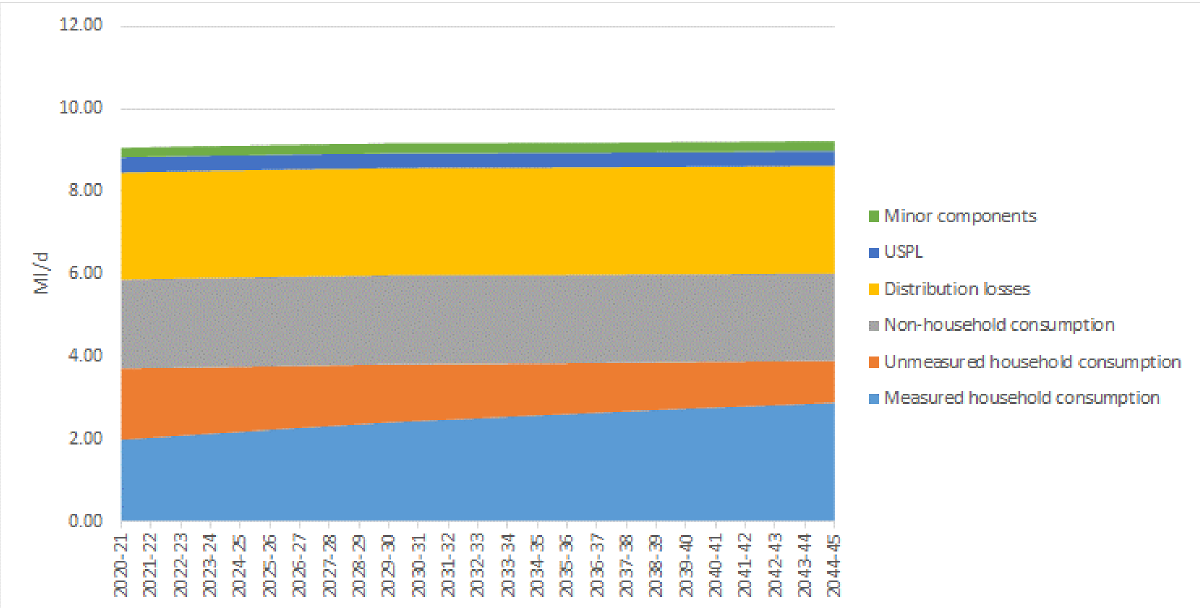


Figure B5.26: Whitchurch & Wem baseline dry year DI



Wolverhampton zone

Figure B5.27: Wolverhampton baseline dry year PCC

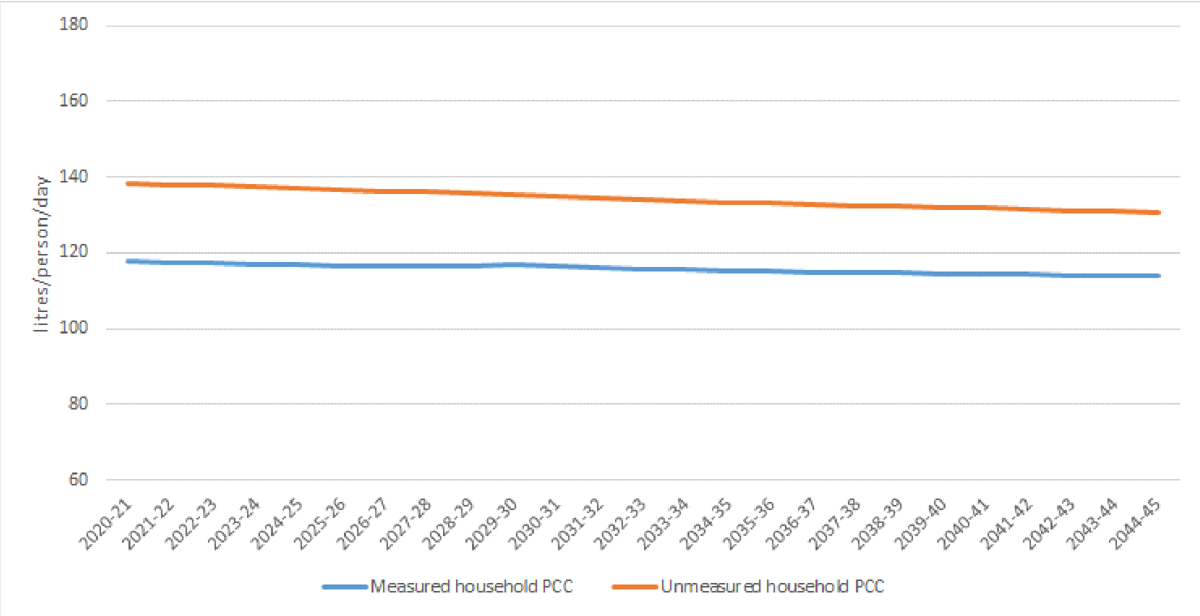
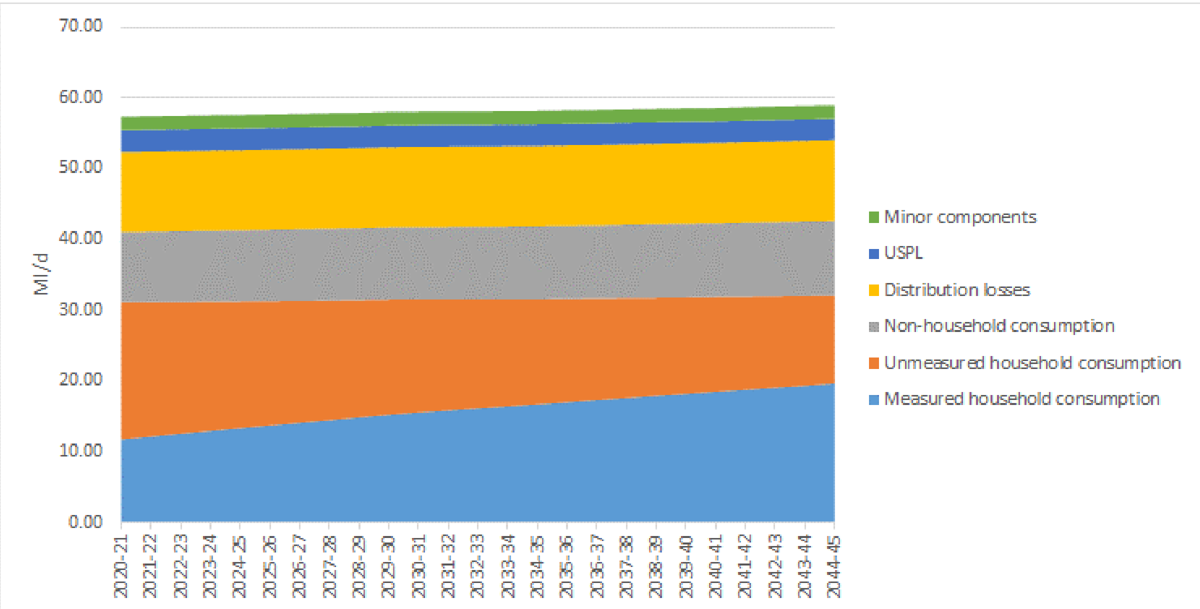


Figure B5.28: Wolverhampton baseline dry year DI



B5.2 Baseline water efficiency activities

Our baseline demand projections incorporate the ongoing benefits of our baseline water efficiency activities. During AMP 6, we have set ourselves the target to deliver 18 Ml/d water savings through our baseline water efficiency work.

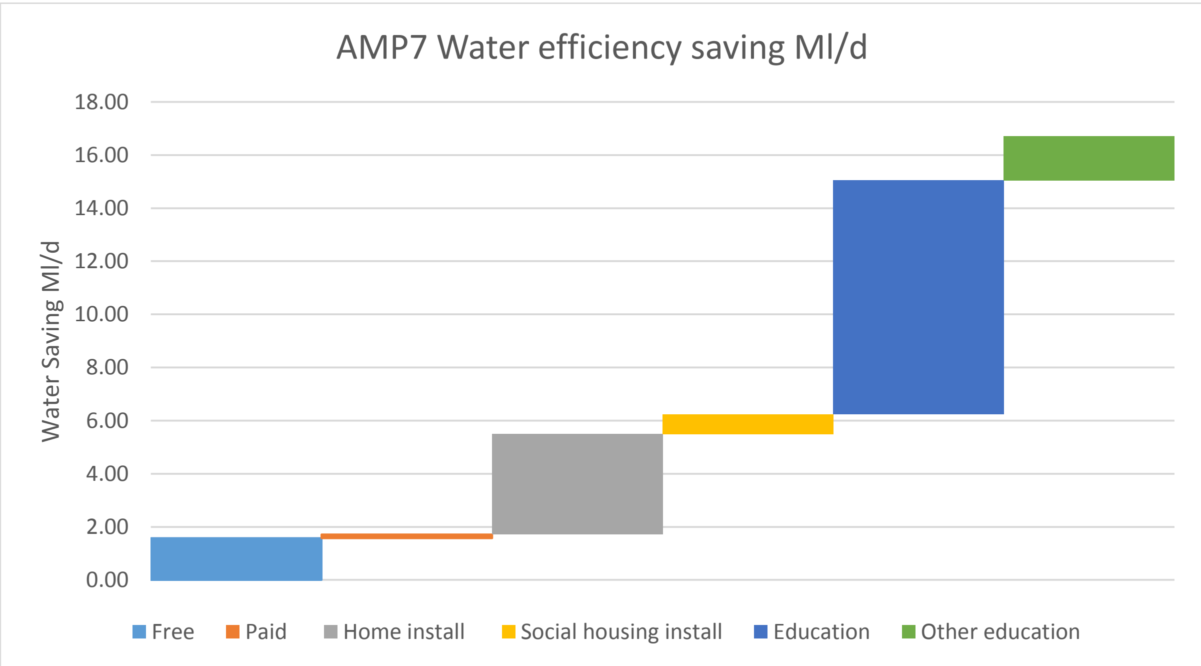
For AMP 7, we have made a decision to undertake as a minimum the same level of activity to meet our on-going statutory water efficiency duty as well as opportunities to deliver enhanced savings to help meet the supply demand challenge.

In line with our understanding of customer, regulator and Government expectations, we will continue to offer a range of water efficiency services to our customers. We expect the key metrics to deliver on our statutory duty will be:

- Provide information to consumers on how to save water. This includes maintaining our provision of direct engagement with schools and adult groups via our education team.
- Provide a range of water saving products which are free to customers on request.
- Provide discounted higher value water saving products (e.g. water butts, showerheads).
- Improve and increase our links with third parties to form partnerships – internal and external - to take advantage of scheduled visits to promote water efficiency and to retrofit water efficient devices.
- Provide water efficiency advice and access to free water saving devices as part of our free meter optant programme (FrOpt).

In Figure B5.19 below we provide our current expectations of how we will deliver our baseline activity, further explanation of these activities and our enhanced options are detailed in Appendix D. Over time the balance between free products, product installation, and education may change in response to the available opportunities and customer expectations.

Figure B5.29: Breakdown of forecast activity in AMP7



During our development of our WRMP we also actively engaged with all non-household Retailers to gain an understanding of their forecasts for non-household demand and any demand management (water efficiency) activity they have carried out or are planning to implement in the future. Unfortunately, responses from Retailers were limited in detail, with no evidence of any significant demand reduction initiatives delivered to date. Retailers are mostly offering demand reduction initiatives as ‘added value’ services which customers have to pay for, significantly limiting uptake. No Retailers provided any evidence or forecasts of demand reduction, with demand predicted to be stable throughout the planning period. We have continued to seek opportunities to engage Retailers as we develop our final WRMP and have undertaken a research project to explore Retailers’ appetite for collaboration to develop incentives around non-household demand reduction initiatives. We are currently assessing the outputs from this work and we will update our non-household demand projections as and when new intelligence becomes available. We will include the results of our investigations in our final WRMP.