APPENDIX I

Household Demand Forecast

ABSTRACT

Technical appendix for the approach to forecasting household consumption out to 2044/45.

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Overview of Approach

In WRMP14 Portsmouth Water used a Micro-component based approach to forecast demand. For WRMP19 a regression based approach is used to model Unmeasured and Measured Per Household Consumption (PHC) trialling weather variables and features of the customer base. As mentioned in the 'WRMP19 Methods – Household Consumption Forecasting 15/WR/02/9, UKWIR, 2015' guidance, regression models can perform well in the short term but in the longer term wider factors may need to be considered. Portsmouth Water have considered the effect of Water Efficiency outside of the regression models in an approach more consistent with the 'Variable flow' method.

FIGURE 1 : PROCESS OF FORECASTING PHC

Variables

Two Multiple Linear Regression models are developed, one for measured PHC (mPHC) and another for Unmeasured (uPHC). Per Household Consumption (PHC) is modelled rather than Per Capita Consumption (PCC) as it is less sensitive to changes in past assumptions of population and occupancy rates. PCC is later derived by diving the PHC by Unmeasured and Measured occupancy rates.

An appropriate subset of 17 variables for the period 2007/08 to 2016/17 are made available for the Unmeasured and Measured PHC models.

Name	Type	Sample	Source	Description
UHH.Prop	int	246695, 240271, 234532…	June Return	Number of Unmeasured household properties
UHH.Perc.Remain	num	1, 0.974, 0.951, 0.939, 0.918, ...	June Return	% of Unmeasured Households remaining
MHH.Prop	int	27617, 34163, 41069, 47288, …	June Return	Number of Measured household properties
MeterRatio	num	0.112, 0.142, 0.175, 0.204, ...	June Return	No. Measured HH Props/ No. Unmeasured HH Props
Meter.Penetration	num	0.101, 0.124, 0.149, 0.17, …	June Return	No. Measured HH Props/Total HH Props
Meter.Opt.Prop	int	3734, 5219, 5362, 3604 …	June Return	No. meter optants
Meter.Opt.Perc	num	0.135, 0.262, 0.349, 0.…	June Return	No. meter optants/Total No. Measured HH Props
UM.Occ	num	2.51, 2.54, 2.56, 2.56, 2.57, ...	June Return	Unmeasured Occupancy
M.Occ	num	1.56, 1.64, 1.73, 1.79, 1.87, ...	June Return	Measured Occupancy
Company.Occ	num	2.41, 2.43, 2.44, 2.43, 2.44, ...	Experian	Company Occupancy
Reallocation	int	0, 0, 0, 0, 0, 0, 0, 0, 0, 1	Billing System	Dummy variable representing 2015/16 data cleansing exercises
total.rainfall	num	702, 720, 890, 691, 525, ...	Company Data	Total annual rainfall
total.drydays	num	204, 207, 180, 227, 232, ...	Company Data	Total annual dry days
total.sum.rainfall	num	384, 345, 244, 352, 285, ...	Company Data	Total summer rainfall
total.sum.drydays	num	102, 111, 116, 114, 111, ...	Company Data	Total summer dry days
avg.max.temp	num	14.1, 13.2, 13.5, 13.2...	Met Office (HadCET)	Average annual daily maximum temperature
avg.sum.max.temp	num	17.7, 17.8, 18.4, 18, 18.3, ...	Met Office (HadCET)	Average summer daily maximum temperature

TABLE 1: REGRESSION MODEL CANDIDATE VARIABLES

Final Models

The final models are selected based upon two criteria:

1. Akaike information criterion (AIC) - an estimator of the relative quality of statistical models for a given set of data.
2. Plausibility of forecast – Judgement as to whether the forecast in the long term is reasonable given past trends and expectations of future changes in the Portsmouth Water customer base.

Regression Models

The final models are presented below. Both models produce a reasonable 'R squared' score and the models are significant to p=0.05.

Unmeasured PHC

```
Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        412.449      1.458 282.917 1.82e-15 ***
UM.Occ               6.738      1.543   4.366  0.00329 **
total.sum.rainfall  -4.334      1.543  -2.808  0.02621 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.61 on 7 degrees of freedom
Multiple R-squared:  0.7804,   Adjusted R-squared:  0.7177
F-statistic: 12.44 on 2 and 7 DF,  p-value: 0.00496
```

Measured PHC

```
Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)         266.02      30.24   8.795  0.00012 ***
Reallocation         32.28      10.11   3.193  0.01877 *
Meter.Penetration    25.22      30.34   0.831  0.43768
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 8.314 on 6 degrees of freedom
Multiple R-squared:  0.747,    Adjusted R-squared:  0.6626
F-statistic: 8.857 on 2 and 6 DF,  p-value: 0.0162
```

Fit to Historic Data

Figure 2 demonstrates that the models fit well to the historic data.

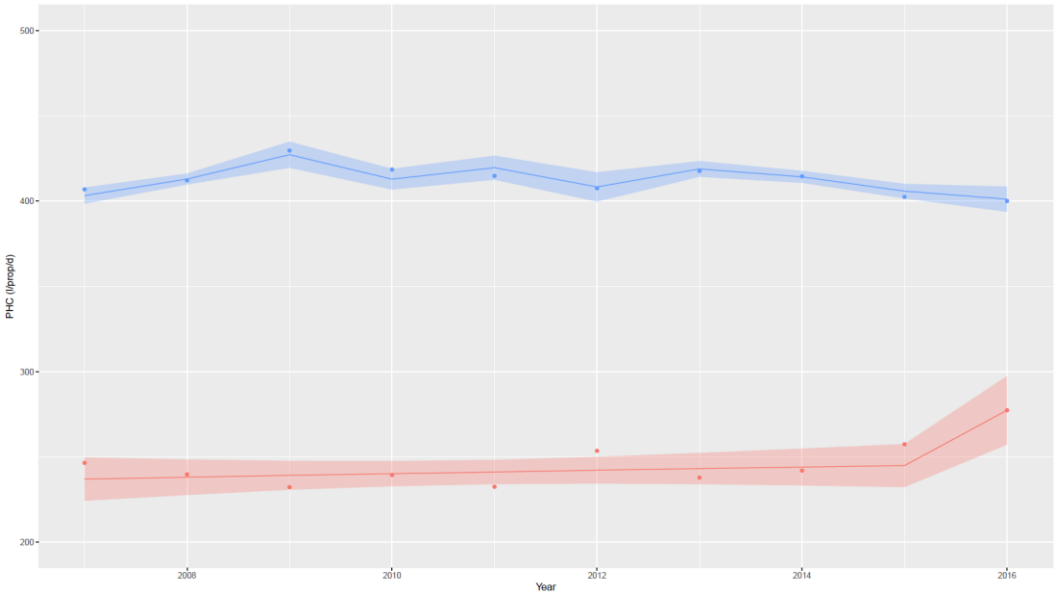

FIGURE 2: PHC FIT TO HISTORIC DATA

Forecasted PHC

In Figure 3 the models are fit to the forecasted data. Weather variables are held notionally as at 2013 which was a recent example of a dry year, these are not assumed to change over the forecast period. Variables relating to changes in the customer base such as 'Meter Penetration' and 'Occupancy use a spreadsheet model based upon new properties and populations and movements between the Unmeasured and Measured customer base. Further detail relating to the movement of customers from Unmeasured to Measured status is detailed further in the 'Occupancy Forecast' appendix.

Notably the prediction interval for the Measured PHC forecast at Q95 is larger than that of the Unmeasured PHC forecast, particularly towards the end of this period. This is because the 'Meter.Penetration' predictor variable increases fairly significantly over time causing the confidence bands to expand with time.

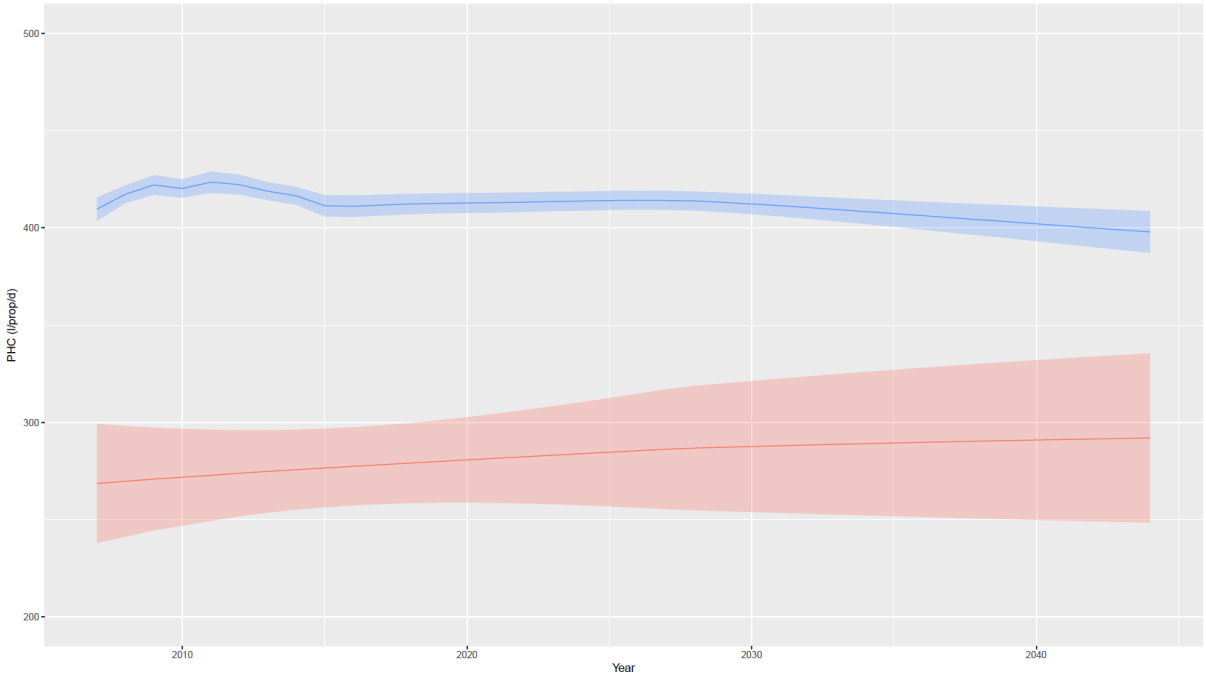

FIGURE 3: PHC FORECAST

Unmeasured PHC is shown to remain relatively flat over time whilst a slight increase in observed in the Measured PHC. These observations align with the Company's view that the Unmeasured PCC will continue a falling trend. Furthermore it is feasible that Measured PHC in the future will rise. Portsmouth Water currently has a relatively low meter penetration consisting of 'New Properties' which are deemed to be more efficient and 'Meter Optants' who have selectively chosen to be on a meter as they are likely lower consumers, these reasons likely explain why Portsmouth Water has one of the lowest PCCs in the country. Over time, as the company's meter penetration level increases it is more likely that higher consuming customers will move into measured properties and therefore cause a steady increase in the PHC.

These estimates do not explicitly account for water efficiency which are detailed in the following section.

Accounting for Water Efficiency

Whilst changes in the customer base are included within the regression models, reductions in consumption as a result of water device replacement are handled outside of the model using litre reductions in PHC/PCC in each year.

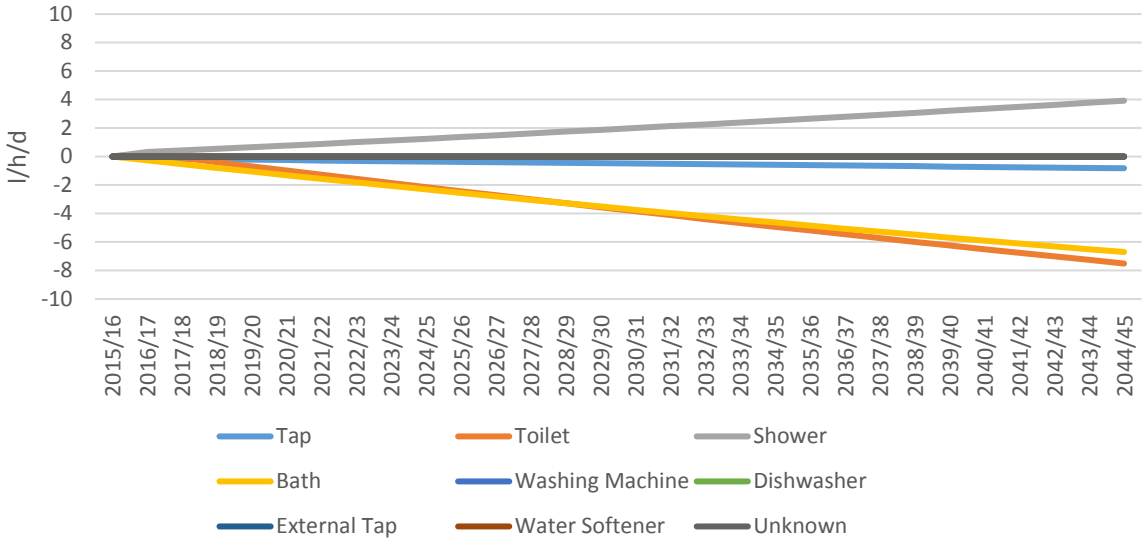

FIGURE 4 UNMEASURED PHC WATER EFFICIENCY

Volume reductions are based upon Defra Market Transformation Program (MTP) baseline reductions although some adjustments have been made, for example reductions associated with toilet flushing have been reduced by 8pp as newer dual flush toilet systems have been shown to leak leading to a reduced benefit.

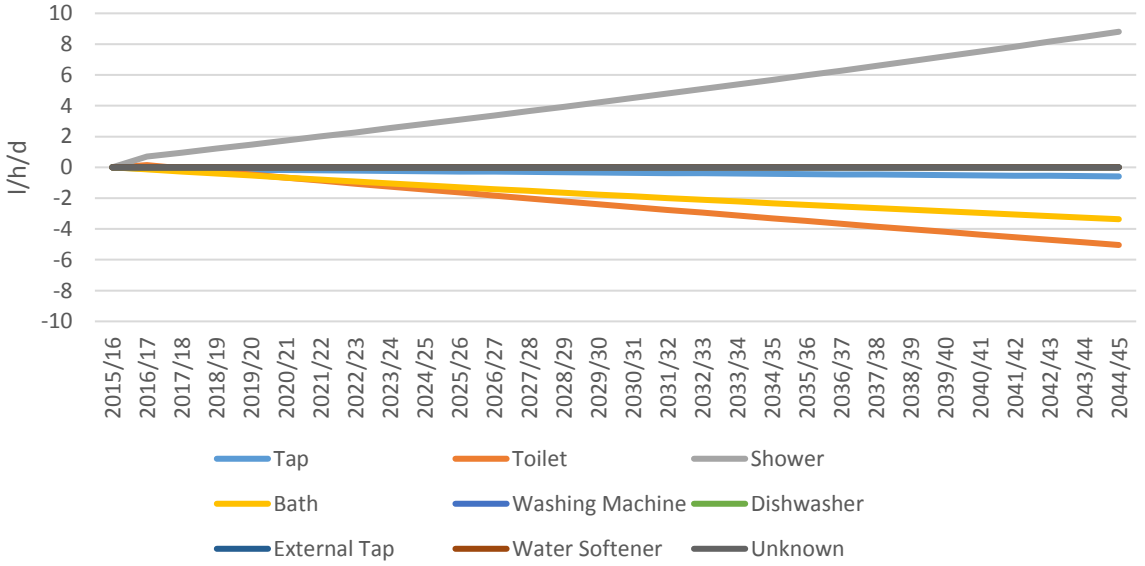

FIGURE 5 MEASURED PHC WATER EFFICIENCY

By 2044/45 Unmeasured PCC is expected to fall by 11.1 l/h/d as a result of device replacement, largely due to reduced volumes in bathing and replacement of single flush toilets. Measured PCC is expected to remain mostly unchanged with a total reduction of 0.2 l/h/d by 2044/45.

Final Model

The final PCC forecast is presented in Figure 6 whilst the resulting Water Delivered forecast is shown in Figure 7. The PCC shows a reasonable result with current trends generally continuing out to 2044/45. A kink in the Average PCC line is observed in 2029/30 when the rate of metering falls below 5,000.

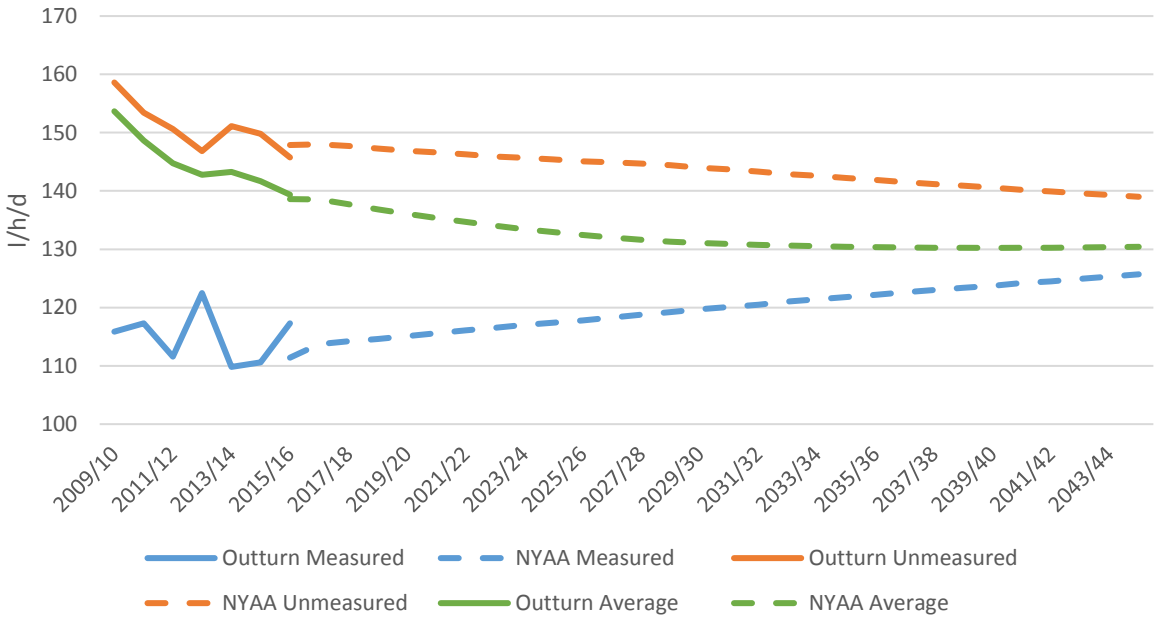

FIGURE 6 NYAA PCC FORECAST

The PCC falls to 130 l/h/d by 2044/45 when the Company is expected to be at a 66% level of meter penetration. This broadly reflects companies that have achieved similar PCC's around this level.

The Water Delivered result also looks sensible against the historic data with a continuing trend present.

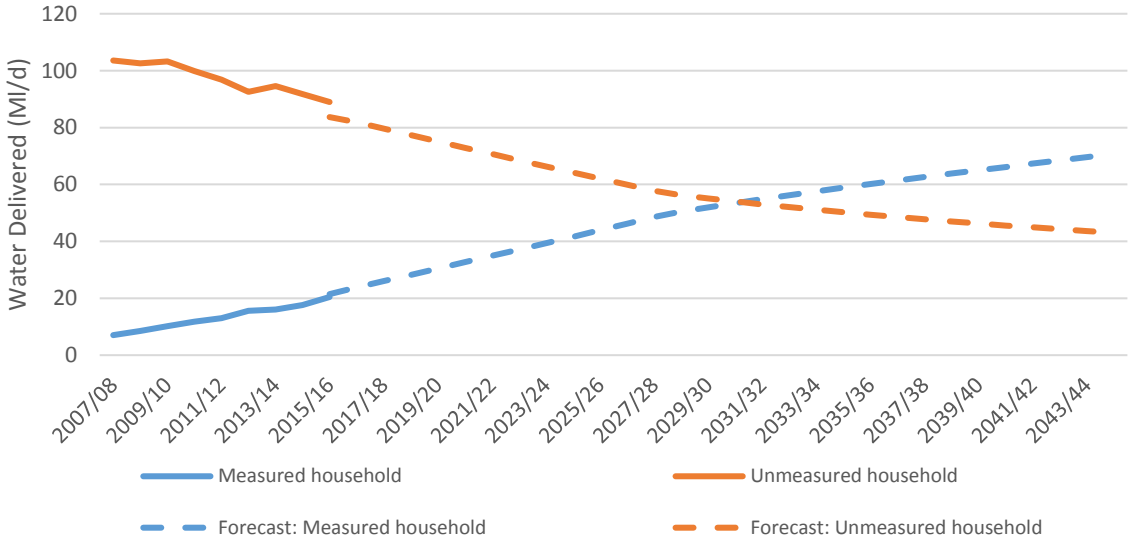

FIGURE 7 PHC FORECAST

**The unmeasured consumption is lower that the outturn 2015/16 as a result of a reconfigured Water Balance due to a change in the leakage calculation methodology, and, the forecasted figures are Normal Year adjusted.*