Member of the SNC-Lavalin Group

SWS Demand Analysis Update

Effectiveness of drought restrictions: Technical report update

Southern Water

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Rev 1.0	Final for client review	JD		DH	JD	02/03/2021
Rev 2.0	Final for issue					29/04/2021

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1. Introduction

This technical note provides an update to the empirically based analysis of the impacts of the demand restrictions that were applied by Southern Water during the 2005-06 drought, which was completed in 2017 (Southern Water, 2017). The models for each of the four Areas (Western, Central, Eastern and Isle of Wight (IOW)) were updated to March 2020 and reviewed through a calibration and a validation exercise.

2. Data used

The following data sources were used in the analysis:

- Daily Distribution Input (DI) data from 2001 to 2020 inclusive, aggregated according to Area
- Monthly leakage calculations from 2001 to 2020 inclusive
- Annual average Non-Household (Non-HH) demand based on regulatory return data (‘Table 10’) from 2001 to 2020 inclusive
- Daily rainfall for the Otterbourne, Ditchling road, Canterbury and Worlds End rain gauges from 2001 to 2020 inclusive
- Daily mean air temperature for Crawley (Central), Southampton (Western) and London (Eastern) from 2001 to 2020 inclusive
    - Note: 29th February data missing for Crawley (Central) for all leap years
- Number of metered household and total properties 2001 to 2020 inclusive
- Metered domestic consumption 2016 to 2020 inclusive (for comparative purposes to DI analysis to examine changes in the measured base since previous report)

Data was received up until March 2020. In order to verify the data was correct before being used in the model some basic checks were undertaken. There were overlap periods in the data received in the DI, rainfall, non-HH, temperature and leakage data, and therefore a comparison exercise was completed to check data consistency. Where any discrepancies were identified, the new data was used in preference to the data previously used.

The data received was at the Water Resource Zone (WRZ) level and were grouped into four Areas for modelling, as set out in Table 2-1. This maintains the original model format.

Table 2-1 - WRZs amalgamated into each Area

Western Area	Central Area	Eastern Area	IOW Area
Hampshire Kingsclere	Sussex North	Kent Medway East	Isle of Wight
Hampshire Andover	Sussex Worthing	Kent Medway West	
Hampshire South (Rural + Winchester + Southampton East + Southampton West)	Sussex Brighton	Kent Thanet	
		Sussex Hastings	

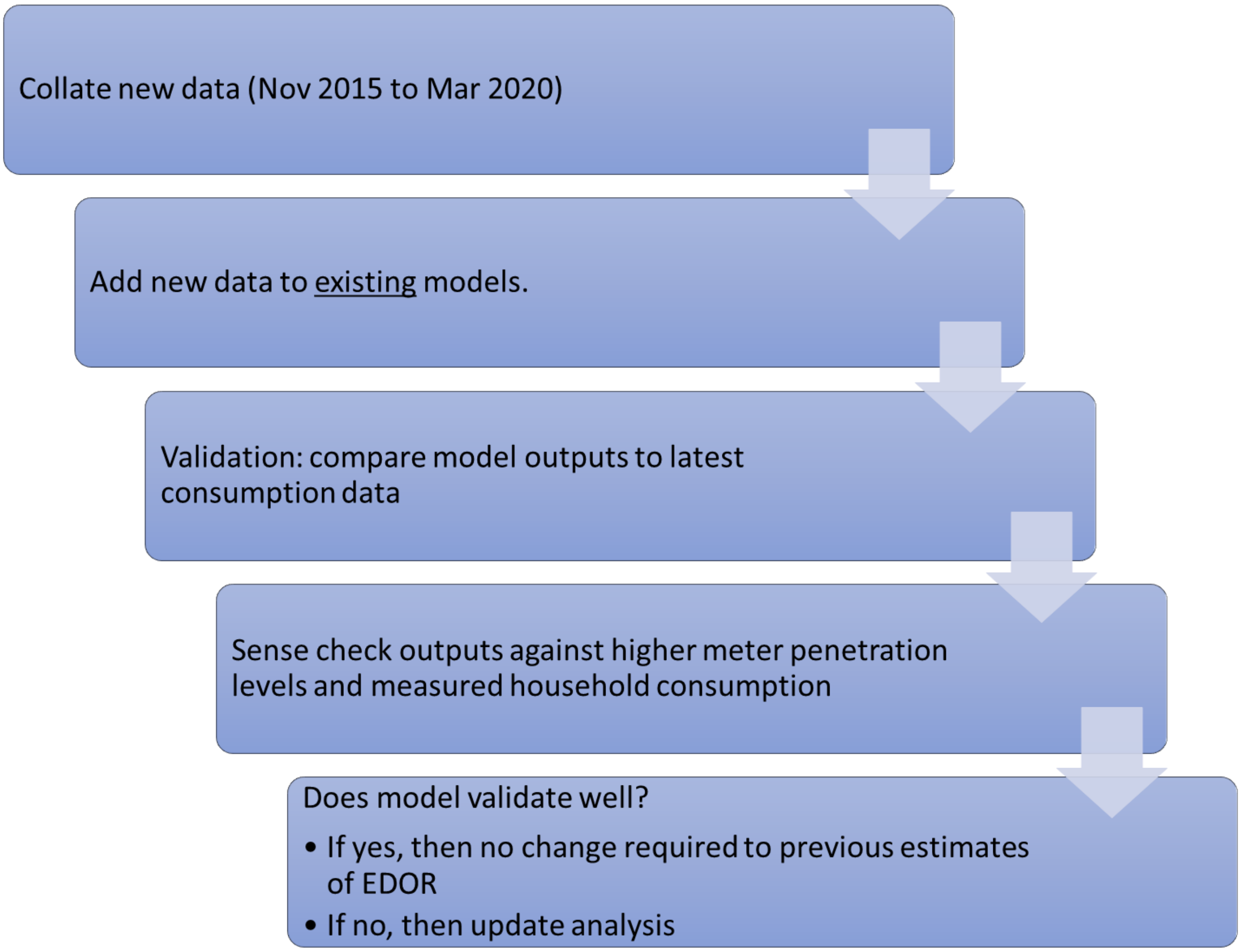
3. Methodology

The models for all Areas were previously calibrated using data from January 2001 to October 2015. In this current exercise to review and update the analysis, the **models were re-validated** using data covering November 2015 through to March 2020.

The **existing models were updated with the new input data** (weather, measured percentages) and then the outputs were compared to the latest consumption data (DI minus leakage minus NHH).

The **existing models were checked to ensure the models were still valid** (the model coefficients are summarised in Table 3-1).

The approach can therefore be broadly summarised as in the diagram below.



As before, observed household demand was calculated for each day using the equation below:

HH Demand = DI – Non-HH Demand – Leakage

Where:

DI = daily distribution input

HH Demand = household demand

Non-HH Demand = interpolated daily figure of non-household demand based on mid-year to mid-year linear trend using the 'Table 10' data

Leakage = leakage monthly figure

The **model format was unchanged**; this model structure was derived for the previous report in 2017 from significance analysis of the data to identify which variables provided a statistically significant explanation of household demand, and which model formats provided the best calibration against observed data. Therefore, the following equation was applied to the new data:

D = A + B(*Meter*)^C + (1 ⁄ (*Meter*)^D) × ((E(*Temp>10*)^2 + F(*dry day*) + G(*lograin7*) + H(*lograin30*))

Where:

D = household demand (l/prop/d)

A to H are regression coefficients

Meter = proportion of households that are metered

Temp>10 = number of degrees above 10 °C in each day (min = 0 at 10°C)

dry day = no rainfall on that day stated as a binary 1 (no rain) or zero (some rain)

log rain7, 30 = logarithm of the total rainfall over the last 7 or 30 days

Table 3-1 - Summary of calculated model coefficients

Area	Model (time of year)	A (underlying demand)	B (meter)	C (meter power)	D (meter weather response)	E (Temp)	F (dry day)	G (Log Rain7)	H (Log Rain30)
IOW	Summer	300 [2]	0.0	0.0	0.0	0.9	11.4	-11.6	-9.6
	Winter	270 [2]	0.0	0.0	0.0	0.0	0.0	-4.9	-9.6
Western	Spring/ Early Summer	422.5	-104.6	0.60	0.3	0.6	12.9	-15.0	-12.0
	Late Summer	387.6	-110.6	0.60	0.3	0.5	9.5	-12.0	-4.9
	Winter	390.0	-75.0	0.60	0.0	0.0	0.0	-2.1	-14.9
Central	Spring/ Early Summer	451.4	-116.3	0.40	0.2	0.6	2.7	-17.6	-17.3
	Late Summer	370.5	-77.3	0.40	0.2	0.4	7.7	-10.5	-0.2
	Winter	360.0	-55.0	0.40	0.2	0.4	0.0	0.0	0.0
Eastern	Spring/ Early Summer	473.0	-200.5	0.55	0.3	0.7	0.0	-23.2	0.0
	Late Summer	437.7	-180.4	0.55	0.3	0.7	0.0	-14.0	0.0
	Winter	405.0	-120.0	0.55	0.3	0.0	0.0	-9.1	0.0

Notes:

[1] Zero values indicate the explanatory factor was not statistically significant so was not used.

[2] These values were updated from the 2017 report to reflect new data and subsequent minor revision to the model

This model structure is typical of wider demand modelling approaches, which also tend to use lagged rainfall and temperature above a threshold. As discussed further in Section 4, the models were found during validation to still perform well with the original coefficients.

4. Results and analysis of model update

4.1. Modelled versus observed demand validation

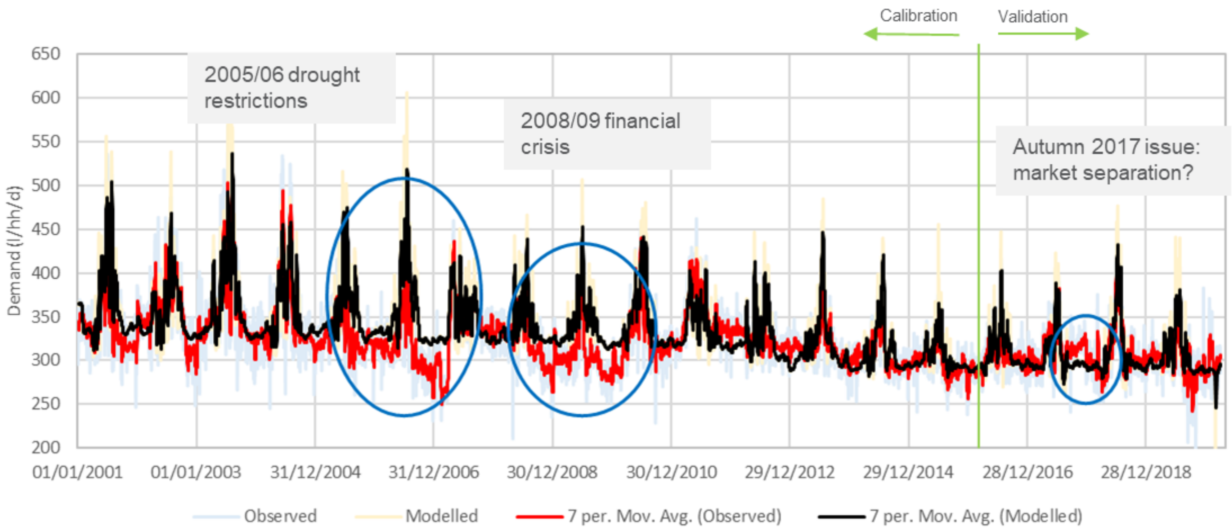
A comparison of the modelled versus the observed demand for each Area is provided in Figure 4-1 to Figure 4-4. The green line separates the period of calibration and the period of validation where the new data was used. Each figure shows two plots: the first covers the entire time period; while the second is for the validation period only.

The **models for the Western, Eastern and Central Areas were found to provide a good fit in the validation period (2015-2020)**, i.e. – the modelled household demand validated well against the new data, including for recent hot prolonged dry periods, such as those in 2018. Previously in the IOW model non-HH data was assumed to be a constant 3Ml/d, but with the current updated data the actual non-HH data was used, and hence coefficient A was adjusted to ensure a good fit. The relatively poor fit in 2002-05 in the IOW outputs can also be explained due to known issues with bulk supply.

For the Western area, the validation exercise showed that the September behaviour had a 'bimodal' performance where the summer model (which was previously used to model September) tends to under-estimate demand when the weather is cold and wet. Therefore, as a refinement, the September demand was determined as the greatest output from the summer and winter models. Hence, the winter model included October to March and sometimes September, the spring/early summer included April to July and the late summer included August and sometimes September.

The impact of the 2005-06 demand restrictions is evident in the Western and IOW models (Figure 4-1 and Figure 4-4) more so than in the Eastern and Central Areas (Figure 4-2 and Figure 4-3). The financial crisis in 2008-09 is also evident in all Areas, with the greatest effect demonstrated in the Western and Central Areas. The impacts of demand restrictions for 2005-06 have been compared to the expected impacts with current metering levels in Section 4.3. This has been used to develop the recommendations on the allowances for the effectiveness of demand restrictions in Section 4.5 taking into account the metering increases since 2005-06.

During the validation period around August 2017, for the Western Area the model diverges from the observed data, which could be due to market separation (MOSL) around this time. The exact cause of the error in MOSL in the Western Area is not known, but it affected the reported measured household consumption figures. The temporary increase in household demand is not apparent in the other Areas. This suggests it was caused by a temporary move of specific blocks of flats (or similar), which would have been reported as single customers, so would add significant volume without associated properties, and is known to have affected other companies during the process of market separation.



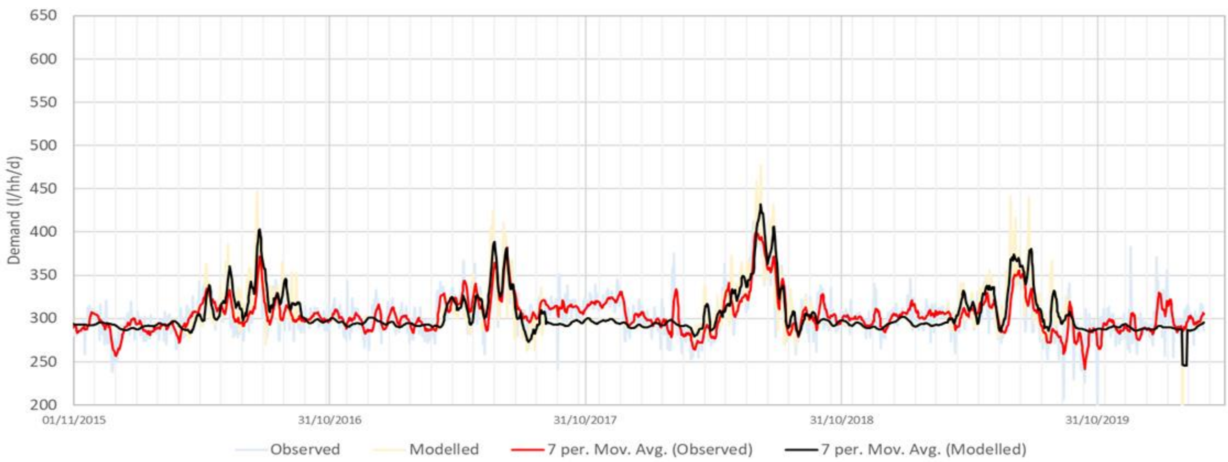


Figure 4-1 – Observed versus modelled demand for the Western Area (excluding IOW). September as winter and summer

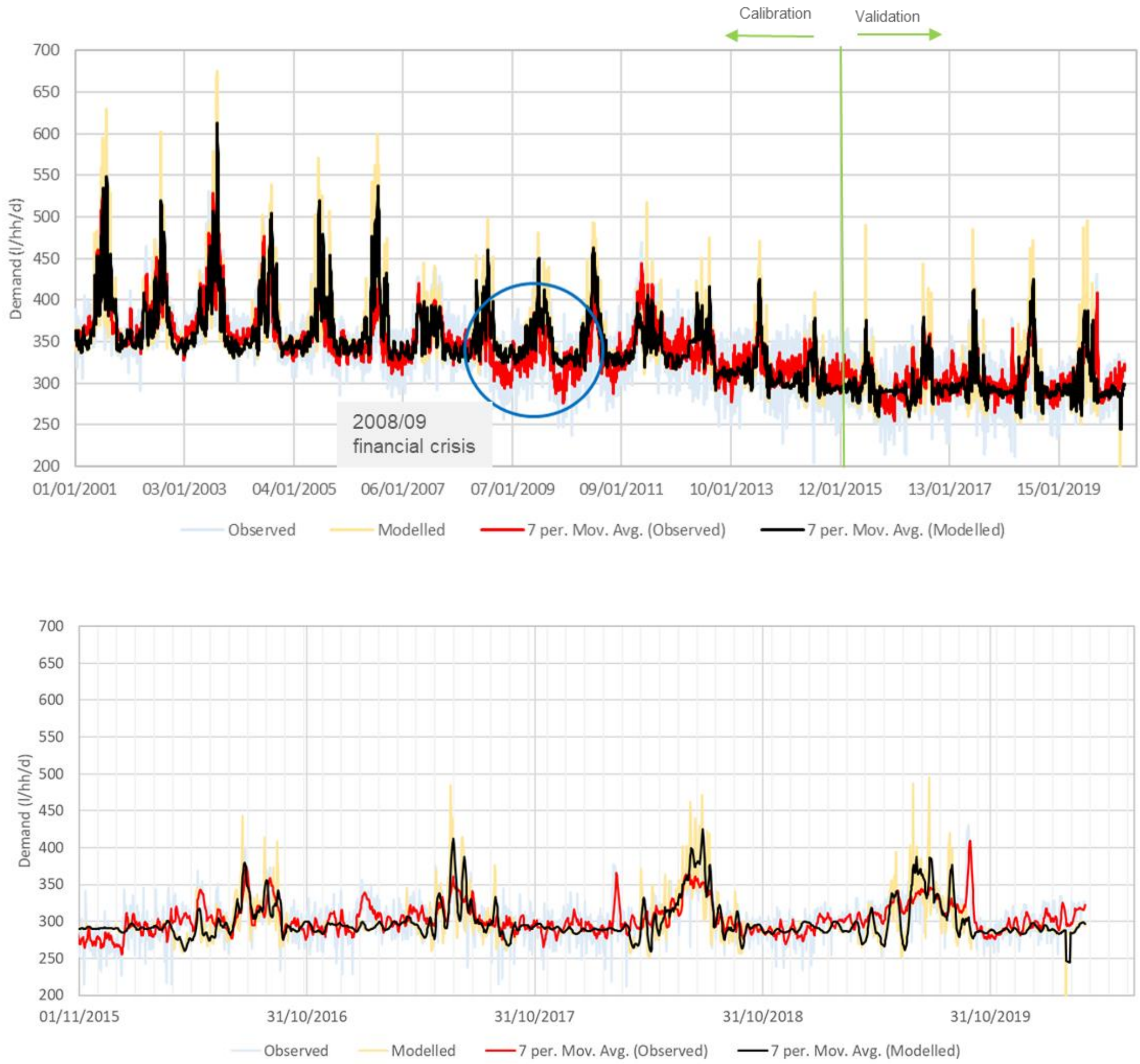


Figure 4-2 - Observed versus modelled demand for the Eastern Area

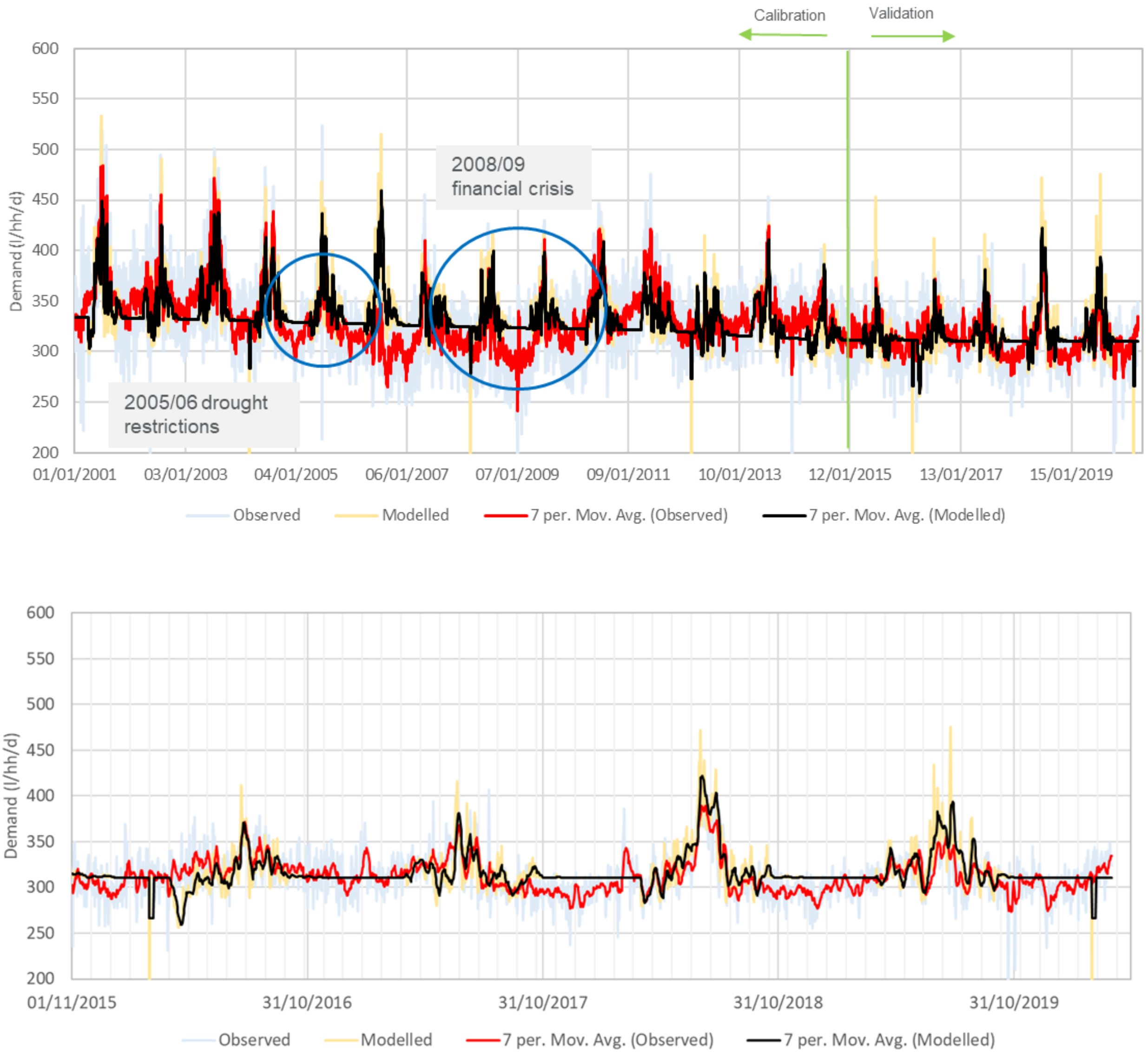


Figure 4-3 - Observed versus modelled demand for the Central Area

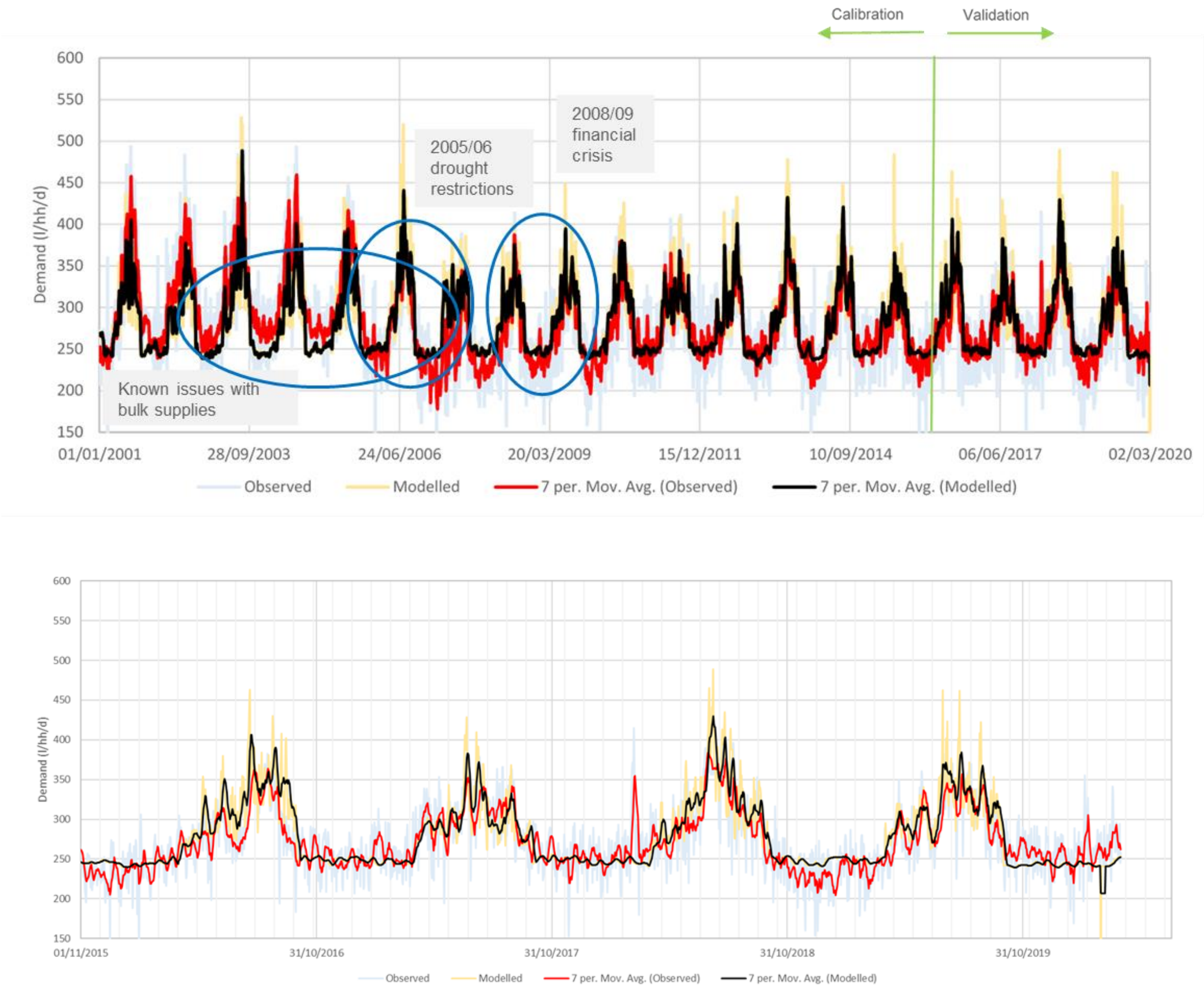


Figure 4-4 - Observed versus modelled demand for the IOW

4.2. Modelled Versus measured household consumption validation

A **further validation test was completed to ensure the model reflects recent data appropriately**. The modelled Per Household Consumption (PHC) was plotted against the measured household consumption along with the observed data which drove the model, using the 12-month rolling average for all three, as presented in Figure 4-5 to Figure 4-8. Some differences are to be expected as the PHC from the model represents all households, whereas measured data are only for those households charged on a metered basis.

The modelled PHC largely matches well with the measured household consumption in the Western and Eastern Areas. The fits for the IOW and Central Areas are not as good. For the Central Area there has always been some volatility in the baseline demand (demand outside of summer peaks as seen in Figure 4-3 above), which is not explained by weather variability, and also the baseline in 2017 and 2018 was lower than expected, although this seems to have recovered for 2019.

Overall, some differences between reported measured household consumption and observed/modelled values are to be expected because observed measured data was derived as DI minus *operational leakage* minus non-HH. The differences can therefore be attributed to trunk main and service reservoir leakage, as well as minor components of demand, meter under-registration and the influence of unmeasured households which could not be taken account of in the observed data which drives the model, because they are not reported at a regular time step.

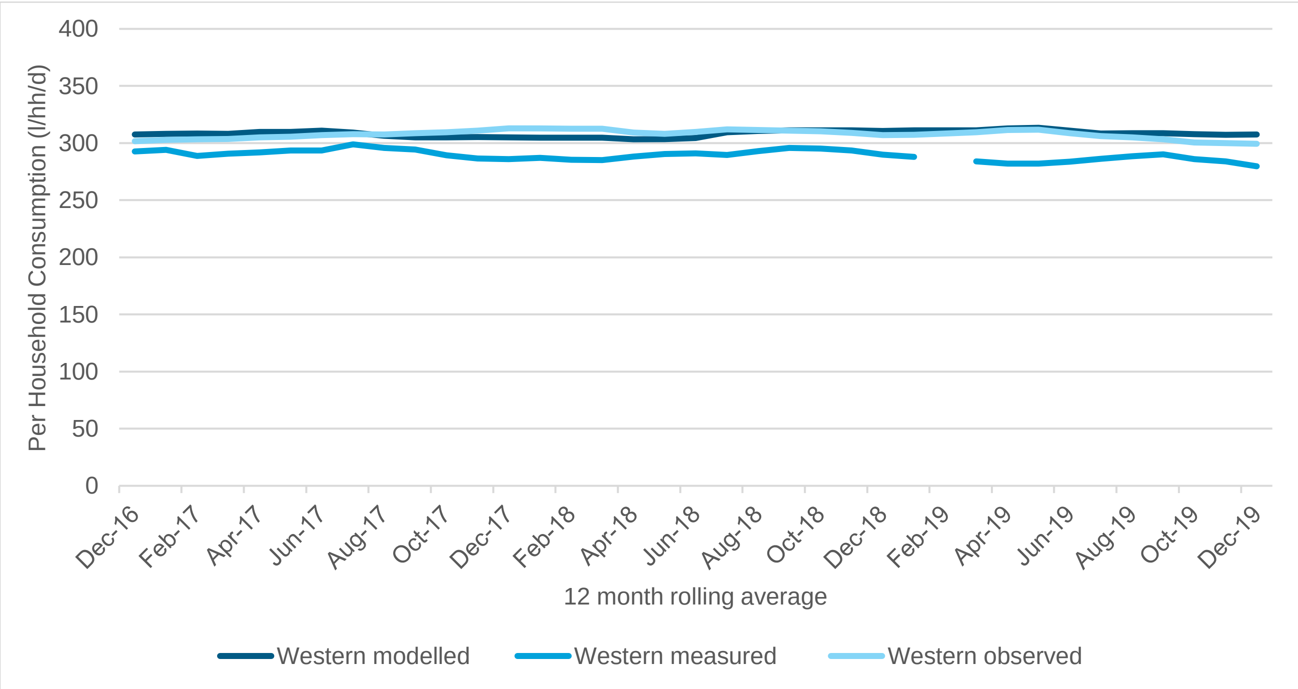


Figure 4-5 - Western modelled PHC versus Western measured

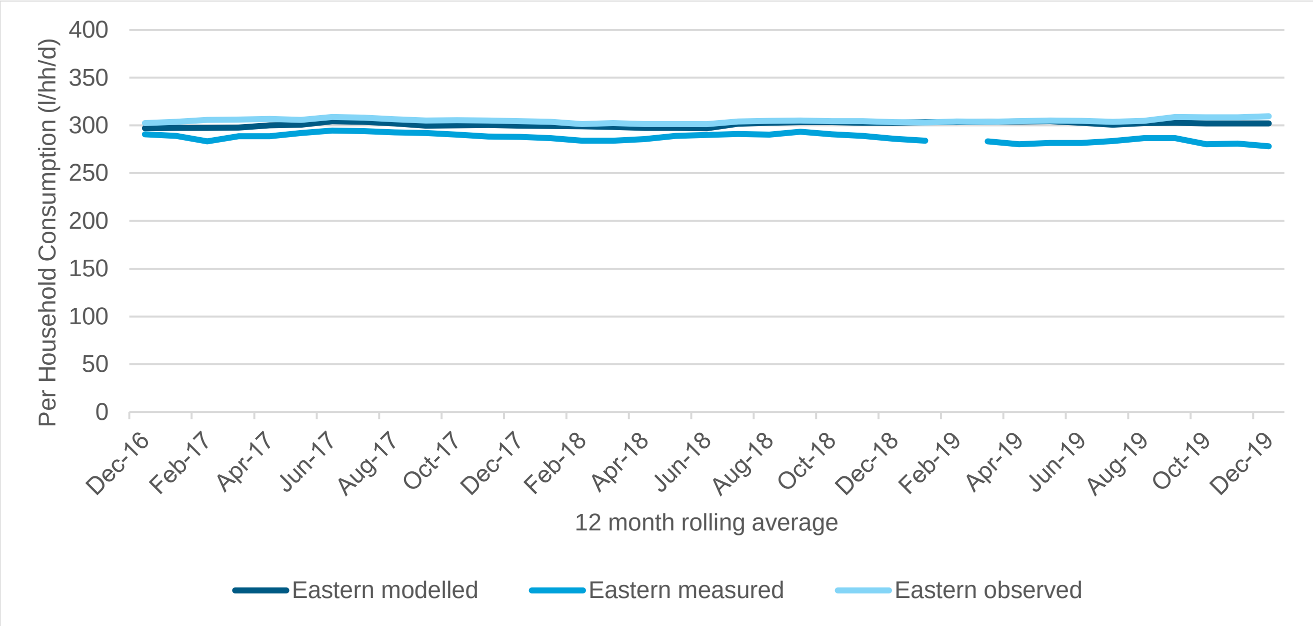


Figure 4-6 - Eastern modelled PHC versus Eastern measured

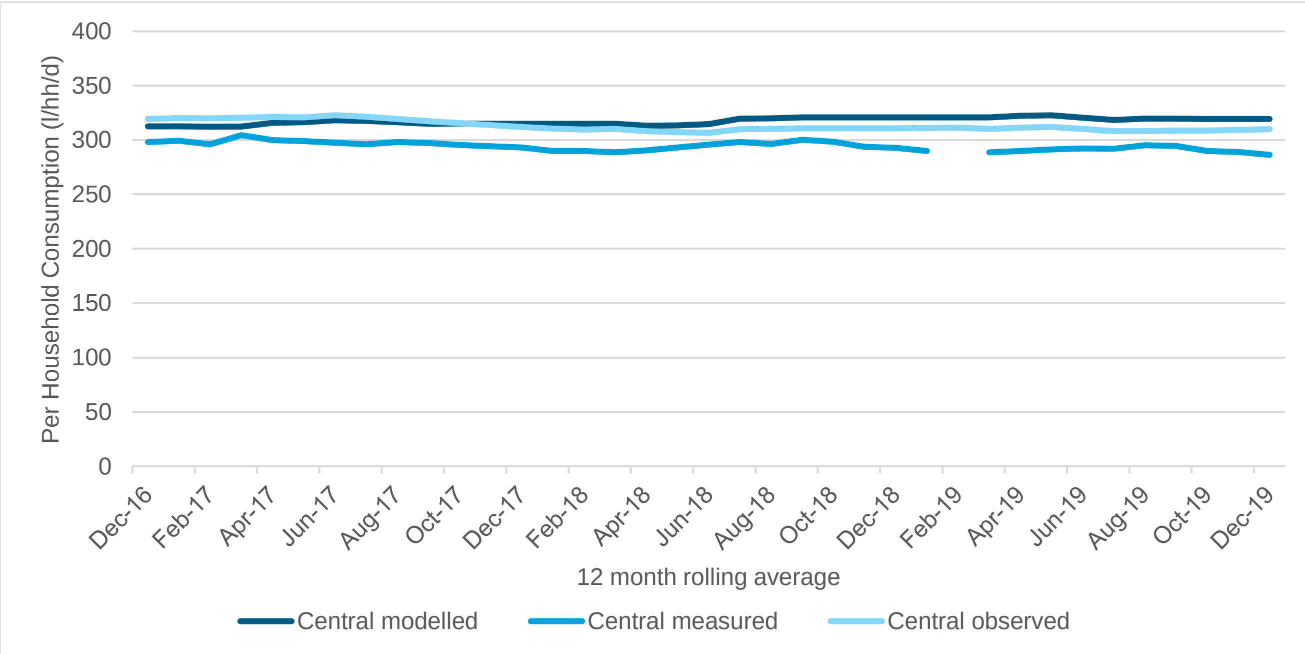


Figure 4-7 - Central modelled PHC versus Central measured

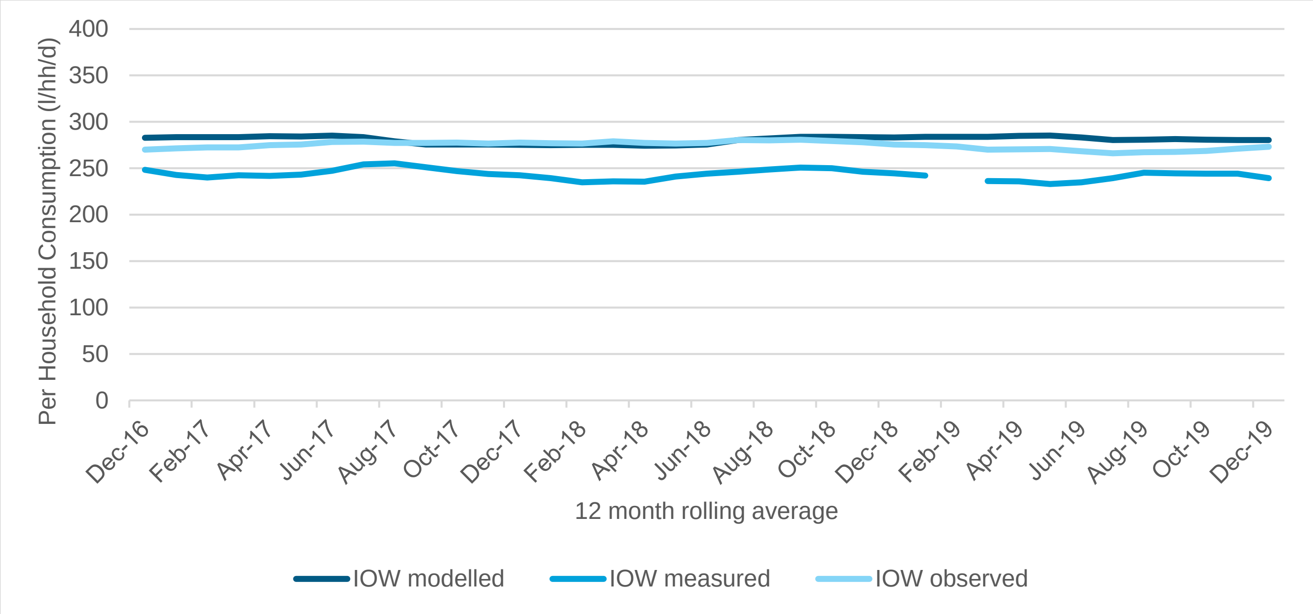


Figure 4-8 - IOW modelled PHC versus IOW measured

4.3. Evaluation of Impacts of Demand Restrictions

As **all models continue to validate well against the measured customer percentages and the weather patterns seen since 2016**, it has been concluded that the **estimation of the impacts of demand restrictions contained within the 2016 assessment are still valid** – as presented below. The 2016 assessment was based on two elements:

1) The impact of Temporary Use Bans (TUBs) and Non-Essential Use Bans (NEUBs) which were based on the difference between modelled and actual PHCs during the 2005-06 drought event. This resulted in the estimated impacts described as the 'at the time' values presented in Table 4-1 to Table 4-3.
2) These impacts were then scaled according to the difference in the peaks during those events that would have occurred if the level of metering had been at 2016 levels. The rationale behind this was that TUBs and NEUBs affect discretionary use, and the change in peak response is proportional to the amount of discretionary use within households. These scaled impacts are described in Table 4-1 to Table 4-3 under the 'current metering levels' column.

Table 4-1 - Estimated impacts of restrictions – Western Area

	At the time	Current metering levels
2005 (HPB)	10% max monthly	7% max monthly
	6% JJAS	4% JJAS
	2% MDO	1% MDO
2006 (HPB with NEU) (NEU publicity only)	15% max monthly	10% max monthly
	10% JJAS	7% JJAS
	4% MDO	3% MDO

Table 4-2 - Estimated impacts of restrictions - Central Area

	At the time	Current metering levels
2005 (HPB)	8% max monthly	5% max monthly
	6% JJAS	4% JJAS
	3% MDO	2% MDO
2006 (HPB with NEU)	18% max monthly	12% max monthly
	13% JJAS	8% JJAS
	5% MDO	3% MDO

Table 4-3 – Estimated impacts of restrictions – Eastern Area

	At the time	Current metering levels
2005 (HPB)	10% max monthly	4% max monthly
	5% JJAS	2% JJAS
	1% MDO	Negligible MDO
2006 (HPB with NEU)	11% max monthly	5% max monthly
	7% JJAS	3% JJAS
	2% MDO	1% MDO

4.4. Constant 80% Metered Population

For the 2016 analysis, the scaling of impacts was based on 80% meter penetration (to provide an illustration of the impact that metering would have had in 2005-06). Actual meter penetration rates are slightly higher than this now, but a constant 80% metering was used for testing and comparison against the validation period. Figure 4-9 to Figure 4-11 demonstrate the impact of setting metering at a constant 80%. By setting metering to a constant 80% from 2001 to 2020 it allows us to use the models to demonstrate the expected demand when metering is at that level. As seen in all models, and particularly in the Eastern Area, setting metering to 80% significantly reduces demand. In 2005/06 restrictions were put in place to reduce customer demand, although if metering had been at 80% or close to that at the time, as seen in most areas now, demand restrictions are unlikely to have been required to reduce the demand, since demand is seen to be sufficiently reduced solely through metering.

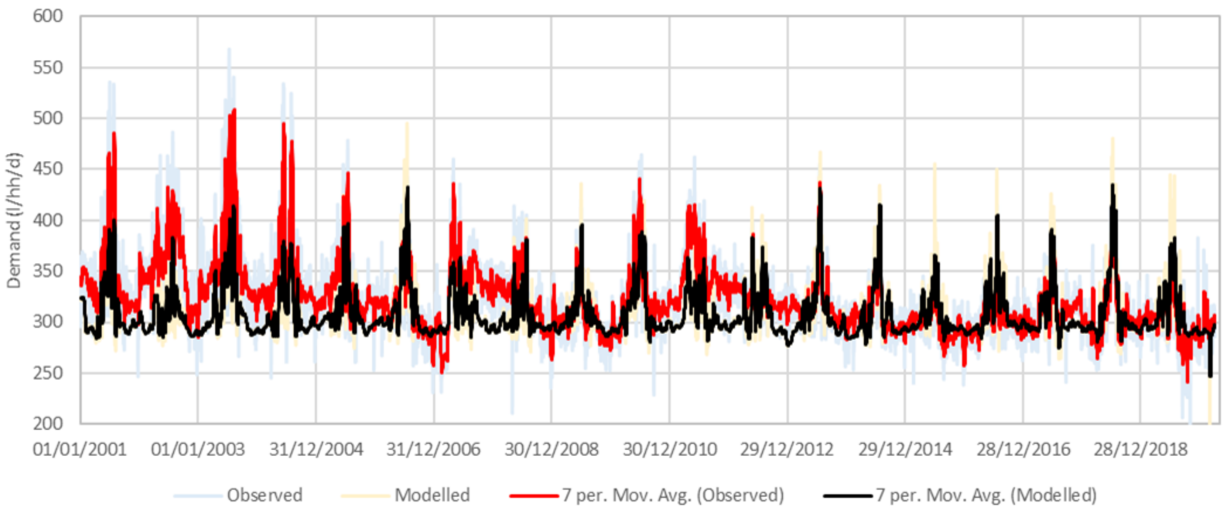


Figure 4-9 - Estimate of demand for a constant 80% metered population area - Western Area (excluding IOW)

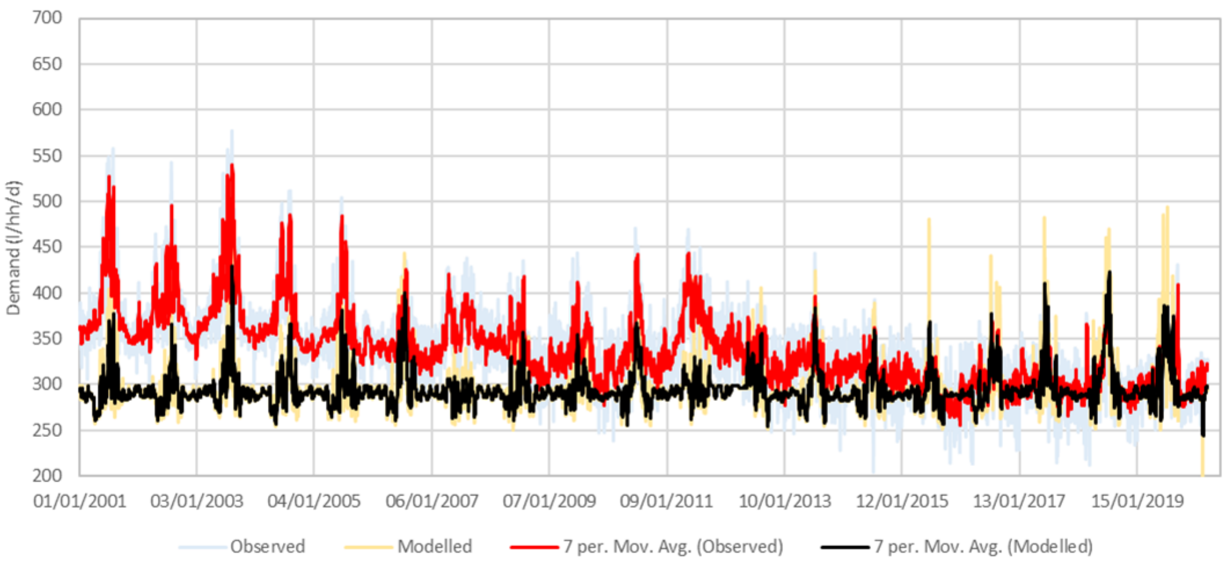


Figure 4-10 - Estimate of demand for a constant 80% metered population area - Eastern Area

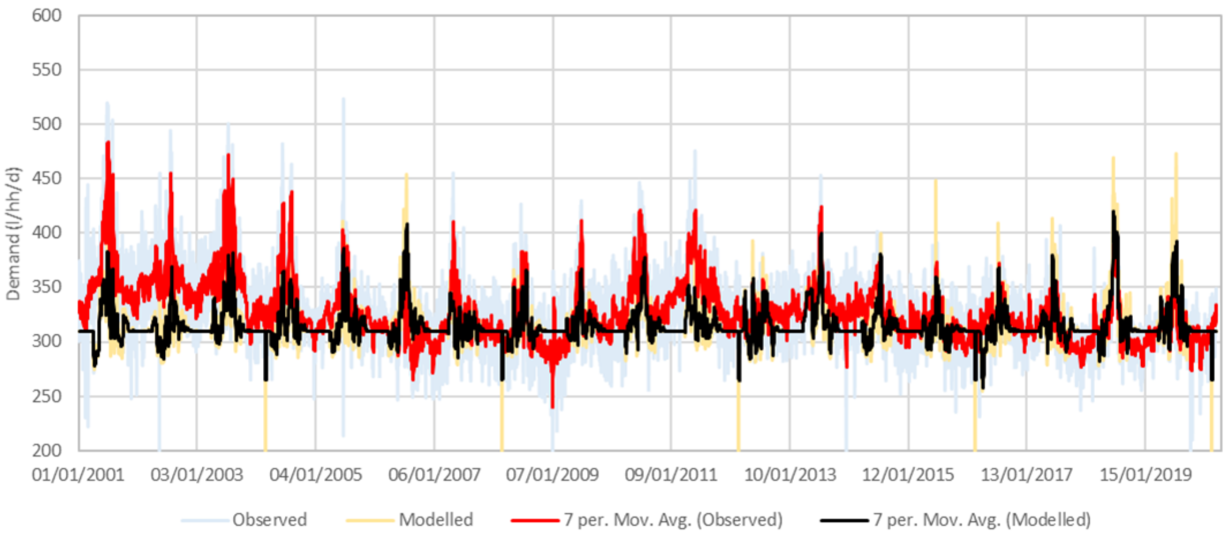


Figure 4-11 - Estimate of demand for a constant 80% metered population area - Central Area

This analysis also **demonstrates that the minor changes in meter penetration since 2016 have not had a significant impact on the peak in comparison with an 80% metering scenario, so the results from the previous study remain valid**. In the previous study the impact of restrictions were scaled proportionally according to the ratio of the 80% metering peak compared to the actual metering peak modelled for the 2005/06 event.

4.5. Recommended Profiles for Effectiveness of Demand Restrictions

Based on the above analysis it is **recommended that the profiles for the effectiveness of demand restrictions remain unchanged from those that were developed for the previous report (2017)**.

It was noted at the time that for the Central and Western Areas, a large proportion of the apparent benefit in the second year of restrictions (2006) was associated with ongoing publicity that caused a time-based trend over the course of the drought. Some caution was therefore advised in the Central Area, where major droughts only have a critical period of 12-18 months, and this time-based effect would not therefore occur in time to benefit the drought supply/demand balance. The 18% maximum monthly saving in July 2006 in the Central area (which we have re-assessed as equivalent to 12% with current metering levels, in Table 4-2) also appeared to be an outlier and possibly represented a model over-response to the record-breaking temperatures encountered in that month – the average over the summer includes this figure, but we have recommended using a smoothed value over the summer, rather than specific in-month estimates, which would be too focused on the specific conditions of 2006. This seems prudent, as **it is not possible to reliably forecast what weather conditions will be like during a future drought event**.

The Effectiveness of Demand Restrictions (EODR) benefits profile recommended in the previous report are re-produced below in Table 4-4 to Table 4-6. These profiles were developed from the summer versus MDO period values and have been profiled according to typical seasonal demand variability. **These recommended EDOR profiles are based on current metering levels and the observed empirical evidence**.

Table 4-4 - Recommended EODR profile - Western Area, including IOW

Month	TUBs	NEU
Jan-April	1%	3%
May-June	2%	4%
July-Aug	5%	8%
Sept	3%	4%
Oct-Dec	1%	3%

Table 4-5 - Recommended EODR profile - Central Area

Month	TUBs	NEU
Jan-April	2%	3%
May-June	3%	5%
July-Aug	5%	8%
Sept	3%	5%
Oct-Dec	2%	3%

Table 4-6 - Recommended EODR profile - Eastern Area

Month	TUBs	NEU
Jan-April	0%	1%
May-June	1%	1%
July-Aug	3%	4%
Sept	2%	2%
Oct-Dec	0%	1%

The data issues previously identified and discussed around the IOW in 2002-05 have led to the prudent step of not including an IOW specific table; a more general western area table was provided instead.

5. Conclusions

The models for the **Western, Eastern and Central Areas performed well in the validation exercise for the period of November 2015 to March 2020 and there was no reason to re-model or change the original models for these Areas**. The IOW model was also revised to better reflect new data and was then validated successfully. **Minor changes in meter penetration rates across all areas since the 2016 report were also shown to have had a negligible impact on peaking factors**.

For all Areas the previous analysis of the impact of TUBs and NEUBs is therefore considered to remain valid, and the Effectiveness of Demand Restrictions profiles recommended in the previous 2017 report should continue to be used.

The current social and economic restrictions due to the COVID-19 pandemic have affected household demand, but are transient and cannot meaningfully be incorporated into the assessment of the benefits of future demand restrictions, unless there is a long term change in customer behaviour (e.g. as a result of home working). This would need to be included in the model once the new pseudo steady-state response is known.

6. References

Southern Water (2017). Annex A: Effectiveness of Restrictions. Technical Report.

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