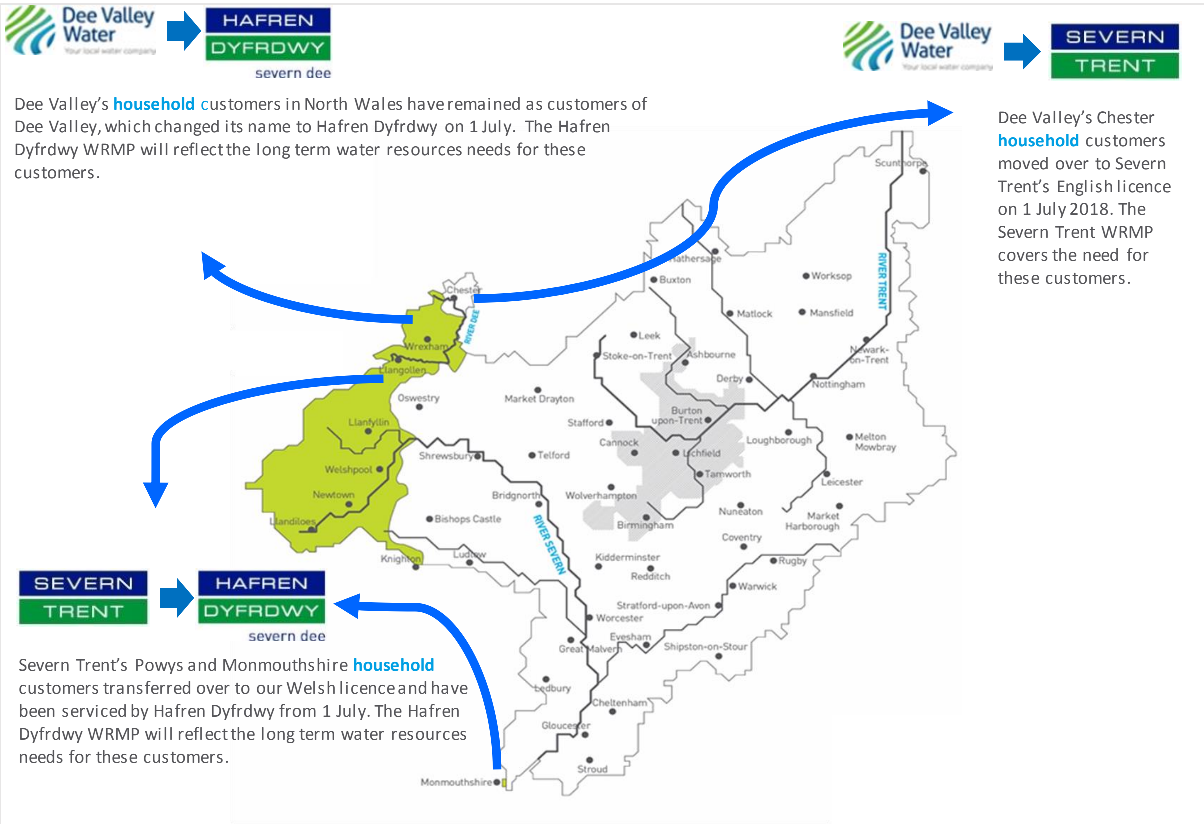
Appendix F – Incorporating Chester WRZ into our WRMP

In February 2017, Dee Valley Water became part of the Severn Trent group. In 2018, Ofwat approval was received to align the boundaries of Severn Trent and Dee Valley Water to the national boundaries of Wales and England. In line with this approval, we launched Hafren Dyfrdwy on 1st July 2018 to serve our customers in Wales.

Figure F1 below shows how customers have moved between the two companies and how this impacts the final WRMPs which have been produced based on the new licences:

Figure F1: Severn Trent and Hafren Dyfrdwy boundary changes



The draft WRMPs that were published in 2018 were based on the old licence boundaries with the subsequent consultations carried out on this basis. For the final WRMPs, we have aligned the Severn Trent and Hafren Dyfrdwy plans to the new company boundaries. This appendix (Appendix F) explains how we have incorporated the Chester water resource zone into our wider Severn Trent WRMP.

F1 Introducing our Chester Water Resource Zone (WRZ)

Following the purchase of Dee Valley Water the WRZs in Severn Trent have been amended to reflect the new company boundaries.

Part of the old Shelton WRZ and the entire Llandinam and Llanwrin WRZ now lie in the Hafren Dyfrdwy WRMP and parts of the Chester WRZ and Wrexham WRZ from Dee Valley Water now form part of this (Severn Trent) WRMP. There have also been some minor changes to the boundary of our Mardy, Bishops Castle, and Llandinam and Llanwrin WRZs to align to the new company boundaries; however these adjustments have no additional impact on our data reporting.

These changes have been implemented to reflect the national boundaries and are due to any change in the connectivity of our supply system. Customers' water supplies will remain the same and a legal agreement is in place between the two companies for the import and export of water. Figures F1.1 and F1.2 show the original Dee Valley Water and Severn Trent boundaries and the new Hafren Dyfrdwy and Severn Trent company boundaries respectively.

Figure F1.1: Historic Dee Valley Water and Severn Trent boundaries

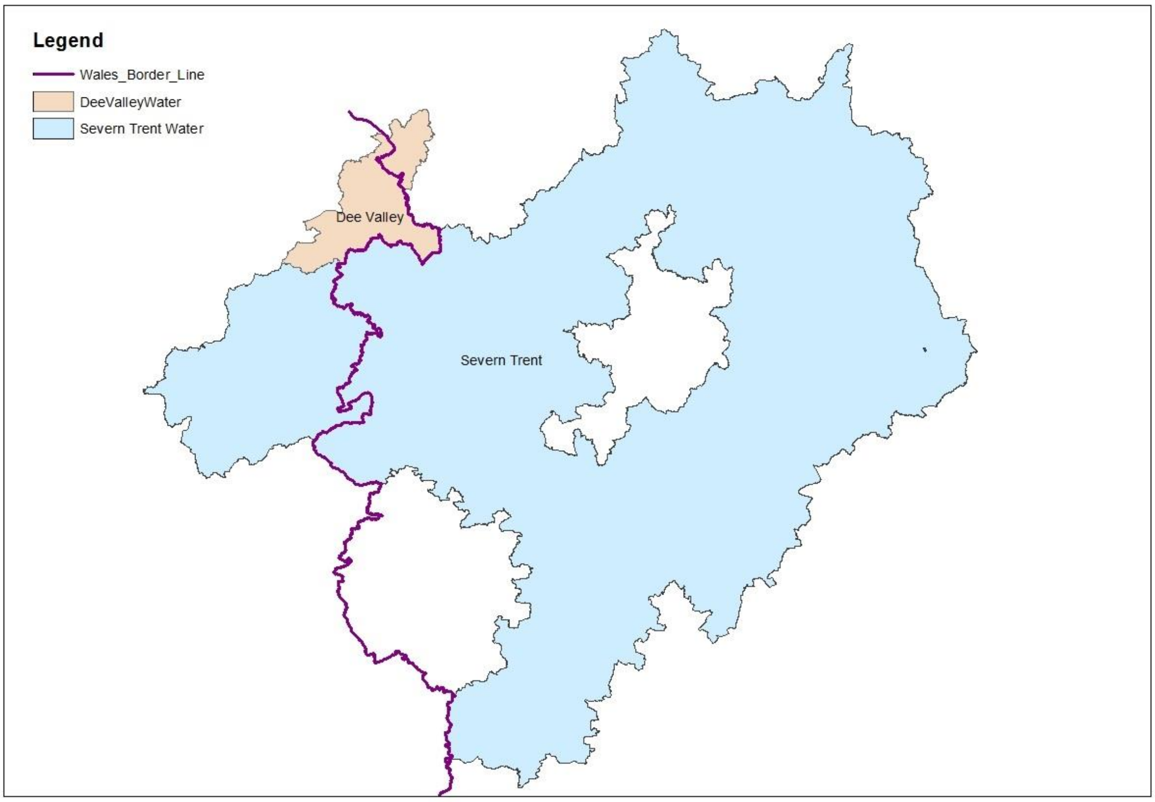
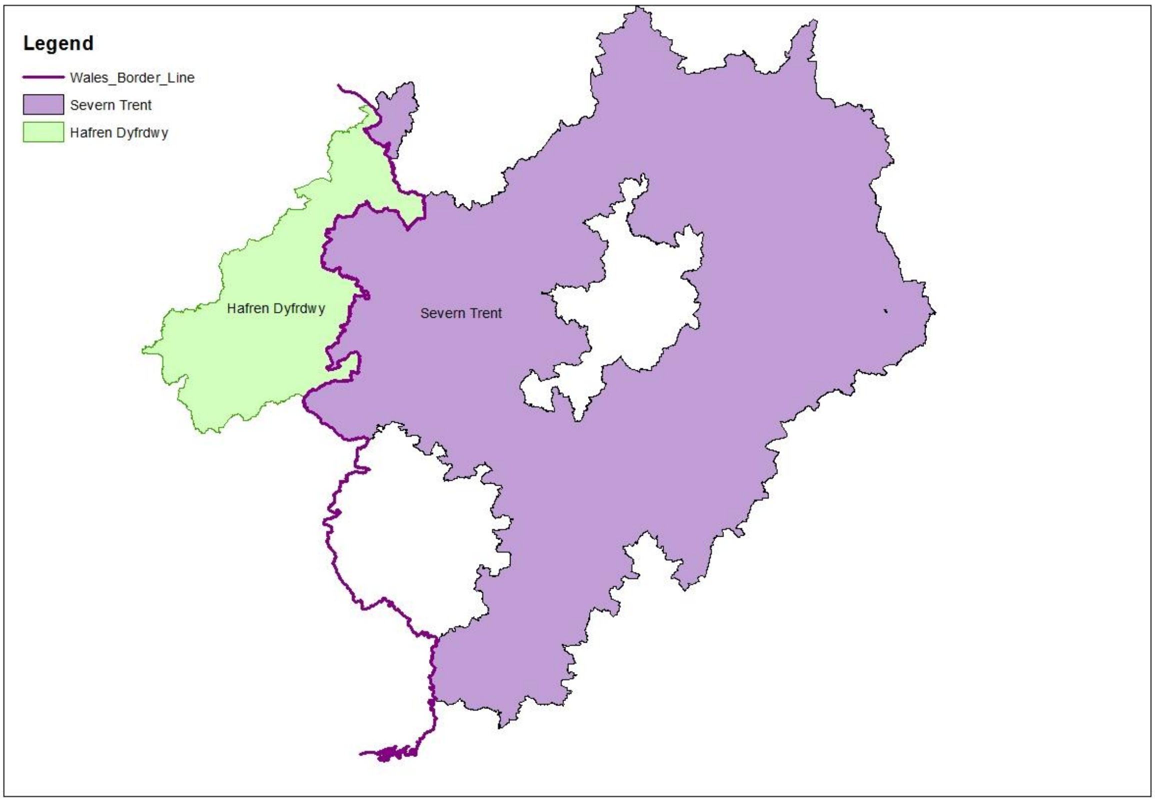


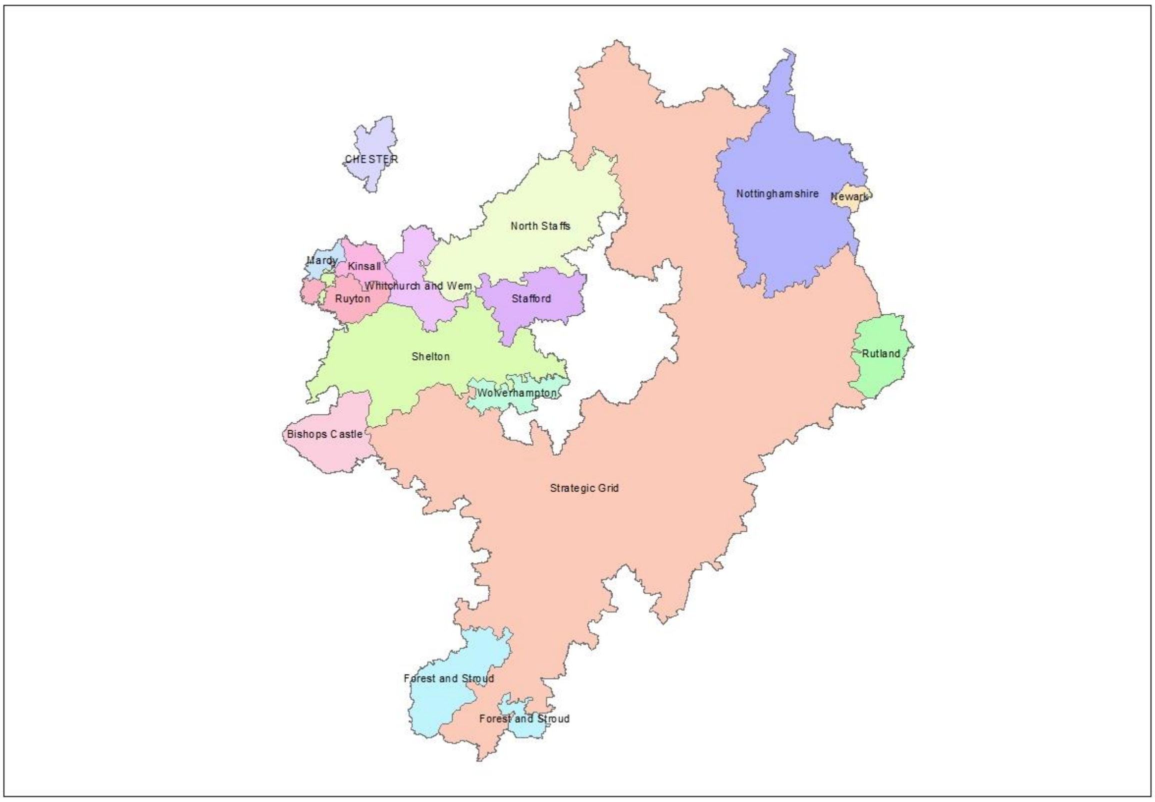
Figure F1.2: New Hafren Dyfrdwy and Severn Trent company boundaries



Detailed analysis of the water resource zones affected by the company boundary changes has been undertaken. This included a review of the company boundaries, original water resource zones, sources of supply and customer connections. This plan reflects the changes and reports on the new 15 water resource zones illustrated in Figure F1.3.

No changes have been made to any other water resource zones. We have checked that the new WRZs of Chester and Shelton comply with the requirements of the Environment Agency document entitled '*Water resource zone integrity - Supporting document for the Water Resource Management Plan Guidelines*' dated July 2016. All other WRZs were checked as part of our previous WRMP. We outlined and agreed the approach that we took to our WRZ boundaries at a meeting with the Environment Agency in autumn 2018.

Figure F1.3: Severn Trent Water Resource Zones



F2 Calculating Deployable Output for our Chester water resource zone

A new Aquator model was originally built for the Dee Valley Water network in 2015, while investigating alternative options to rebuilding the Legacy WTW near Wrexham. For development of this WRMP, an audit and review of the model was conducted and then it was used it for our assessment of the DO for Chester WRZ, and the Hafren Dyfrdwy WRZs supplied by the River Dee.

F2.1 Hydrology – River Dee sources

The main source of water for the Chester WRZ is the River Dee. The Industrial Revolution led to many rivers in industrial areas becoming too polluted to use directly for drinking water but the River Dee was a notable exception. The Chester Waterworks Company was formed in 1826, drawing water from the River Dee to supply the City of Chester; during drier summer months, the natural flows of the river weren't always sufficient to support the high levels of abstraction needed to support the Shropshire Union Canal and these drinking water abstractions. Therefore, sluices were built at Bala Lake outlet to allow controlled releases of water to support the natural flow of the River Dee. Nearly 150 years on, this scheme was expanded with new sluices being built at Bala Lake in the 1950s and the construction of two new reservoirs - Llyn Celyn and Llyn Brenig – in the 1960s and 1970s respectively.

In 1989, following the privatisation of the water industry, the regulation of the River Dee came under the control of the National Rivers Authority, which was succeeded by Environment Agency Wales in 1996. In 2013 the regulation of flows came under the joint control of Natural Resources Wales (NRW) and the Environment Agency.

The Dee Consultative Committee (DCC), which represents the interests of all the major abstractors and river interests, was set up under the Dee and Clwyd River Authority Act 1973. Chaired by Natural Resources Wales (NRW), the current membership is made up of representatives from the Environment Agency, United Utilities, Hafren Dyfrdwy, Severn Trent, Dŵr Cymru Welsh Water and the Canal and Rivers Trust. The complex rules used to operate the regulation scheme are prepared with this Committee's advice, and the special conditions for operation during severe droughts must be approved by all members of the Committee - largely the implementation of additional abstraction restrictions initiated at various drought trigger points as dictated by reservoir storage levels.

For our deployable output modelling, the River Dee sources were modelled using NRW's historical time series of cutbacks produced from their Aquator model, detailing the daily cutbacks that would have been imposed between 1927 and 2015. This time series prescribes the abstraction level that would have been available for us at any time.

F2.2 Operational rules used in Aquator

In our Aquator model the operational rules are broken down into two main components – Dee abstractions and reservoir operation (though these are not relevant for the Chester area). A summary of these is provided below.

Dee abstraction

The Dee General Directions (as published in June 2016) sets out the volumes that we can abstract under different conditions. NRW authorises four levels of abstraction from the Dee at each of our abstraction points as shown in Table F2.1; the abstraction volumes authorised under Stage 1 and Stage 2 cutbacks in drought conditions are reliant upon augmentation of the River Dee from Hafren Dyfrdwy's Pen Y Cae Lower reservoir for which a transfer agreement has been put in place between the companies.

For the DO assessment, NRW provided a time series identifying when these limits would have been imposed from 02/01/1927 to 31/12/2015. This time series was used to control the maximum abstraction at each location, and when augmentation of the Dee from Pen Y Cae Lower was required to maintain the abstraction at Barrelwell Hill.

Table F2.1: River Dee abstractions as set out in the Dee General Directions

Abstraction Regime	Barrelwell Hill / Dee Chester Abstraction Limit (Ml/d)
Above system safe yield line	32.5
Safe yield allocation	28.8
Stage 1 cutbacks	28.8 Note 1
Stage 2 cutbacks	28.8 Note 2

Note 1: Based on augmentation of 0.4Ml/d from Pen Y Cae
Note 2: Based on augmentation of 0.8Ml/d from Pen Y Cae

F2.3 Initial deployable output assessment (unprofiled demand)

Once all of the operational rules had been represented in the Aquator model, an initial deployable output assessment was completed for each WRZ. This used the Deployable Output – English and Welsh Method analyser in Aquator. The analyser scales demand in the zone being assessed until a 'failure' is caused. The events classed as a failure were:

- Reservoir storage reaching dead water
- Failure to meet demand
- Failure to meet the Dee augmentation required due to NRW cutbacks
- Failure to meet compensation flows

The DO is then considered to be the highest demand that can be met without causing a failure over the whole period of the assessment (01/01/1927 to 31/12/2015).

As both our Chester WRZ and Hafren Dyfrdwy's Wrexham WRZ are built into the same model, all demand centres were enabled during the assessment, but only the demand centre in the zone being assessed was scaled, with demand in the other zone being fixed at the baseline DO level. The only interaction between the zones is the potential for abstraction in the Wrexham WRZ to empty Pen Y Cae Upper, eventually preventing Pen Y Cae Lower from meeting the Dee augmentation demand required to maintain the abstraction Barrelwell Hill / Dee Chester during stage 1 and stage 2 cutbacks. However this did not occur during the DO assessments.

The Mickle Trafford / Plemstall demand centre demand was fixed at 2.2 Ml/d and was not scaled during the DO assessment. Demand level was calculated by dividing the annual licence of Plemstall borehole over 366 days and is based on the assumption that the borehole can meet the whole of the Mickle Trafford demand.

The demand in Chester was scaled up to 28.8 Ml/d, above which level failure occurred on 12/02/1927 – as soon as NRW imposed a cutback in the Barrelwell Hill / Dee Chester abstraction limit from Above system safe yield line limit to the Safe yield allocation limit. The demand of 28.8 Ml/d could be met throughout the whole period because Pen Y Cae Lower was able to meet the Dee augmentation demand during all NRW cutbacks. Therefore, the Chester WRZ DO was identified to be 31.0 Ml/d (28.8 + 2.2 Ml/d).

F2.4 Initial deployable output assessment (profiled demand)

The Chester WRZ and Hafren Dyfrdwy's Wrexham WRZ operate conjunctively, we therefore collated distribution input (DI) data for both the Chester and Wrexham WRZs for the period 01/01/1999 to 31/12/2015. We plotted this data, as outlined in Figure F2.1, which showed the years with the largest summer peaks were 2003, 2005, 2006 and 2010. The years with high summer peaks were selected as these were the periods when the highest demands were experienced in the WRZs and were therefore the times when the system was at highest risk of failure.

The mean demands for each month across the selected years were calculated. From this a factor was calculated for each month, by dividing the mean monthly demand by the mean daily demand across the selected year, such that the average factor is 1.0 in each case.

Figure F2.1: Daily distribution input data for the Chester and Wrexham WRZs

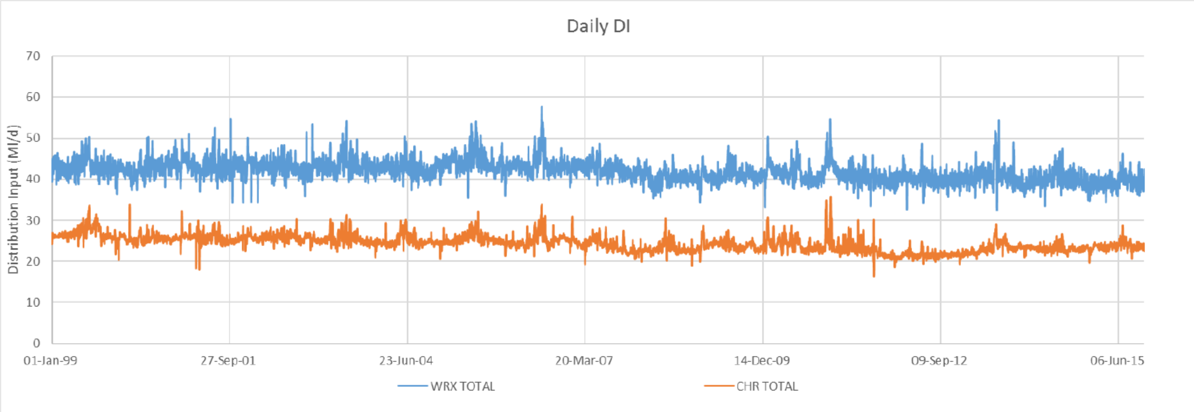


Table F2.2: Monthly demand factors for the Chester WRZ

Month	1	2	3	4	5	6	7	8	9	10	11	12
Chester Dry Years Demand Factors	1.00	0.97	0.98	1.00	0.99	1.04	1.06	1.00	0.99	0.98	0.98	1.01

Note that the Mickle Trafford demand supplied from Plemstall borehole was not varied with the demand profiles and was assumed to be constant at the licence amount of 2.2 Ml/d. This was added to the demand at the Chester demand centre to obtain the WRZ DO.

Using the new demand profiles, the DOs were assessed again using the English and Welsh DO analyser in Aquator, and the new mean DO for Chester zone was 29.3 Ml/d (27.1 + 2.2).

These figures represent the mean demand met across every day of the assessment period (1927 to 2015). For Chester, the demand that was met in the peak demand month (July) was 31 Ml/d (28.8 + 2.2). This peak DO is the average day peak month demand that could be met on every day of July (the month with the highest demand factor) in every year. With these profiled demands, the failure date moved to 01/07/1929, when demand was at its peak and with the failure controlled by asset constraints. The treatment works were working at their maximum capacities to meet the peak in the simulations, and without asset upgrades a higher demand could not be supplied. This indicates that the system would be resilient to hydrological events of a similar scale to those seen in the past.

Conclusion

Our supply system was tested under a number of different conditions using the Aquator model. With un-profiled demands under historic hydrological conditions, the DO of the Chester WRZ was 31.0 Ml/d. When the demands were profiled based on previous dry years, the mean DO was 29.3 Ml/d.

F3 Changes in deployable output

F3.1 Our role in achieving sustainable abstraction

Under the EU Water Framework Directive (WFD), a management plan is required for each River Basin District (RBD). The Dee River Basin Management Plan (RBMP) was first published in 2009, and reviewed and republished in 2015, with another review due in 2021.

The purpose of the RBMPs is to protect and improve the water environment for the wider benefits to people and wildlife. In order to achieve this, the plan includes a summary of the Programme of Measures needed to achieve the objectives of the WFD together with the predicted environmental outcomes over the next six years. As major abstractors from the River Dee, we must ensure that our WRMP19 supports the achievement of these objectives.

The Dee RBD is home to over 500,000 people and covers an area of 2,251 square kilometres of North East Wales, Cheshire, Shropshire and the Wirral. The district consists of a single river basin; the River Dee, its tributaries and estuary. The RBD is characterised by a varied landscape. It ranges from the mountains and lakes of the Snowdonia National Park in the upper part of the basin, through the Vale of Llangollen in the middle reaches, to the open plains of Cheshire and the mudflats of the Dee Estuary in the lower basin. Chester is a major urban centre, but the land is mainly rural with rough grazing and forestry in the upper catchment and arable and dairy farming on the Cheshire Plain. The Dee and its tributaries are renowned for their excellent fishing and there is an important cockle fishery in the estuary. There is an EU designated bathing water at West Kirby and a number of other non-EU bathing waters managed by Local Authorities around the estuary. The river Dee is popular for canoeing and the National Whitewater Centre is located on the Afon Tryweryn near Bala.

The importance of the landscape of the Dee catchment, its biodiversity, geodiversity, heritage and the importance for recreation, access and culture are recognised through a range of designations. The Dee and its estuary has a high conservation value, it is designated as two Special Areas of Conservation (SAC), and notified as three separate Sites of Special Scientific Interest (SSSIs). Interest features contributing to the SSSI and SAC designations of the freshwater sections of the river include floating water plantain, Atlantic salmon, lamprey, otter, and structural changes in the meandering section of the main river. The intertidal habitats of the Dee Estuary support significant populations of wading birds and is also designated as a Special Protection Area and a Ramsar site.

The strategic importance of the Dee as a potable water source and the risk posed to it from pollution have led to the Dee becoming one of the most protected rivers in Europe, with a highly developed water quality monitoring regime. We and our neighbouring water companies – Hafren Dyfrdwy, United Utilities and Dŵr Cymru Welsh Water - co-fund an intensive monitoring programme of river water quality, working closely with Natural Resources Wales and the Environment Agency. This includes continuous on-line analysis for a range of potential pollutants at 3 locations on the main river, supplemented with the analysis of spot samples taken from 8 locations, including the major tributaries, twice a day, 365 days of the year. In 1999, the lower part of the Dee was designated as a Water Protection Zone.

We must ensure that our planned abstractions will prevent deterioration in water body status; support the achievement of protected area objectives; support the achievement of the environmental objectives in the 2015 plans and, where relevant, ensure any new activities or new physical modification does not prevent the future achievement of good status for a water body.

We work closely with NRW and the EA through the DCC to ensure that our planned abstractions are not at risk of causing deterioration. In addition, we provide weekly abstraction forecasts to NRW and Hafren Dyfrdwy currently chair the Dee Steering Committee which oversees the DEEPOL water quality monitoring regime. Since November 2015, we have collaborated with United Utilities and the Welsh Dee Trust to run a Catchment Management Programme. We have jointly funded two Catchment Advisors (CAs) - employed by the Welsh Dee Trust – to cover the Middle Dee and the Upper Dee. Their key role is to engage with landowners and local pesticide suppliers with the aim of reducing the use of metaldehyde and other problematic pesticides in the catchment through a range of activities and interventions. We intend to continue, and expand on this programme over the next AMP. As a starting point for this process, the Dee Catchment Protection Group the aim of which is to coordinate catchment activities in supporting the objectives of the Dee Steering Committee with specific objectives to provide intelligence from catchment teams regarding potential risks to abstraction which require monitoring; coordinate catchment activities in response to abstraction risks highlighted through incidents and routine sampling undertaken, and coordinate promotion of the River Dee as a drinking water source and some of the challenges to quality from activities within the catchment.

F3.2 Possible changes to abstraction licences

During 2018 the Environment Agency shared their water industry national environment programme (WINEP) which identified our Plemstall borehole as posing a risk of deterioration of WFD status, if we were to abstract the maximum licenced amount. Table F3.1 provides greater detail regarding the water bodies at risk from our abstraction at boreholes.

Table F3.1: Details of water bodies at risk of impact from our borehole abstraction

SW body	Stanney Mill Brook	Gowy (Milton Brook to Mersey)	Bridge Trafford GS (Lower Gowy)
GW body	Wirral and West Cheshire Permo-Triassic Sandstone Aquifers	Wirral and West Cheshire Permo-Triassic Sandstone Aquifers	Wirral and West Cheshire Permo-Triassic Sandstone Aquifers
% of GW body that is covered by this SWB	5.10	1.48	2.48
% of recent actual uptake compared to fully licensed quantity	59.45	59.45	59.45
Proportion of impact of this point-purpose line on the SW body	32	4	64
Long Term Average Full licence impact (Ml/d)	2.18	2.18	2.18
Long Term Average Recent Actual impact (Ml/d)	1.296	1.296	1.296

We have had initial discussions with the Environment Agency to seek to understand the potential nature and impact of voluntary licence reductions, but the continuing position is consistent with the statement in our draft WRMP that this is still to be determined. WINEP version 3 (WINEP3), issued in March 2018, set out a driver (ref. 7DV201824) for investigating impacts of groundwater abstraction in the Wirral and West Cheshire Permo-Triassic Sandstone Aquifers and its surface waterbodies, against our groundwater abstraction near Chester. This investigation is due to be delivered by March 2022 and any future licence reductions will be dependent on the outcome of this investigation.

Following consultation of the draft WRMP and our subsequent Statement of Response we have taken the opportunity to carry out scenario modelling of the potential impact of a licence reduction to our groundwater source in the Chester WRZ. We have used the same assumptions that we used in our WRMP for all other Severn Trent abstractions being investigated during AMP7. That is, we have assumed a reduction of 50% of the difference between the current deployable output and recent actual abstraction of the source. Deployable output for the source is 2.2Ml/d and recent actual abstraction has been 1.32Ml/d, we have therefore modelled the source with reduced annual average constraint of 1.76Ml/d. The resulting modelled deployable output reduction for the zone was 0.4Ml/d.

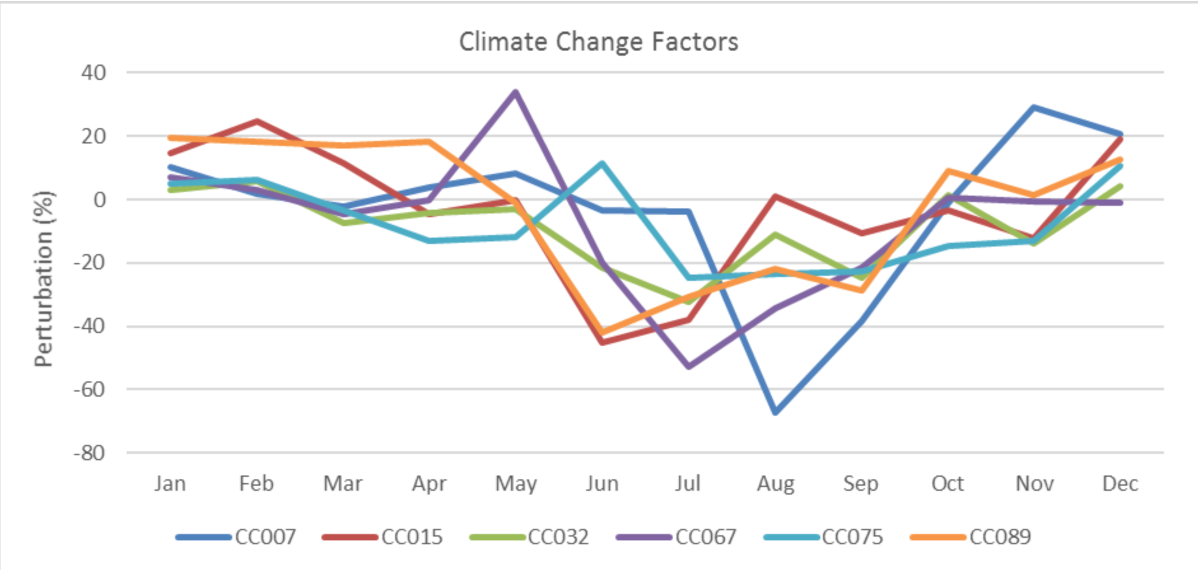
For our final WRMP we have now included this assumed reduction in our planning tables for Chester from 2025, and we can confirm that this assumed reduction does not cause the supply demand balance to go into deficit. The final deployable output reductions won't be known until we have completed out investigation.

F3.3 Climate Change

We assessed the possible impact of climate change on the deployable output of the Chester WRZ using our Aquator model and NRW's River Dee climate change analysis. Because the Severn Trent and Hafren Dyfrdwy River Dee abstractions operate conjunctively, we have modelled the climate change impacts across the River Dee system as a whole. In our modelling and reporting, we consider how the impacts are apportioned across both companies' River Dee abstractions.

For climate chance scenario modelling, NRW tested 100 scenarios and used the six median scenarios to generate climate change versions of the abstraction tables from the Dee General Directions. NRW provided the flow perturbation factors for each of the scenarios. The flow factors relating to the Manley Hall gauging station were used to perturb the inflows to Hafren Dyfrdwy's reservoirs in the Aquator model. When plotted, it was found that the flow factors were generally higher in the winter, and lower in the summer, than the baseline flows. All six scenarios have been used here to test our supply system. Figure F3.1 shows the flow factors for the six climate change scenarios considered in our analysis.

Figure F3.1: Flow factors for the selected climate change scenarios



The same demand profiles as described in our baseline DO modelling were used to vary the demand during the climate change DO runs. This makes the implicit assumption that future demand will vary over the year in a similar way to the variation observed in the past.

Based on this assessment, our net abstraction volume was reduced by 1.61 Ml/d. As the Chester zone is 100% consumptive the most efficient way to apply the reduction was at the Dee Chester abstraction point. The cutback levels remained the same as they were in the baseline run, as did the maximum allowable abstraction. The updated abstraction levels for the climate change scenarios are given in Table F3.2.

Table F3.2: River Dee abstraction limits from the DGD

Abstraction Regime	SVT's Dee Chester Abstraction Limit (Ml/d)	HD's Bangor on Dee Abstraction Limit (Ml/d)
Above system safe yield line	32.50	45.50
Safe yield allocation	27.19	41.50
Stage 1 cutbacks	27.19	41.50
Stage 2 cutbacks	27.19	41.50

The Safe Yield Take (VBA) parameter on the Dee Chester abstraction was thus reduced by 1.61 Ml/d from 28.80 to 27.19 Ml/d for the climate change runs.

The Chester WRZ DO is supplied wholly from the River Dee and Plemstall borehole and is not affected by the climate change impacted inflows to Hafren Dyfrdwy's impoundment reservoirs. The effect of the climate change scenarios was to change the frequency and timing of the cutbacks imposed by NRW. However, if the augmentation from Hafren Dyfrdwy's Pen Y Cae reservoir could be maintained during the cutbacks, abstraction could take place at the safe yield allocation at all times. If the augmentation was not maintained, this would cause failure in the DO test of Hafren Dyfrdwy's Wrexham WRZ. The assessment of Chester WRZ was therefore based on the assumption that the augmentation was maintained and that abstraction could take place at the safe yield allocation throughout all of the climate change runs.

It was assumed that the output from Plemstall borehole would be constant at the licence amount of 2.2 Ml/d and the demand at Mickle Trafford would not vary.

Therefore the DO of the Chester WRZ was 27.8 Ml/d (25.6 + 2.2). This is the mean DO across the whole run, based on the demand at Chester being factored according to the demand profile. In the peak month of July the demand being met would be 29.4 Ml/d (27.2 + 2.2). The impact of climate change on DO in the Chester WRZ was 1.5 Ml/d.

In arriving at this value, it is important to consider that whilst the reduction in take specified by NRW was 1.61 Ml/d, the use of a demand profile makes it appear the reduction is 1.5 Ml/d. The baseline DO for the Chester demand centre is 27.19 Ml/d, when tested to 0.01 Ml/d increments. Under climate change scenarios the DO is 25.67 Ml/d. The reduction in mean DO was therefore 1.52 Ml/d. The reduction is fully implemented at the peak, when the demand factor is highest and at this time the reduction is 1.61 Ml/d (1.52 x 1.06 or 28.80 – 27.19).

F4 Resilience of supply

F4.1 Drought resilience

At the draft plan stage the Chester water resource zone was part of Dee Valley Water and therefore not part of a WRMP that was wholly or mainly in England. Thus, in the draft WRMP provided for consultation and our subsequent Statement of Response, we did not present our deployable output or level of service under a 1 in 200 year drought scenario for the Chester WRZ.

Now that the Chester WRZ has been incorporated into the wider Severn Trent plan, we have carried out the modelling necessary to understand the level of service for the Chester WRZ during a 1 in 200 year drought scenario.

The only sources in the Chester WRZ are the River Dee and the Mickle Trafford borehole. The borehole is resilient to drought and the River Dee abstraction is protected from Dee General Direction (DGD) cut-backs by augmentation from the Pen Y Cae Lower reservoir in Hafren Dyfrdwy's Wrexham WRZ. Stochastic modelling of the NRW River Dee model has shown that flow levels in the River Dee have high resilience to droughts and abstractions from the River Dee are not affected by severe and extreme droughts. This indicates that the Chester WRZ deployable output and levels of service during severe and extreme droughts will only be determined by the resilience and capability of Pen Y Cae Lower reservoir to augment the River Dee as per the DGD rules.

To assess this, testing was undertaken by running the stochastic data that has been prepared for deployable output modelling (i.e. 8,700 years) through the Wrexham water resources model, with the Wrexham zonal demand set at a level above forecast demand plus target headroom for that zone.

In our modelled scenarios, augmentation from Pen Y Cae Lower reservoir was fully maintained throughout all plausible severe and extreme droughts in the stochastic data. Therefore, the Chester WRZ was found to be resilient to plausible severe and extreme droughts, and the deployable output at all return periods is consistent with the historic, asset capacity / licence-based deployable output of 29.3 Ml/d. Therefore we can conclude that the 1 in 200 year deployable output for Chester is 29.3Ml/d and the Level of Service remains consistent with the baseline level of service. For the final WRMP, Table 10 - Drought plan links have been updated to show this result.

A raw water transfer has been agreed between Hafren Dyfrdwy and Severn Trent to enable the augmentation from Pen-y-Cae Lower Reservoir. Hafren Dyfrdwy are anticipating that there may be potential impacts on the stream bed of Trefechan Brook if they carry out this augmentation. To further understand this, they are going to test and monitor the discharge from Pen-y-Cae Lower Reservoir and the corresponding inflow into the River Dee. We will continue to work with Hafren Dyfrdwy, Natural Resources Wales and the Environment Agency to plan and coordinate these trials.

In our draft WRMP for consultation and our subsequent Statement of Response we did not quantify a risk of emergency drought orders as we do not feel these are acceptable to include in our 'business as usual' planning, and therefore they would only be used as part of our Emergency Plan. However, to fully comply with WRMP direction 3(b) we have calculated the likelihood of this level of restriction and our drought resilience analysis demonstrates that we are able to meet DEFRA's reference level of service (a 1 in 200-year drought) without the use of emergency drought orders, as shown in table F4.1 overleaf.

Table F4.1: Chester WRZ Annual Average Risk of Drought Restrictions for each AMP from 2020 to 2045

Drought Restriction	DGD Stage	Our levels of service	2020-25	2025-30	2030-35	2035-40	2040-45
Temporary Water Use Ban	Stage 2 /3	1 in 40 (2.5% annual risk)	2.5%	2.5%	2.5%	2.5%	2.5%
Ordinary Drought Orders (Non-Essential Use Bans)	Stage 3	We do not plan for NEUB	0.47%	0.47%	0.47%	0.47%	0.47%
Emergency Drought Orders	NA	We consider these unacceptable	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%

F4.2 Wider resilience

Our WRMP sits alongside our wider PR19 business plan, in which we describe our plans to protect and enhance water supply resilience for our customers. Our PR19 plan sets out how our approach considers 'resilience in the round' in order to provide holistic, risk based plans for ensuring resilient water supplies. Through the PR19 process, Ofwat has recently asked us to provide more information to further improve our approach to resilience planning. Ofwat has asked us for a commitment that we will, by 22 August 2019, prepare and provide an action plan to develop and implement a systems based approach to resilience and ensure that we can demonstrate an integrated resilience framework.

We have agreed to make this commitment, and we are currently updating our resilience planning and asset management approach to better demonstrate our systems based thinking. This is work in progress and while it is not yet complete, we have committed to submitting this updated resilience plan to Ofwat by 22 August 2019, and we will also share this with Defra and the Environment Agency. This will include details of our new asset management framework and our latest plans to maintain asset health through AMP7. In response to Defra's request for further information, we will now also report on progress through our annual WRMP report.

Beyond drought resilience, our planning for the Chester zone takes into account the following:

- Response to pollution events on the River Dee – our bankside storage reservoir at Boughton, Chester and treated water storage reservoir at Chester treatment works provide us with approximately 3 days of storage should we have to cease abstraction in the event of a pollution event on the River Dee. We are members of the Dee Steering Committee which oversees the DEEPOL notification system, providing early warning to abstractors of pollution events in the Dee catchment. Through our catchment management programme, we have actively engaged with a wide range of businesses who have the potential to negatively impact waterbodies through their activities, to help them identify best practice and advise on pollution prevention techniques.

- Ingress of saline / brackish water at our Chester intake – our abstraction point in Chester is within the upper tidal limit of the Dee and at periods of high tide, there is a significant risk of ingress of saline water. Not only is our treatment works not designed to treat this type of water, it can have a corrosive effect on metal over an extended period of time and would be damaging to our pumps, significantly increasing maintenance costs. Therefore, the control room at our Chester works carry out daily checks of the tide tables and cease abstraction during periods when the tide is predicted to be above 9.5m as measured at Gladstone Docks, Liverpool.

- Freeze-thaw and extreme weather events – we are putting actions in place that address the lessons learnt from the significant freeze-thaw event which occurred in March 2018 and the hot weather of summer 2018. We will also include the plans we are putting in place to improve our measurement and management of unplanned outages, as per our new AMP7 performance commitment. Anything affecting our water resource assets will be reported on in the annual WRMP review.

F5 Outage Allowance

Between the preparation of WRMP09 and WRMP14 Dee Valley Water developed complex 'source to tap' models, which calculate the loss of supply in hours per year for each District Metered Area (DMA). The components included in the models depict how water is supplied. All critical components are modelled and comprise, for example, a raw water source, an aqueduct or a single stage in a treatment works. To carry out the outage allowance assessment, failure data was assigned to each component and Monte Carlo simulations were then carried out to determine the risk of loss of supply for each DMA.

The models were constructed using data and parameters from the following sources:

- Industry standard failure rates (e.g. loss of power);
- Company specific rates (e.g. for pipe failure);
- Expert judgement (e.g. one in ten years for an algal bloom).

The models were calibrated against observed failure rates and a good correlation was achieved between the observed loss of supply and the model predictions.

Interdependencies and redundancies within the system were assessed by modelling different supply scenarios, e.g. from different treatment works. The results from the models were used to determine the loss of supply caused by a failure in the route from the source to the outlet from the treatment works in hours per year (hrs/yr). This DMA based approach was used to calculate outage allowance for the Chester WRZ and the outputs from the models are shown in Table F5.1.

Table F5.1: Outage assessment for Chester WRZs

Treatment works	Capacity (Ml/d)	Unavailability (hrs)	% Unavailability	Outage (Ml/d)
Plemstall	2.2	0.0165	0.00019	0.000004
Boughton	36.5	1.4590	0.01666	0.006079
Chester WRZ				0.0061

To align Chester WRZ with the rest of the Severn Trent region and to meet our new PR19 performance commitment relating to unplanned outage, we will review our outage allowance methodology and ensure consistency across all water resource zones.

F6 Water transfers and bulk supplies

Presently the main connection to the Chester WRZ is from Hafren Dyfrdwy's Wrexham WRZ. Under normal conditions, historically the two zones have been operated separately and no transfers take place.

Dee Valley Water had a DWI commitment – linked to the decommissioning of the old Legacy WTW – to install a pumping station at Chester Business Park to allow transfers between the Chester and Wrexham systems by the end of AMP6. This work has now been completed, with the new pumping station located in Hafren Dyfrdwy's Wrexham WRZ. This gives us increased resilience through a greater capacity for water transfers between Hafren Dyfrdwy and Severn Trent. Modelling suggests a supply benefit to the area south towards Wrexham Industrial Estate, which includes a proposed housing development of 1,300 to 1,800 homes. Depending on valve operation, the above areas can fall within the supply boundaries of either WRZs. This gives a potential of up to 5Ml/d of demand that can be supplied from the Wrexham Road pumping station and a new bulk supply agreement between Hafren Dyfrdwy and Severn Trent has been set up accordingly.

We also have existing bulk supply agreements with Hafren Dyfrdwy (HD) and Dŵr Cymru Welsh Water (DCWW), summarised in Table F6.1. Most of these are for emergency use only and therefore not included in the SDB calculations. The remaining supplies that are used regularly to supply single customers or very small supply areas account for less than 0.5 Ml/d.

Table F6.1: Bulk supply agreements

Location	Company	Transfer type	Use
Old Warren	Welsh Water	Import	Feeds small area
Foxes Lane, Sealand	Welsh Water	Import	Emergency use only

Donor WRZ	Receiving WRZ	Total quantity (Ml/d)
Severn Trent to Hafren Dyfrdwy		
Chester	Saltney	3.51
Hafren Dyfrdwy to Severn Trent		
Wrexham	Chester	3.07

Recent dialogue with DCWW has resulted in an agreement for an additional bulk supply import of 4.00Ml/d into our Chester WRZ from their Bretton WTW. This will bring supply resilience to ca. 12,000 properties to the south of the river Dee. However, as with the majority of our other bulk supplies this will not be used on a day to day basis so has not been included in the SDB calculation.

F7 Drinking Water Quality

The River Dee is the most highly regulated water body in the UK. As such, there are a range of protections in place to prevent deterioration in the water quality including a proactive monitoring regime - which is part funded by the water companies who abstract from the Dee – and associated 'early warning system' which provides notification of any significant pollution events to key abstractors. The monitoring regime is managed by the Dee Steering Committee (DSC). In May 2017 the DSC sanctioned the setting up of a Dee Catchment Protection Group, a working group with representatives from Hafren Dyfrdwy, Severn Trent, United Utilities, Dwr Cymru Welsh Water, Natural Resources Wales and Environment Agency. The aim of the group is to coordinate catchment activities in supporting the objectives of the Dee Steering Committee with specific objectives around providing intelligence from catchment teams regarding potential risks to abstraction which require monitoring; coordinating catchment activities in response to abstraction risks highlighted through incidents and routine sampling undertaken, and coordinating promotion of the River Dee as a drinking water source and some of the challenges to quality from activities within the catchment.

The EA/NRW guidance requires us to consider measures to protect our supplies against long term risks of pollution. We believe that contributing to the work of the Dee Catchment Protection group, along with continued support of the DSC and wider catchment management programmes within the Dee catchment, will enable us to pro-actively manage any risks of pollution through collaborative working with other abstractors and engagement with key land and water users in the catchment on the wider benefits of good water management practices.

F8 Treatment works losses and operational use

For our Chester water treatment works, the volume of water attributed to operational usage and losses was calculated by analysing the difference between the daily readings recorded on the meters monitoring flow in to and out of the works. Due to the raw water storage at the site, the daily readings were rolled on a seven day basis to remove negative values (or change in storage). The results are shown in Table F8.1.

Table F8.1**:** Treatment works losses and operational usage

WTW	2011/12	2013/14	2020/21
Chester	0.3 Ml/d	0.3 Ml/d	0.3 Ml/d

F9 Demand

F9.1 Forecasting household demand for water

Appendix B of this WRMP explains in detail the methods we use to estimate future household demand for water. We have used the same methodologies to understand future household demand for water in the Chester WRZ. A separate report is available on request describing how data from the old Dee Valley Water supply area has been apportioned and incorporated into the Severn Trent and Hafren Dyfrdwy demand models.

Household growth

The EA and NRW WRMP technical guidance (2016) explicitly instructs 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.

We work closely with Local Authorities to understand their projections for future growth and alongside discussions with the Local Authorities we gather data on their housing trajectories from planning department's documents including:

- 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

However, planning horizons for Local Authorities do not reach 2045, and are only projected up to 15 years ahead. Within the planning horizon councils specify a cumulative housing need and present a yearly profile to meet this need. Beyond each council's specified planning horizon, we have extrapolated assuming the annual average housing need from the planning horizon continues to 2045.

For estimates of future total population we have used trends from the Government Local Authority population projections and applied forecast percentage rates of change to our base year data. This gives the underlying change in population due to births, deaths and migration in the region. The population projections held by Local Authorities do not extend to 2045, ending 5 to 10 years earlier. To extrapolate to 2045, the rate of change in the last year of the available data is assumed for remaining years.

Metering

The former Dee Valley Water draft WRMP assumed that we would continue with our past metering policy of providing free optional water meters in the Chester WRZ at a pace set by our customers' demand for these devices. However, in response to feedback on the draft WRMP we have revised our long term metering strategy for Chester WRZ to align with the wider Severn Trent region. We will now adopt a proactive approach to household metering for the new Severn Trent region, and we aim to achieve full meter coverage by the end of AMP9. Although we haven't undertaken a separate consultation for metering of customers in the Chester WRZ, the sampling of customers for the initial consultation is representative of the entire Severn Trent region, and applicable to customers in Chester WRZ. The preparations for our next plan (WRMP24) will provide an opportunity to re-consult customers.

Our strategy is to deliver this metering programme in an affordable way over three AMP periods, prioritising those parts of our region facing the greatest water resources pressures. Given the favourable supply / demand balance position, our current plan is for proactive metering to commence in Chester in early AMP9.

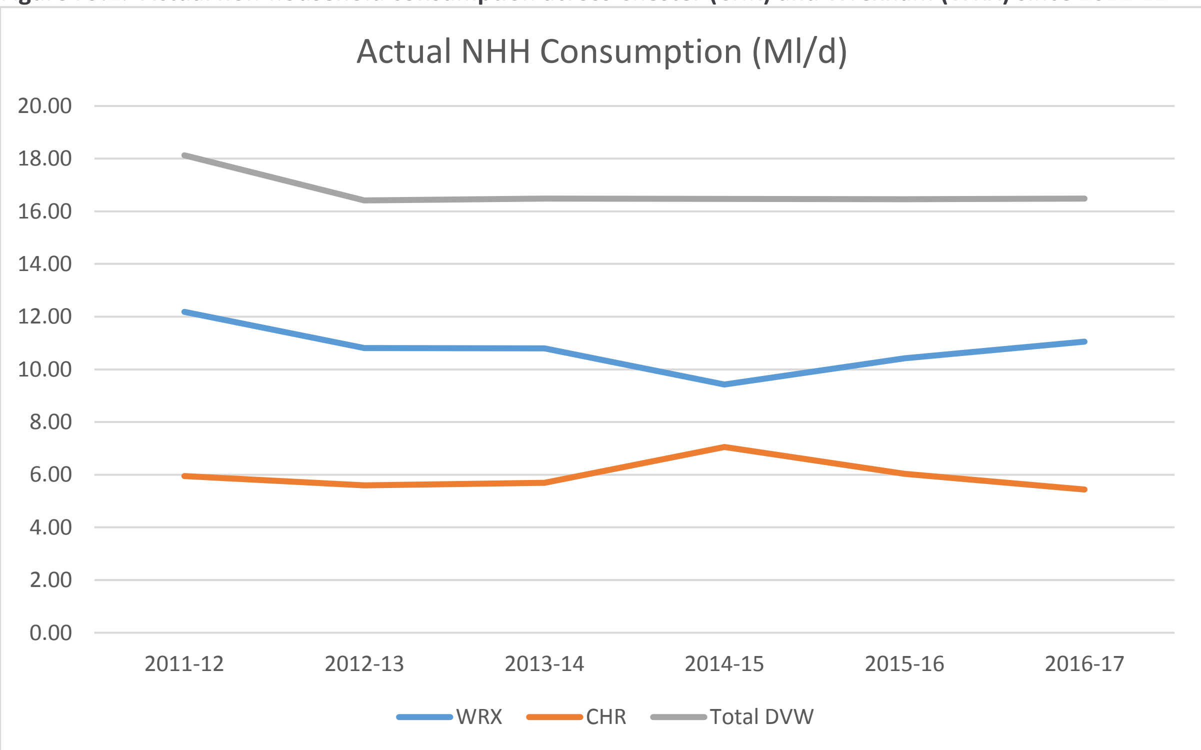
We see metering as key to delivering the long term demand reductions and lower per capita consumption (PCC) ambition set out in the UK Government's 25 Year Environment Plan, as well as the ambition of our stakeholders and customers to use water wisely. When assessing the benefits of a persuaded optant strategy (implementing metering through engagement and collaboration with householders), we have taken a precautionary approach to the demand management impact and we have assumed that there will be an average 10% demand reduction. Our current thinking is that to secure the full demand saving benefits of metering would require us to adopt an external metering policy and combine this with a policy of helping customers tackle supply pipe leakage at their properties.

Based on this metering approach and consumption reduction assumption, our projected dry year annual average PCC values have been updated since the draft plan and are now 144 l/h/d in 2020, reducing to 118 l/h/d by 2045. Similarly our projected normal year annual average PCC values are now 134 l/h/d in 2020 reducing to 110 l/h/d by 2045.

F9.2 Forecasting non-household demand for water

Our forecast for the amount of water likely to be needed by our non-household (NHH) customers in the Chester WRZ is primarily based on industrial use trend analysis and assumptions taken from Dee Valley Water's previous plan (WRMP14). Figure F9.1, shows the recent history of consumption in Chester, as taken from the Dee Valley draft WRMP.

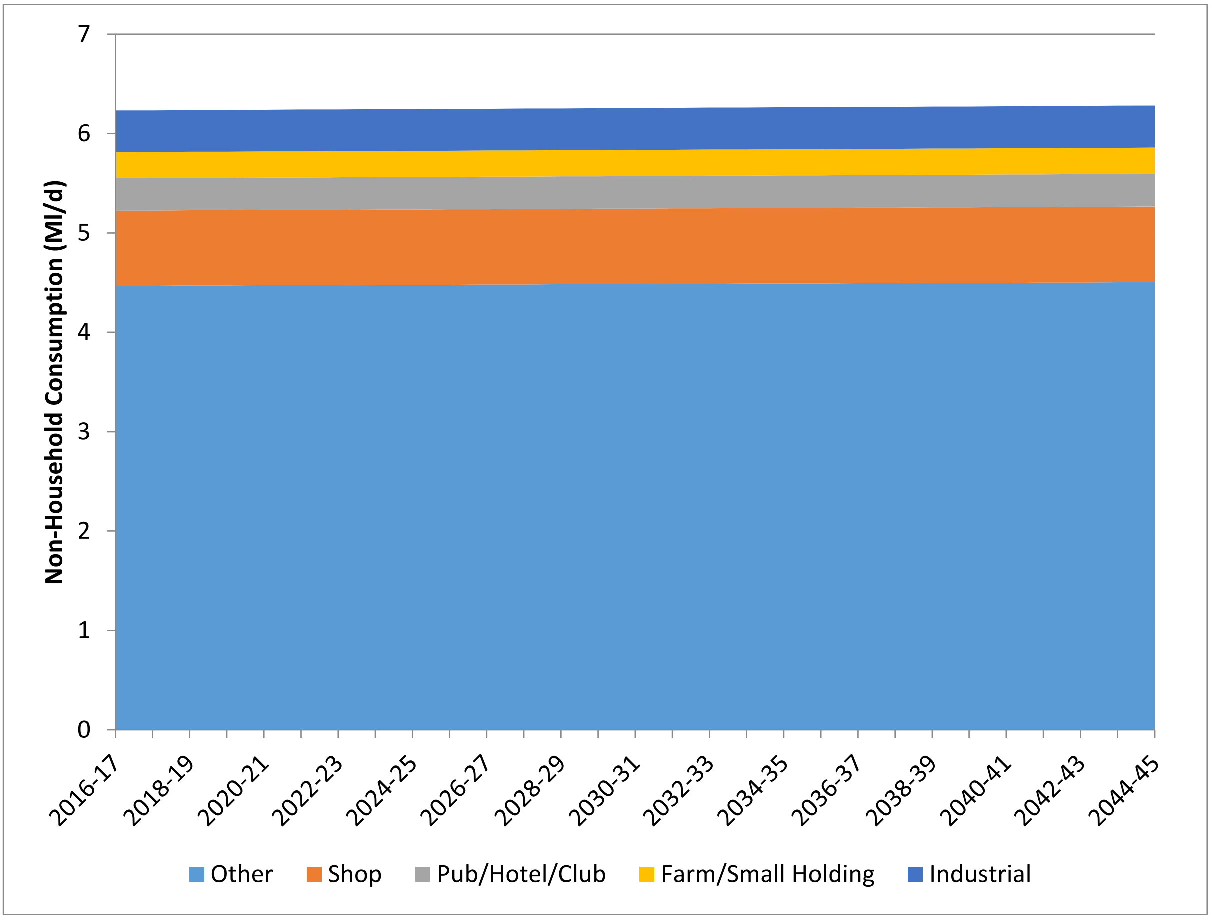
Figure F9.1: Actual non-household consumption across Chester (CHR) and Wrexham (WRX) since 2011-12



Non household consumption in the Chester WRZ is predominantly influenced by planning decisions made by Cheshire West and Chester Council. Small units of industrial land are available for development, but the Council is not aware of any potential large water users planning to set up business in the Chester City area. Instead, the City tends to favour the expansion of the service sector, such as the corporate banking sector.

Based on the information provided by the councils and the non-household trend analysis, the proposed non-household demand forecast for the Chester WRZ across the planning horizon is to remain constant at the value calculated for the base year. Figure F9.2 shows the breakdown of the non-household consumption, in the Chester WRZ, by property type. The slight increase in non-household consumptions is due to the projected impact of climate change on non-household demand.

Figure F9.2: Actual non-household consumption across Chester and Wrexham since 2011-12



F10 Target Headroom and the Supply-Demand Balance

F10.1 Target Headroom calculation

As agreed with NRW and EA, the target headroom assessment for the Chester WRZ was undertaken using the UKWIR methodology '*A Practical Method for Converting Uncertainty into Headroom'* (1998). Although a newer headroom methodology was published by UKWIR in 2002, the relative simplicity of the supply system in Chester WRZ mean that it is more suited to the original methodology.

The methodology we have used to determine target headroom in the Chester WRZ was designed to identify the principal uncertainties in the supply-demand balance and convert these into headroom. The calculation is based on assigning a score to each source of uncertainty and then converting the total score for each WRZ to target headroom.

The sources of uncertainty have been grouped under eleven headings, as shown in Table F10.1 – eight are supply related and three are demand related.

Table F10.1: Target headroom calculation factors

Supply Factors	Demand Factors
S1 Vulnerable Surface Water Licences	D1 Accuracy of Sub-Component Data
S2 Vulnerable Groundwater Licences	D2 Demand Forecast Variation
S3 Time Limited Licences	D3 Uncertainty of Climate Change on Demand
S4 Bulk Transfers	
S5 Gradual Pollution Causing a Reduction in abstraction	
S6 Accuracy of Supply-side data	
S7 Single Source Dominance and Critical Periods	
S8 Uncertainty of Climate Change on Yield	

The methodology works through each of the factors, assigning an appropriate headroom score which is directly related to the degree of uncertainty and the impact it may have on the supply-demand balance for the WRZ under assessment. The scores are aggregated for each WRZ and then transformed by means of a conversion chart into a value for target headroom. The target headroom results for Chester WRZ are shown in Table F10.2.

Table F10.2: Chester WRZ target headroom results

	Present Day →						Planning Horizon
	2016/17						2044/45
Water Available for Use (Ml/d)	28.98						27.25
Target Headroom (%)	6.45 Of which 0% Climate Change						6.55 Of which 0.27% Climate Change
Target Headroom (Ml/d)	1.87 Of which 0 Climate Change						1.78 Of which 0.074 Climate Change
Available Headroom (Ml/d)	3.90						3.41

The results of the headroom assessment, combined with the supply and demand forecasts provide us with our 'supply-demand balance' details of which are set out in the next section.

Components

As explained above, the methodology considers a number of components to make up the headroom score. The explanation of our calculations for some of the key components is set out below. In addition, we have included justification for those components that were not included in the uncertainty calculation, resulting in zero scores.

S1 and S2 – licensing vulnerabilities

In accordance with the planning guidelines therefore, we have made no allowances for S1 (vulnerable surface water licences) or S2 (vulnerable groundwater licences) issues in our target headroom assessment. All sustainability changes are dealt with outside of target headroom, as part of the supply demand balance calculation. We have no vulnerable surface water licences within our supply area.

S3 Issues – time limited licences

Although the Environment Agency's Water Resource Planning Guidelines now allow companies to make an allowance for uncertainty around non-renewal of time limited licences we have made no explicit allowance for it in our headroom assessment.

S4 Issues - uncertainties relating to bulk transfers

Any significant bulk transfers are included within the modelled deployable output, and so any corresponding uncertainty is allowed for under S6 (accuracy of supply side data) issues. No explicit allowance has been made for S4 issues in our headroom assessment.

S5 – Gradual pollution causing a reduction in abstraction

None of the abstractions in the Chester WRZ have been identified as being at risk from gradual pollution.

S6 – Accuracy of supply side data

NRW provided a historical time series of cutbacks for the River Dee (1927 to 2015) which were fed into the Aquator model for initial DO assessment and we therefore have fairly high confidence in this data. However, our reservoir catchments are ungauged and there was therefore no gauged flow data that could be used as reservoir inflows in Aquator. Overall, therefore, we feel sufficiency of supply side data is average.

S7 – Single Source Dominance and critical periods

Due to over 85% of our water coming from the River Dee, it meets the criteria for single source dominance.

S8 – Uncertainty of climate change on yield

NRW tested 100 scenarios and used the six median scenarios to generate climate change versions of the abstraction tables from the Dee General Directions. We used these six scenarios to inform the climate change deployable output (DO) modelling. As described in section F3.3 monthly climate change factors, provided by NRW, were applied to the baseline inflows to the Dee Valley Water reservoirs previously generated using a resampling procedure. This created a perturbed time series of flows for each of the six climate change scenarios, and similarly, new time series for the NRW imposed cutbacks were created for each scenario.

As the Chester WRZ is 100% consumptive the most efficient way to apply the reduction was at the Dee Chester abstraction point. The cutback levels remained the same as they were in the baseline run, as did the maximum allowable abstraction.

The target headroom assessment used for our draft WRMP included an allowance for climate change based on the median climate impacts in the Chester WRZ. We have reassessed target headroom using assumed “wet” (CC075) and “dry” (CC015) projections to provide a range of uncertainty. Under these scenarios the maximum reduction in baseline deployable output was 0.33Ml/d (1.1% of water available for use). The headroom score is the same for all 3 scenario because the impacts are less than 15% which is the threshold for the next step on the scoring matrix. We will be carrying out further modelling to test the impacts of the more extreme 5th and 75th percentile climate change projections to ascertain whether this changes the headroom score and will report on the outcome via the annual review process.

D1 – Accuracy of sub-component data

Our baseline demand forecasts assume a continuation of current rates of optional metering of unmeasured households - this is 3.2% of unmeasured household properties in the old Dee Valley Water region opting for a meter each year. For demand headroom analysis, a triangular distribution has been assumed around the central rate with upper and lower parameters set as follows:

- Lower bound – 2.85% of unmeasured customers opt per annum
- Upper bound – 3.55’% of unmeasured customers opt per annum

The 2019 EA WRMP guidelines explicitly instruct 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 projection of growth from AMP7 onwards for the WRMP19 central housing growth forecast. We have prepared the new property forecast using the Welsh Governments Local Authority Households Projections data set published March 2017 and local authority data sets for English councils.

However, the local authority forecasts represent a stepped increase in new households over current. For uncertainty analysis we have assumed a triangular distribution using the LPA growth projections and historically observed growth in our region:

- Upper/central assumption - LPA projections
- Lower bound – Historic average growth rate

For estimates of future total population we have used trends from the latest Cheshire West/Chester Council population forecasts and Welsh Government Local Authority population projections and applied these to our base year data.

Population uncertainty is based on high and low population projections for Welsh Government Local Authorities and Cheshire West/Chester Council projections, each of which are based on projections combining variants of births, deaths and migration for Wales and England.

D2 – Demand Forecast Variation

Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption:

- Sustainable development - in this most extreme efficiency scenario, we have assumed that water saving is driven by both technological advancements and attitudinal changes. Sophisticated filtration technology would allow recirculation of shower water saving both energy and water. Waste water and washing functions are fulfilled by greywater recycling, aided by hydrophobic frictionless surfaces. Bathing is pretty much obsolete.
- Market trend - this scenario assumes that the projected trend in micro-components does not continue beyond 2022. This would require a situation such as Brexit where UK building regulations

may be de-coupled from current standards and the logical decline in flush volumes is curtailed. The observed upward trend in showering continues to increase.

For measured non-household water consumption, we have based uncertainty bounds on a high and low economic growth scenario forecast, relative to the central estimate. 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 as explain below.

The high scenario envisages that the UK economy will quickly recover after a modest initial post-referendum dip. This assumes that the rapid formation of the new government reassures investors and leads to good early progress on negotiating new trade arrangements with the EU, perhaps similar to the existing EEA member status for the UK but including a provision for some emergency brakes on migration. It also assumes promising initial discussions with other major trading partners such as the US, China and the Commonwealth countries, although actual deals would take longer to agree.

In the medium to long-term, the UK economy will slowly return to long-term growth rates of 2.5 per cent projected by the Office for Budget Responsibilities (OBR) which was produced prior to the EU referendum and represents a more optimistic outlook for the UK's long-term growth path. The inflation pressure has soon subsided following the recovery of the value of Sterling, stronger economic fundamentals allow the Bank of England to raise interest rates at a faster pace than the central scenario.

The low scenario assumes that negotiation with the EU has proved difficult, raising concerns for a possible 'hard-Brexit' and the UK perhaps relying on WTO rules to trade with the EU. This has led to a further fall of the value of Sterling, which in turn leads to a further increase in inflation coupled with the loss of consumer and business confidence which undermine both consumer spending and business investment. In this case, the UK could enter a period of recession for the next 12-24 months and permanently lower the nation's growth potential. The Bank of England keeps the interest rates low in support of economic growth despite a period of higher inflation, the pace of interest rates rises is likely to be slow and gradual. The UK economy finally emerges from the recession stabilising at a below trend growth trajectory until the end of the forecast period.

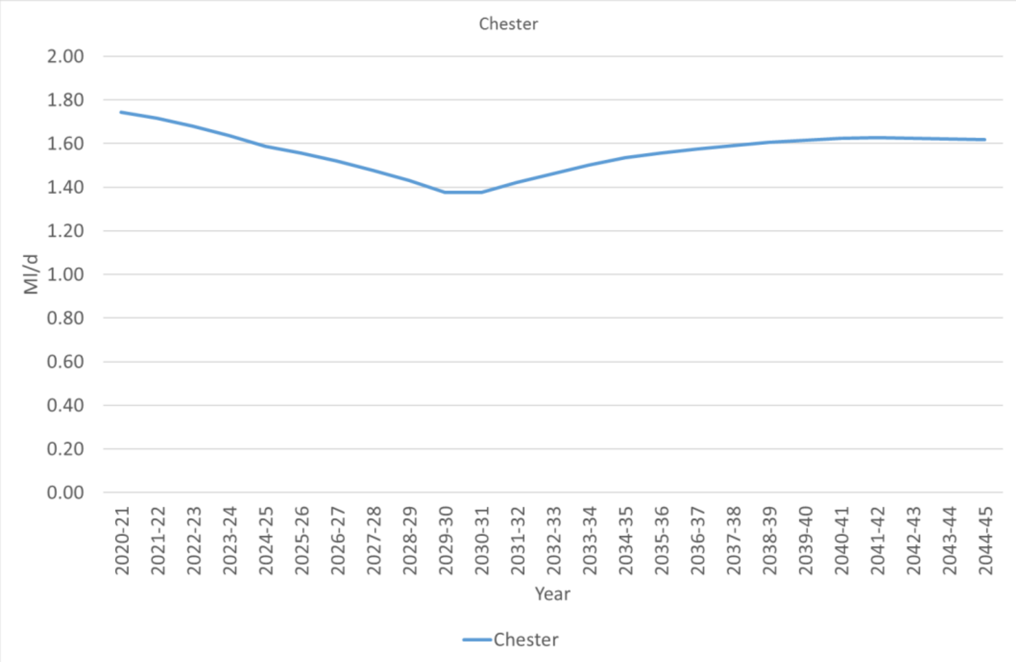
D3 – Uncertainty of Climate Change on demand

We used the UKWIR (2013) Impact of Climate Change on Water Demand methodology, as required by the EA/NRW guidance, to determine the likely impact of climate change on our demand forecast. Reference data used was the Severn Trent Household Relationship - Annual Average, 50th percentile scaling factor. This results in a less than 1% increase in demand over the planning period.

F10.2 Supply-Demand Balance

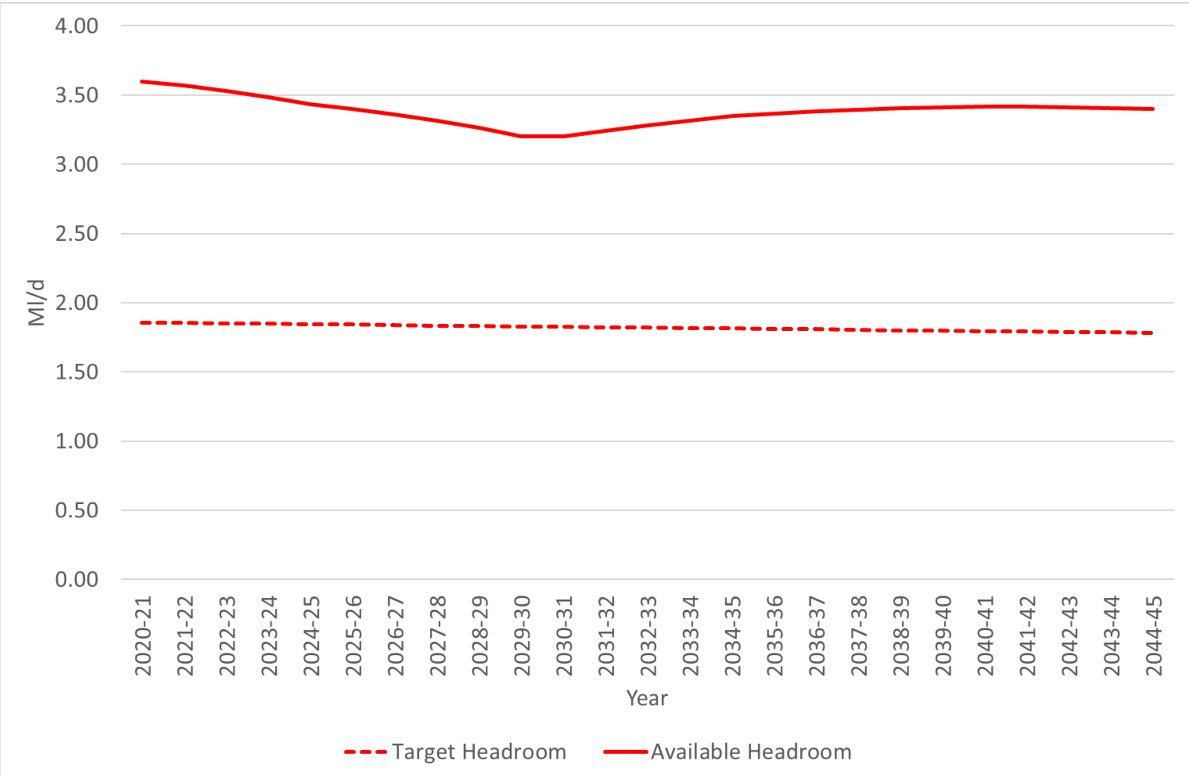
To calculate the supply-demand balance, we take the water that is available to supply and subtract our required demand and headroom to give the balance. Our assessment of the dry year annual average supply-demand balance indicates that there will be adequate resources to meet water needs in our Chester WRZ through to 2044/45. The supply demand balance for the Chester WRZ is shown in Figure F10.1

Figure F10.1: Supply-Demand balance for Chester WRZ



Figures F10.2 shows the results of the headroom analysis for the Chester WRZ. As shown, the available headroom never crosses the target headroom, indicating that there is no deficit throughout the planning horizon and therefore we do not need to develop any new supply-side options.

Figure F10.2: Chester WRZ headroom profile for WRMP19



F11 Water Resource Zone baseline demand projection

The general trend 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 (this is what is required in a baseline forecast)

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

Figure F11.1: Chester baseline dry year PCC

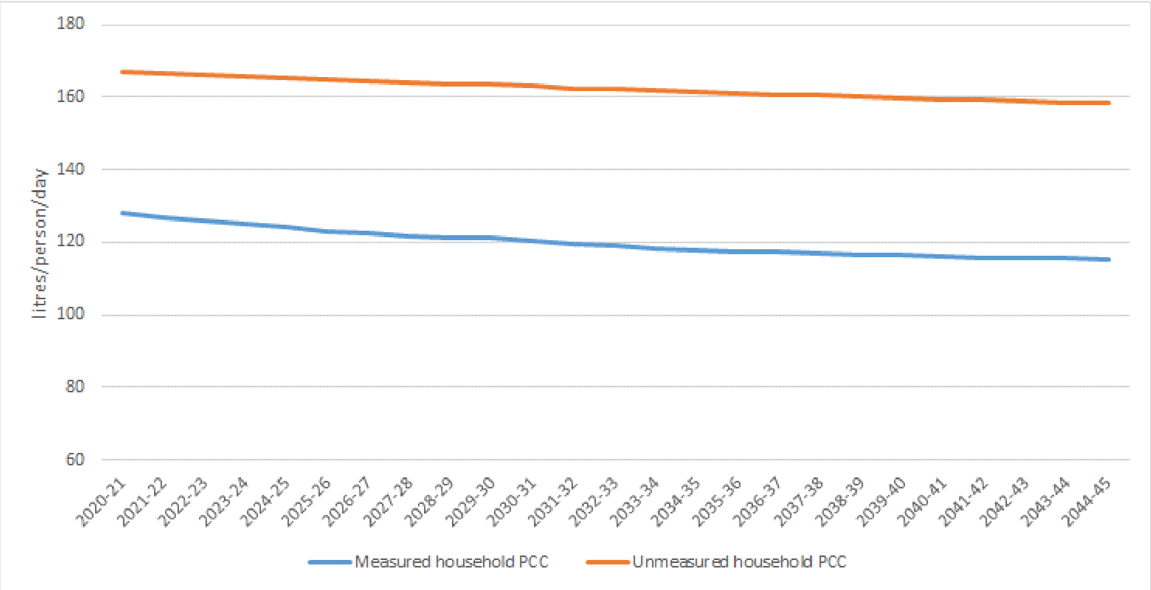


Figure F11.2: Chester baseline dry year DI