Water Resources Management Plan

Appendix A – How much water do we have available?

Water Resource Strategy team
September 2019

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APPENDIX A – How much water do we have available?

A1. Defining our Water Resource Zones

Water resource zones, often referred to simply as WRZs, are the building blocks of our Water Resource Management Plan (WRMP19). They provide a strategic framework for water resources supply-demand management and investment.

Following the creation of Hafren Dyfrdwy, the water resource zones have been amended to reflect the new company boundaries. Part of the Dee Valley historic Chester and Wrexham WRZs now lie in the Severn Trent WRMP and parts of Shelton zone and all the Llandinam and Llanwrin zone now form part of this WRMP. These changes are to reflect the national boundaries and are not because of changes to connectivity in 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 A1.1 and A1.2 show the original Dee Valley Water and Severn Trent Water boundaries and new Hafren Dyfrdwy and Severn Trent Water company boundaries.

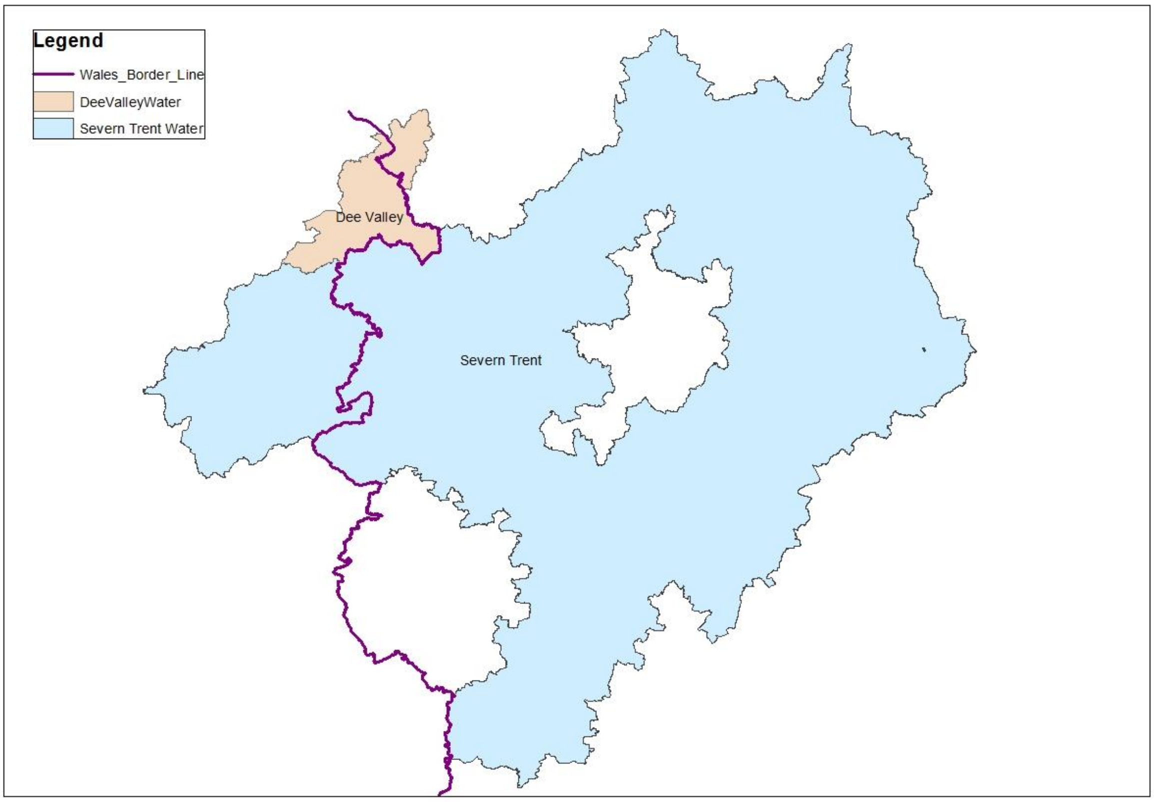


Figure A1.1 - Historic Dee Valley Water and Severn Trent Water boundaries

Appendix A – How much water do we have available?

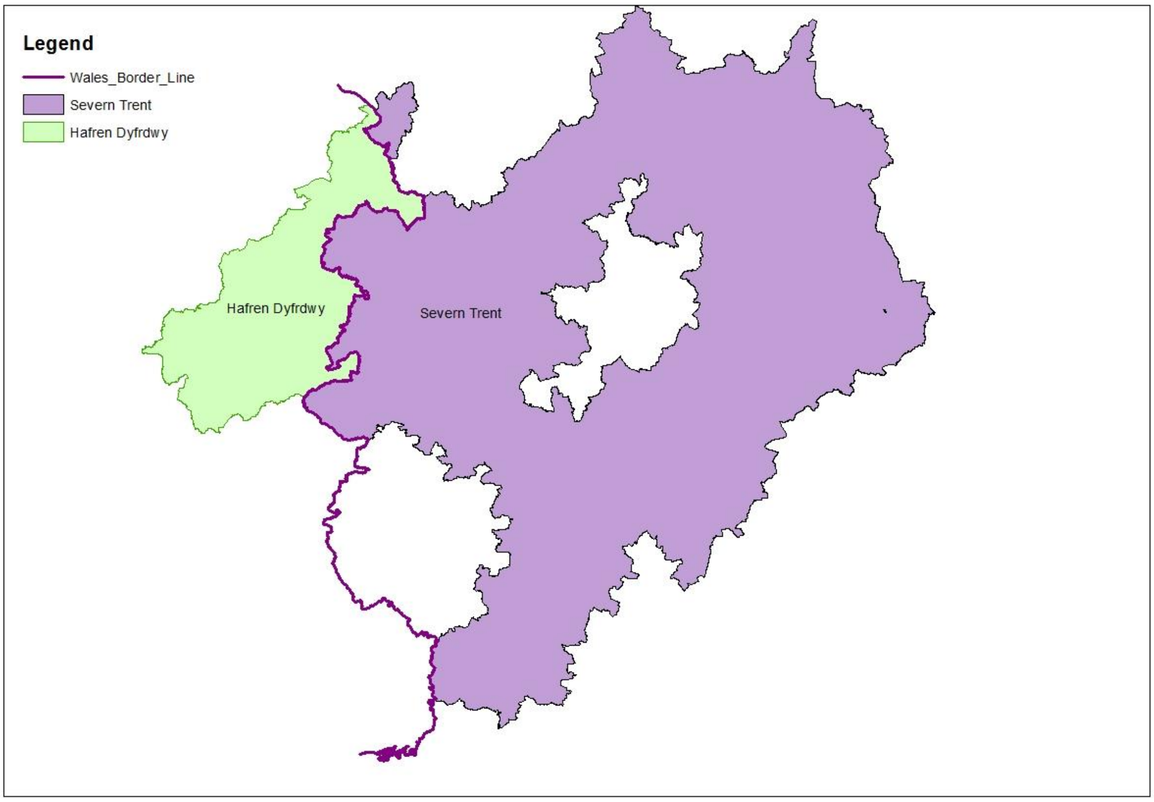


Figure A1.2 - New Hafren Dyfrdwy and Severn Trent company boundaries

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 resource zones, sources of supply and customer connections. This plan reflects the changes and reports on the new four WRZs – Wrexham, Saltney, Llanfyllin and Llandinam & Llanwrin (Figure A1.3).

We are required to 'define' our WRZs and agree these with Natural Resources Wales (NRW) and the Environment Agency (EA). For this definition process, there are a number of factors to consider, but the starting point is the definition provided by these regulators that a WRZ "*describes an area within which, managing supply and demand for water is largely self-contained (apart from defined bulk transfers of water); where the resource units, supply infrastructure and demand centres are linked such that customers in the WRZ experience the same risk of supply failure".* The main factor we have to consider is that significant numbers of customers should not be experiencing different risks of supply failure in a zone. We met with EA and NRW in autumn 2018 to share our approach and agree the new WRZs.

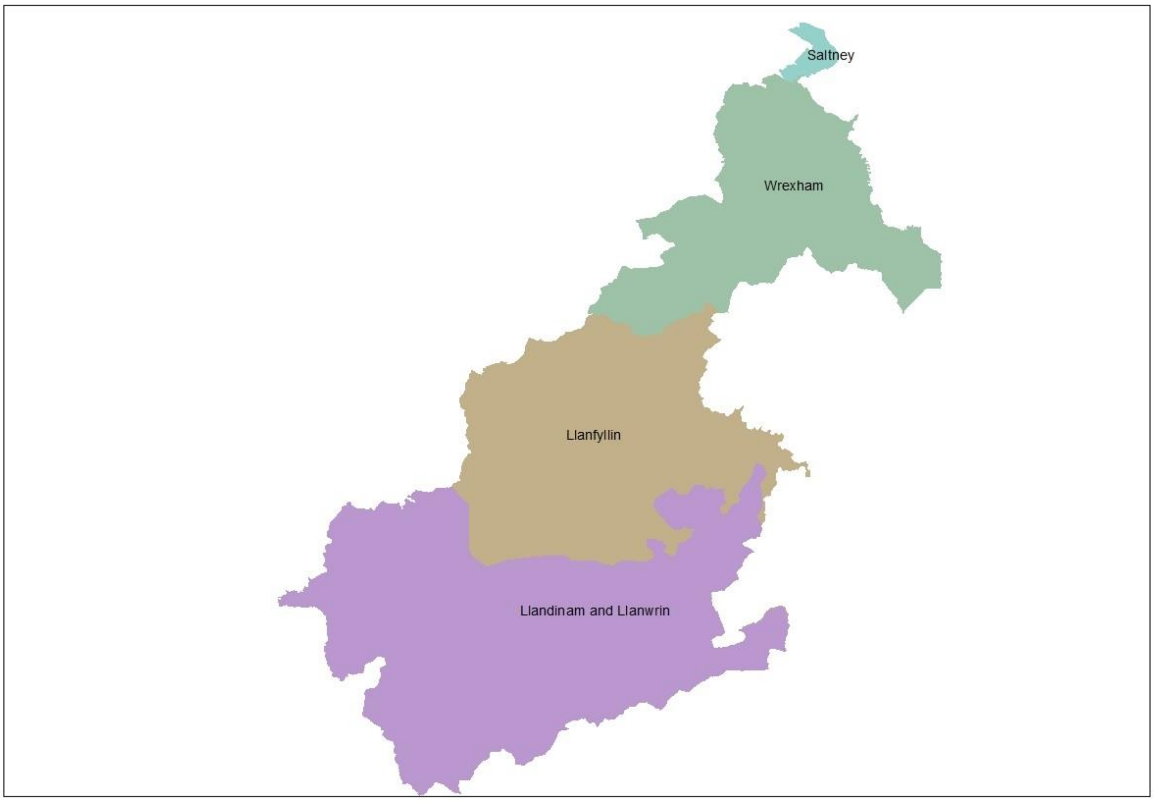


Figure A1.3 - Hafren Dyfrdwy water resource zones

A2. Calculating Deployable Output

Once we have defined our Water Resource Zones, we need to establish the amount of water available for use (commonly referred to as WAFU). The starting point for this is the 'deployable output' or 'DO' – the maximum amount of water that can be output from a source or a group of sources.

We have four water resource zones, these are split between conjunctive use, groundwater only and bulk supply zones. The deployable output for the zones is calculated differently depending on which type of zone they are. The zones and methods used are tabulated below in Table A2.1.

WRZ Name	Type	Method	Reason
Wrexham	Conjunctive Use	Aquator modelling	River and reservoir surface water supplies with a complex network.
Llandinam and Llanwrin	Ground Water Only	UKWIR Assessment	Groundwater Only
Saltney	Bulk Import	Apportionment of DO	New WRZ created as import from Severn Trent water for final plan.
Llanfyllin	Bulk Import	Apportionment of DO	New WRZ created as import from Severn Trent water for final plan.

Table A2.1 - Deployable Output Methodologies Used

Wrexham WRZ – deployable output methodology

We used modelling software called Aquator to calculate an initial[1] DO. An Aquator model is set up to mimic the various components of a water company network (water sources, treatment works, key trunk mains, demand management zones etc), and each component can then be manipulated within the model to assess how the network would perform against a range of scenarios.

An Aquator model was originally built for the Dee Valley Water network in 2015, when the company was looking for alternative options to rebuilding Legacy WTW in Wrexham WRZ. For development of this WRMP, an audit and review of the model was conducted and followed by an initial assessment of the DO for Wrexham WRZ. In March 2017, Dee Valley Water produced a report[2] describing the setup of the revised model, the inputs, parameter values and operating rules implemented, and the outcome of initial DO assessment. The report also made a number of recommendations for future improvements to the model and operating procedures within Dee Valley Water which could optimise the DO of the system.

Assumptions

A number of assumptions were made during the model build, including:

- The model assesses supply only, therefore the demand that the system can meet will not match the DO provided.
- No account has been taken of leakage, process losses or headroom etc.
- No imports or exports have been included in the model. These will need to be accounted for in the WRMP tables.
- All runoff from the Pendinas Indirect and Direct catchments enters Pendinas reservoir.
- Pen Y Cae Upper reservoir will be used to refill Pen Y Cae Lower reservoir when it drops below top water level.
- Water used to augment the River Dee from Pen Y Cae Lower is considered to be abstracted under the Pen Y Cae annual licence.
- Nant Y Ffrith reservoir can supply 0.6 Ml/d from May to December if the water is mixed with water from Pendinas / Llyn Cyfynwy in a 25:75 ratio.
- 36 Ml/d of water can be transferred from Ty Mawr, Pen Y Cae and the Dee to Llywn Onn water treatment works (WTW) through Marchwiel storage reservoir if available in the sources. Any other water in Marchwiel reservoir cannot be used for supply under normal conditions.
- Legacy WTW has been decommissioned for the baseline.
- Oerog Springs compensation flow has been accounted for when calculating the yield as 2.8 Ml/d.

Hydrology – river sources

As previously stated, our main source of water in this WRZ is the River Dee. The Industrial Revolution led to many rivers in industrial areas becoming too polluted to use directly for

[1] I.e. does not take account of leakage, outage, headroom or any other losses, and the model does not incorporate any imports or exports.
[2] *Aquator model audit and review – Dee Valley Water*: 22 March 2017

drinking water but the 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 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 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 NRW, 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 in severe droughts must be approved by all members of the Committee, largely the additional abstraction restrictions which are invoked at various drought trigger points as dictated by reservoir storage levels.

The River Dee sources were therefore modelled very simply for the purposes of the DO assessment. NRW provided a 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 and as a result the Dee catchment was given an essentially infinite flow sequence (9999 Ml/d) in our Aquator model.

Hydrology – impoundment reservoirs

In the Wrexham zone, our second largest water source is our impoundment reservoir system. We have 9 licenced impoundment reservoirs, combined into three reservoir 'groups' for the purpose of contribution to the overall DO.

The reservoir catchments are currently ungauged, therefore there was no gauged flow data available that could be used as reservoir inflows in the Aquator model. Therefore, alternative generation of data representative of the historic flow into each operational reservoir was required. When considering which datasets to use for generating the inflow sequences, the most important consideration was to ensure the variability in the flow record was similar to that in the historic record, so that the system is tested under similar conditions to those seen in the past. For example, in generating the hydrology it was particularly important that droughts were of a similar magnitude to those in the past. Furthermore, given that prolonged events cause the greatest risk to supply from reservoirs (as the effects of daily variability in inflows are damped by the storage), it is important to have a representative mean flow.

Initially, historical Dee Valley Water operational data was considered for use in generating the inflow sequences for the reservoirs from mass balance calculations. However, when compared to Low Flows 2000 (LF2K)[3] outputs, the calculated inflows were far lower than the LF2K estimates. As we no longer hold details of the method used to generate / estimate the flows it was not possible to fully assure the provenance or quality of the data, or to create a correction method. Therefore, an alternative sampling method was used to create the inflow sequences using the LF2K outputs and records from local gauged catchments. The catchment details used in the LF2K software are set out in Table A2.2.

Catchment shapefile name	Catchment Area (km^2)	Base Flow Index	Annual run off (mm)	Mean flow (Ml/d)
Nant Y Ffrith	1.247	0.367	679.3	2.33
Pen Y Cae Upper	6.217	0.398	687.5	11.75
Pen Y Cae Lower	0.349	0.631	541.7	0.52
Pendinas (res group)	3.524	0.425	715.6	6.91
Llyn Cyfynwy	0.17	0.667	639.4	0.26
Ty Mawr (res group)	4.834	0.328	722.9	9.59

Table A2.2: Catchment details used in the LF2K software

We used a procedure called resampling to create continuous flow sequences for each of the reservoir catchments from 1st January 1927 to 31st December 2015, a period of 89 years. This was a sufficient record to test the system under a range of hydrological events.

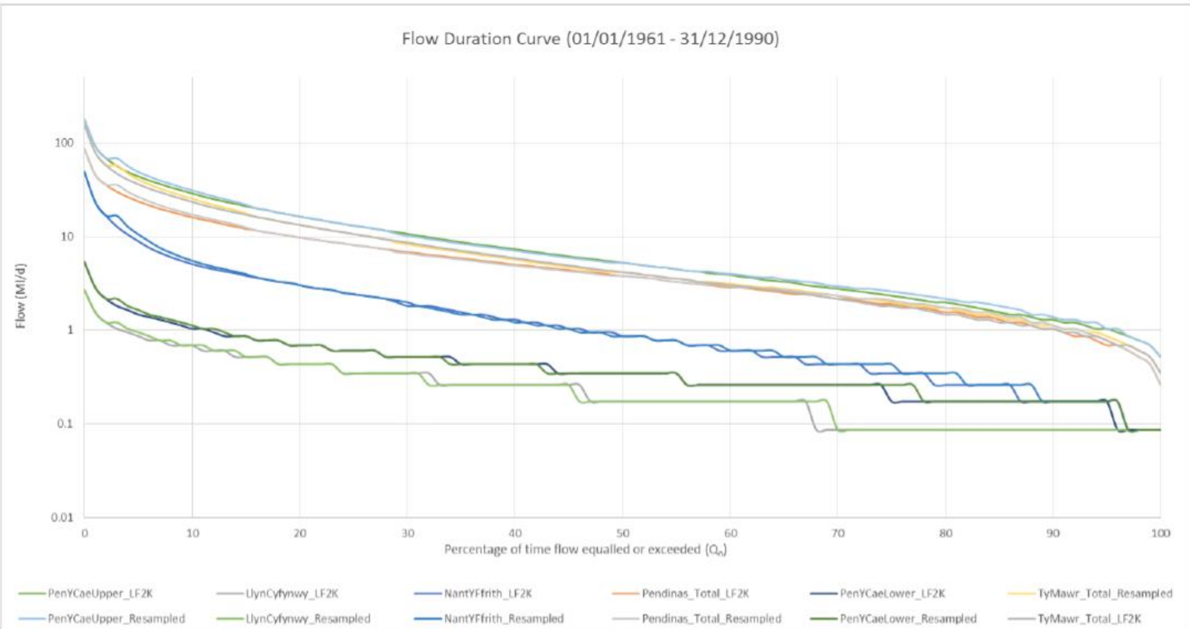


Figure A2.1 - Flow duration curves from LF2K and for flows generated by resampling method

[3] LF2K is a software package – developed by Wallingford Hydrosolutions – which can estimate river flows for any river reach within the UK, even where measured flow data is not available.

Operational rules used in Aquator

The operational rules are broken down into two main components – Dee abstractions and reservoir operation. A summary of these is provided below.

Dee abstractions

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 point (Table A2.3); the abstraction volumes authorised under Stage 1 and Stage 2 cutbacks in drought conditions are reliant upon augmentation of the River Dee from Pen Y Cae reservoirs.

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 (now a Severn Trent asset).

Abstraction Regime	Barrelwell Hill / Dee Chester Abstraction Limit (Ml/d)	Bangor on Dee / Twll Abstraction Limit (Ml/d)
Above system safe yield line	32.5	45.5
Safe yield allocation	28.8	41.5
Stage 1 cutbacks	28.8[4]	41.5
Stage 2 cutbacks	28.8[5]	41.5

Table A2.3 - River Dee abstractions as set out in the Dee General Directions

Reservoir operation

The following rules for reservoir operation were built into the model:

- Nant Y Ffrith can be used all year round; the maximum take is 0.6 Ml/d (25m^3/hr); water from Nant Y Ffrith must be mixed with water from Pendinas / Llyn Cyfynwy in a 25:75 ratio.
- Pendinas and Llyn Cyfynwy storage was aggregated as the water is equally accessible from both sources and it simplified the model to allow shorter run times. The same below curve take limits are imposed on supply that is blended with Nant Y Ffrith water and that which is supplied directly to Pendinas WTW.
- Storage in Ty Mawr and Cae Llwyd was aggregated as the water is equally accessible from both sources.
- Pen Y Cae Lower is no longer used for supply but can be used to augment the River Dee, to offset the Dee stage 1 and stage 2 cutbacks in accordance with the time series provided by NRW.
- Pen Y Cae Upper fills Pen Y Cae Lower whenever storage in the latter drops below top water level. To ensure the annual abstraction licence limit was applied, the inflows to the Upper and Lower reservoirs were modelled as flowing into the Upper reservoir and the transfer to the Lower reservoir was constrained by the annual licence, in addition to the output from the Upper reservoir for supply.

[4] Based upon augmentation of 0.4 Ml/d from Pen Y Cae
[5] Based upon augmentation of 0.8 Ml/d from Pen Y Cae

- The daily output from the Pen Y Cae Upper and Lower reservoirs could not exceed the daily licence, therefore any flow released for Dee augmentation from the Lower reservoir reduces the abstraction available from the Upper reservoir. A single control curve was used to control abstraction when storage was below the curve.

Reservoir yields

A simple reservoir yield assessment model was created in Aquator and used to assess the yield of each reservoir group / system individually. The yields and storage curves from the model runs indicate the supply that could be maintained from each reservoir under historic conditions, and can be used to inform the abstraction rates that our sources can support.

No control curves or abstraction limits were implemented so the only constraining factor was hydrological. Constant demands were placed on the abstraction demand centre and were increased using the English and Welsh Deployable Output analyser, until the reservoir failed to satisfy modelled demands and levels decreased to emergency storage level. The highest demand that could be met without causing failure was considered to be the yield of the reservoir. The emergency storage volume was re-calculated by the model for each DO run as the dead water volume plus 30 days of supply at the demand being tested, plus 30 days of compensation flow.

In the case of Pen Y Cae, the second reservoir was enabled to represent Pen Y Cae Lower reservoir, which was able to supply the Dee augmentation demand but not the abstraction potential demand. The lower reservoir was refilled from the upper reservoir as soon as storage dropped below 100%.

The outputs of this assessment are shown in Table A2.4 below. The majority of the reservoirs failed under 2011 conditions.

Reservoir	Dead water (Ml)	Compensation flow (Ml/d)	Yield (Ml/d)	Emergency storage (Ml)	Failure date for yield run
Nant Y Ffrith	5	0.00	0.59	22.7	27/10/2011
Pendinas / Llyn Cyfynwy	205	0.57	2.10	285.1	31/10/2011
Ty Mawr	59	0.11	3.72	173.9	26/11/2011
Pen Y Cae	1	0.01	1.24	38.5	08/10/1933

Table A2.4 - Results of reservoir yield assessment

Wrexham WRZ Initial deployable output assessment (unprofiled demand)

Once all of the operational rules were in place, an initial deployable output assessment was completed using the *Deployable Output – English and Welsh Method* analyser in Aquator. This 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 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).

The model used to assess DO has both our Wrexham WRZ and Severn Trent's Chester WRZ within it because both of these zones have a key supply from the River Dee. Both WRZs are built into the same model so 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 DO of the Wrexham WRZ, with an unprofiled demand under historic conditions and retaining 30 days of emergency storage in each reservoir, was 51.7 Ml/d. The failure occurred on 07/10/1933 when Ty Mawr reservoir reached emergency storage. Whilst a number of reservoirs were more susceptible to the dry period in 2011 when tested individually (see 'Reservoir yields' section above), the conjunctive system was more vulnerable to the 1933/34 event. Therefore, the Wrexham WRZ DO was **51.7 Ml/d.**

Initial deployable output assessment (profiled demand)

We collated distribution input (DI) data for Wrexham for the period 01/01/1999 to 31/12/2015. We have plotted this data and the years with the largest summer peaks were identified as 2003, 2005, 2006 and 2010 (Figure A2.2). The years with high summer peaks were selected as these were the periods when the highest demands were experienced in the WRZ and were therefore the times when the system was at highest risk of failure.

The mean daily flows for each month across the selected years were calculated and a factor calculated for each month, by dividing the mean monthly daily flow by the mean daily flow across the selected years, such that the average factor is 1.0 in each case.

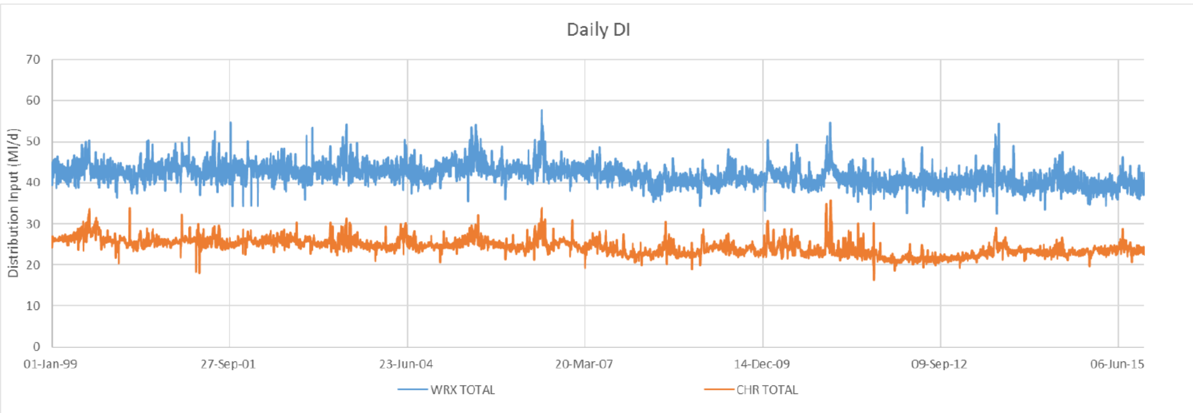


Figure A2.2 - Daily distribution input data for Wrexham WRZs

Month	1	2	3	4	5	6	7	8	9	10	11	12
Wrexham Dry Years Demand Factors	1.01	1.00	1.00	0.99	0.98	1.04	1.05	1.00	0.98	0.97	0.99	1.00

Table A2.5 - Monthly demand factors for the Wrexham WRZ

Using the new demand profiles, the DO was assessed again using the English and Welsh DO analyser in Aquator, and the new mean DO is **51.2 Ml/d**.

This figure represents the mean demand met across every day of the assessment period (1927 to 2015) meaning that during the peak month of July, the demand being met in the Wrexham WRZ was around 53.7 Ml/d (i.e. 51.2 Ml/d multiplied by the 1.05 factor from Table 2.5). 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 this profiled demand, the failure date moved to 01/07/1927 for the Wrexham WRZ 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 of 53.7 Ml/d 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.

Llandinam & Llanwrin WRZ – deployable output methodology

The deployable output of operational groundwater sources was assessed in 2012 in accordance with the *UKWIR methodology* (UKWIR, 1995 and UKWIR, 2000) to inform the assessment for Llandinam & Llanwrin WRZ for our WRMP in 2009. During 2016-17, we again reviewed and updated the deployable output of our groundwater sources in accordance with the guidance in the UKWIR methodologies. This included a review of groundwater output capacity in relation to all constraints (licence, infrastructure, aquifer and distribution limitations), along with a review of water quality including nitrates, climate change and EA sustainability changes impacts on groundwater DO.

Source Performance Diagrams (SPDs) were derived for each borehole source in order to determine the drought year average deployable yield and the peak week deployable yield. In this document the drought year average DO will be referred to as “average DO” and the drought year peak week DO as ”peak week DO”.

For the assessment, we have updated all available groundwater datasets to mid-2016, and our assessment of groundwater DO incorporates the recent 2011/12 drought, which represented some of the lowest groundwater levels recorded across our resource area.

The review of groundwater DO was carried out in eight stages:

Stage 1: Review of previous DO assessment

The first stage of the process reviewed the groundwater source information reported in our WRMP of 2014 (WRMP14). This forms part of the audit trail for our final WRMP 2019.

Stage 2: Source Licence verification

This stage of the process verified the average and peak licence details reported in our WRMP14 assessment. Several sites were identified to have minor licence changes since the WRMP14 assessment.

Stage 3: Review of network constraints

This stage of the process identified any network constraints up to the first Distribution Storage Reservoir (DSR).

Stage 4: Review of geological / borehole construction logs

This stage of the process re-reviewed the geological and borehole construction logs on a site by site basis, to determine any additional constraints to those identified in 2014. No additional constraints were identified.

Stage 5: Operational verification

This stage of the process captured expert judgement from our operational staff on the deployable output of our groundwater sources. Information on site infrastructure and processes (pump capacities, pump depths, treatment and booster capacities, operational interlocks and Programmable Logic Controls) was captured and reviewed and recent actual production data was also examined. This gave an indication of average and peak DO capability.

Stage 6: Review, collation and update of manual and telemetry groundwater level data and spring flow data

This stage of the process reviewed groundwater level and flow data collated as part of the WRMP14 assessment. Where applicable, manual groundwater dips and telemetry water level and flow data were collated to mid-2016 and records updated on a source by source basis. In addition, available EA regional groundwater level data were collated and records updated to mid-2016.

Saltney and Llanfyllin WRZs – deployable output

Neither Saltney nor Llanfyllin WRZs have their own water sources and are supplied solely via bulk supply transfers from Severn Trent. Therefore DO is reported as 0 Ml/d.

Conclusion

The baseline deployable output (DO) for each zone is presented in Tables A2.6. This is the DO provided by our current supply system at our current level of service and does not include the potential impacts of future climate change or sustainability changes.

WRZ	WRMP19 DO (Ml/d)	Constraint
Wrexham	51.2	Assets. N. DO is 51.7Ml/d with un-profiled demands.
Llandinam and Llanwrin	19.86	Groundwater Yield
Saltney	0	Bulk Import of 3.51Ml/d
Llanfyllin	0	Bulk import of 6.75Ml/d

Table A2.6 - Deployable output of our WRZs

The Wrexham DO under the profiled scenario is constrained by assets rather than water resources, which shows that the system is resilient to previous hydrological events.

A2.1 Changes in deployable output

Once the baseline DO has been established, we then need to take account of any current or future issues that could affect the DO. As a minimum, we are required to consider the following issues with regards to how they could impact our WRMP19 and any actions required:

- Our role in achieving sustainable abstraction
- Invasive non-native species (INNS)
- Possible changes to abstraction licences
- Abstraction reform
- Climate change

The following sections will deal with each of these in detail and set out how we intend to address them through the WRMP19 and/or wider work programmes.

A2.1.1 Our role in achieving sustainable abstraction

Dee River Basin District

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 plans are 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 and Wrexham are the major urban centres, 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 it 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 – United Utilities and Dŵr Cymru Welsh Water - co-fund an intensive monitoring programme of river water quality, working closely with NRW and the EA. 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 will discuss how this impacts our processes in section A5 below.

Severn River Basin District

The Severn RBD, which covers over 21,000km^2 lies both in England and Wales. It extends from the Welsh uplands, through the rolling hills of the Midlands and south to the Severn Estuary.

In total over 5 million people live and work in the region and, although predominantly rural, it includes urban areas such as Bristol, Coventry, Cardiff, the South Wales Valleys and parts of the West Midlands conurbation.

The Severn RBD has a particularly rich diversity of wildlife and habitats, supporting many species of global and national importance. For example, the Severn Estuary and its surrounding area are protected for their bird populations, habitats and migratory fish species such as Atlantic salmon, shad, lamprey and eel.

The river basin district is divided into 10 catchments, five of which are in England (Shropshire Middle Severn, Worcestershire Middle Severn, Warwickshire Avon, Severn Vale and Bristol Avon and North Somerset Streams), three sit across the border between England and Wales (Severn Uplands, Teme and Wye) and two are in Wales (Usk and South East Valleys). These catchments range from energetic upland streams to slower rivers in the lowlands, and include sandstone and limestone aquifers used for public water supply in the Midlands.

Around 80% of the river basin district land is used for agriculture and forestry, which shapes much of the landscape. The sector includes beef and sheep farming, large-scale dairy farms, coniferous forestry plantations and some arable and specialist horticulture. The economy of the district is supported by business, transport, health, tourism and recreation as well as manufacturing, mineral industries and the operation of commercial ports.

Our contribution to maintaining good status

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 are an active member of 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. Hafren Dyfrdwy currently chairs the Dee Catchment Protection Group, the aim of which is to coordinate catchment activities in supporting the objectives of the Dee Steering Committee. The group's specific objectives are 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 highlight some of the challenges to quality from activities within the catchment.

We sit on the Severn Working Group, the purpose of which is to co-ordinate assessment and evaluation of strategic planning matters related to the River Severn. This includes developing a shared understanding of current and future availability of resources; resource development options; environmental impact of proposed WRMP schemes, both individually and in-combination; and river regulation. In addition, for ourselves and the other water company members and other members interested in multi-sector trades, the Working Group also presents an opportunity to develop a list of options available for future raw or treated water transfers and/or trades.

A2.1.2 Invasive non-native species (INNS)

Aquatic and riparian INNS can have significant adverse environmental, economic and social impacts, and can cause deterioration of the ecological status of WFD designated water bodies. We are required to review whether our current abstraction operations and/or future solutions are at risk of spreading INNS, and if so, propose measures to manage that risk.

NRW and EA have introduced a new INNS driver to the National Environmental Programme (NEP) for PR19 – a programme of environmental improvement works issued to each water company to be included in their investment plan for the next AMP. It states that *"water companies will need to understand the key pathways of spread on their assets and catchments, and how those pathways of spread can be mitigated. This driver includes investigations and schemes to deliver the new Invasive Alien Species regulation and the GB strategy for INNS, focussing on the pathways of introduction and spread. The majority of the investigations and schemes contribute to prevention of deterioration for WFD."*

Following early discussions with NRW, we have agreed to produce a list of all water transfers within our system. We will risk assess these using criteria agreed with the regulator, and identify those abstractions and transfers with a high risk of enabling movement of INNS between water bodies. During the next AMP we plan to carry out full investigations of what INNS may actually be present and identify measures to manage the risks they pose.

A2.1.3 Possible changes to abstraction licences

NRW have not identified any Hafren Dyfrdwy abstractions in their WFD 'no deterioration' investigations to date. We are not considering any new water supply-side options in our WRMP but we will continue to work closely with NRW to ensure that our current abstractions, and any other activities on or near vulnerable waterbodies, continue to support 'good' status and not pose a risk of deterioration.

A2.1.4 Abstraction reform

UK Government Water Minister Therese Coffey announced at the end of March 2017 that there are no immediate plans to progress with abstraction reform or associated changes to primary legislation. In June 2017, Welsh Government issued their consultation *Taking Forward Wales' Sustainable Management of Natural* Resources, in which they recognised that there was unlikely to be a joint bill for abstraction reform in the near future, and put forward proposals on whether it could be applied on a Wales only basis. While they are proposing to continue to work with NRW, Defra and the EA to use the powers in the Water Act 2014 to bring water abstraction activities into the Environmental Permitting Regulations, Welsh Government feel that this will not address all of the issues and they may need to consider other legislative mechanisms to provide NRW with the most effective means of managing Wales' water resources.

Welsh Government are proposing a number of small amendments to existing legislation to enable the delivery of a reformed abstraction management system in line with the *Making the most of every drop* consultation and the responses received. In summary, they believe these changes will:

- Increase the amount of water that can be used by systematically linking access to water availability;
- Incentivise abstractors to manage water efficiently;
- Help abstractors to trade available water effectively, ensuring that we get the most value out of our water and do not waste water which could be used;
- Ensure there is a more effective process to review licences, striking the right balance between providing regulatory certainty for abstractors and managing environmental risk; and
- Incentivise abstractors to manage risks from future pressures on water resources, increasing their own resilience and that of river catchments.

As this work is still in an early stage, we have not included any changes to DO from abstraction reform. However, where there are unused licenced volumes associated with our abstraction licences we have considered the future possibilities for water trading and how we can make best use of any underutilised licensed quantity.

Any of our abstraction licences that have the potential to cause environmental harm have been flagged through the Restoring Sustainable Abstraction work or through the Water

Industry National Environment Programme (WINEP) / Wales National Environment Programme (NEP) analysis.

A2.1.5 Abstraction Incentive Mechanism

Ofwat's February 2016 Abstraction Incentive Mechanism (AIM) guidelines state 'no water company wholly or mainly in Wales has proposed an AIM site, and the environmental information we currently have does not suggest there is a need for them to do so. We therefore expect the AIM guidelines will only apply to water companies wholly or mainly in England. However, if a water company wholly or mainly in Wales chose to volunteer an abstraction site for the AIM we would expect that company to follow the AIM guidelines.'

Hafren Dyfrdwy aligns to national boundaries and is wholly in Wales. We have however considered our abstraction sites within Hafren Dyfrdwy to determine whether or not there are any sites that we could volunteer for AIM. This is in line with Ofwat's PR19 final methodology Appendix 2.

The final methodology states that for PR19 there is an expectation that we utilise Natural Resources Wales' NEP as a starting point for AIM site identification and selection. The Welsh NEP was finalised in March 2018. As evident from the NEP there are no identified sites where a reduction in abstraction will provide an environmental benefit. The only Water Resources identified NEP actions relate to eels and invasive non-native species. As per Ofwat's final methodology as we have no suitable AIM sites identified through the NEP, we have looked at our sites in greater detail to determine whether they could be included in AIM.

Hafren Dyfrdwy has 10 abstraction sources. The table below summarises these abstraction sources and whether there is already a mechanism in place to ensure sustainability – the details of these mechanisms are also detailed.

Abstraction Source	Existing Sustainability Mechanism in place?	Details of mechanism
Abersychnant	Yes	Compensation flow to ensure flow in river does not reduce to less than 136.68 cubic metres per day, and to protect other licensed abstractors' rights
Nant y Ffrith	No	N/A
Nant yr Crogfin (Pant Glas)	Yes	Transfer to impoundment reservoir which has a compensation regime
Oerog	Yes	Compensation requirement of 12.5% of flow from spring
Pendinas and Llyn Cwfynwy	Yes	Compensation regime requirement
Penycae	No	N/A
Twll	Yes	Dee General Directions
Ty Mawr and Cae Clwyd	Yes	Compensation regime requirement
Llandinam BHs	No	N/A
Llanwrin BH	No	N/A

Table A2.7 - Hafren Dyfrdwy abstraction sources and existing mechanisms for sustainability

Two of the sources that have no mechanism in place are reservoirs (Nant y Ffrith and Penycae) and so it is not appropriate to reduce the abstraction from these sources for the purposes of AIM as this will not have the desired flow improvements that Ofwat expect to see, using their incentive mechanism. Reducing abstraction from a reservoir will not improve downstream flow as flows are regulated from impounding reservoirs regardless of the quantity of abstraction that takes place. Of the two groundwater sources identified as having no mechanism in place, Llanwrin is currently exempt from needing an abstraction licence but will be brought into the licensing regime over the next couple of years – we have therefore assumed that Natural Resources Wales will licence at a sustainable level. Our Llandinam boreholes were not picked up under a flow driver in the AMP7 NEP, and we have therefore assumed that there are no issues relating to this abstraction.

The sources identified where there is a mechanism in place already have had this mechanism approved by NRW or the Dee Consultative Committee assisted by NRW. The regulator has the opportunity to therefore look to amend any environmental/flow obligations as new environmental information becomes available (but through conversations with Hafren Dyfrdwy). As it stands the regulator has not identified any site through the NEP and have mechanism in place to ensure sustainable abstraction. This means that AIM is inappropriate as an incentive to reduce abstraction to enhance surface water flows as they are already sustainable or have the mechanisms in place to ensure continued environmental protection.

Taking into consideration the information presented above, it is evident that AIM is not appropriate for any of our sources within Hafren Dyfrdwy and therefore no AIM performance commitment is being proposed for PR19.

A2.1.6 Climate change

Wrexham WRZ DO

NRW tested 100 scenarios and used the six median scenarios to generate climate change versions of the abstraction tables from the Dee General Directions (DGD). We then used these scenarios to assess the possible impact of climate change on deployable output for Wrexham WRZ and Chester WRZ (now part of Severn Trent Water's supply area), using our Aquator model.

Based on this assessment, 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 A2.8.

Abstraction Regime	Dee Chester Abstraction Limit (Ml/d)	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

Table A2.8 River Dee abstraction limits from the DGD

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.

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 our 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 A2.4 shows the flow factors for the six climate change scenarios considered in our analysis.

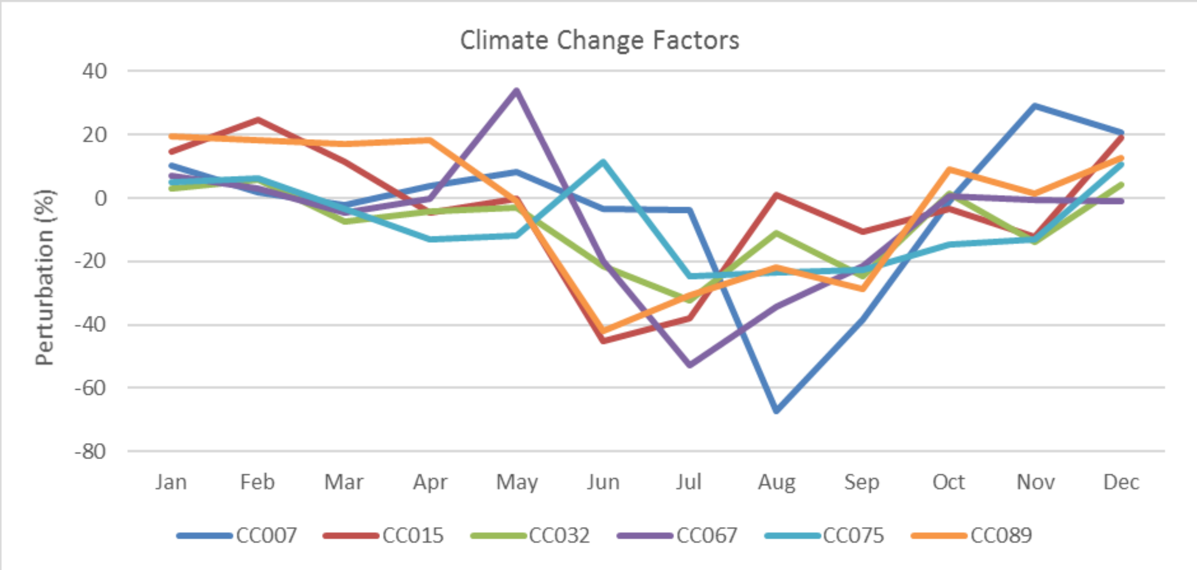


Figure A2.3 - Flow factors for the selected climate change scenarios

The same demand profiles as described in section A2 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. This is a simplistic assumption, and may be incorrect due to varying future weather patterns and demographic changes that could cause the pattern of demand to alter, however it is more robust to test the system with a varying demand than to use a flat demand that would not be expected.

NRW will be reviewing the Dee General Directions in light of the creation of Hafren Dyfrdwy and the move of Chester WRZ to Severn Trent Water; any changes to the current Dee abstraction arrangements and application of climate change impacts will be addressed through the WRMP annual review process.

The monthly climate change factors for the 2030s were applied to the baseline inflows into our reservoirs. This created a perturbed time series of flows for each of the six climate change scenarios. Similarly, new time series for the NRW imposed cutbacks were created for each scenario and limited the Dee abstractions to the volumes shown in Table A2.8 and also dictated when Pen Y Cae Lower reservoir was to be used to augment the Dee.

The 2030s climate change flow factors were used in our modelling to derive climate change impacted DOs for year 2035/36. The average DO for this year, across the six climate change scenarios, was **50.7 Ml/d** compared to a baseline DO of 51.2Ml/d, implying a median climate change impact on DO of **0.5 Ml/d** (0.53 Ml/d in the peak month of July). Failures at the demand step above DO occurred in September or October 1933 for all scenarios and were caused by Ty Mawr reservoir reaching emergency storage. This is likely to be due to the increased demand placed on the system by the long periods of cutbacks imposed by NRW during this event, requiring Dee augmentation from Pen Y Cae Lower reservoir. The augmentation demand was highest during 1933/34 in all scenarios.

Uncertainty around climate change is included in Appendix C-Target headroom and the supply demand balance.

Llandinam & Llanwrin WRZ DO

Our assessment of the Llandinam & Llanwrin zone indicated that the Llandinam source could be sensitive to the impacts of climate change given its location adjacent to the River Severn as the boreholes are in hydraulic continuity with the river. Given this hydrogeological setting it was not appropriate to assess deployable output or climate change impacts using the standard GR2 method.

Clywedog Reservoir, the key regulation reservoir used to help maintain statutory flow requirements at Bewdley on the River Severn is in close proximity of Llandinam, approximately 11 km upstream. Compensation releases are made from Clywedog throughout the year. Regulation releases up to 500Ml/d are made during April to October when flows at Bewdley begin to drop. If appropriate, flood drawdown releases are also made from the reservoir during the winter months. Given the scale of releases and the proximity to the reservoir it is assumed that the river gravels from which Llandinam abstracts would be well supported under potential climate change futures. The Llandinam & Llanwrin zone has therefore been given a classification of low vulnerability to climate change.

To add further validation, Aquator modelling has shown that all water resource zones directly reliant on the River Severn, including Llandinam & Llanwrin, have a low vulnerability to the potential impacts of climate change. Under all 20 of Severn Trent's modelled climate change scenarios these water resource zones showed zero or minimal loss of DO. Analysis of model outputs has shown that greater and more frequent releases will be required from Clywedog under the climate change scenarios, as would be expected under a future with hotter, drier summers. These releases are likely to help maintain the water level in the river gravels in the upper reaches of the River Severn, even under climate change. The reservoir drawdown is more severe under the extreme climate change scenarios but recovers well during the warmer, wetter winter months. The graphs in Figure A2.4 show modelled drawdown and recovery of Clywedog reservoir under the rank 50 (central estimate) and rank 10 ("dry") climate change scenarios for a dry or drought period (1975-77), average period (1982-84) and a wet period (1978 to 1980).

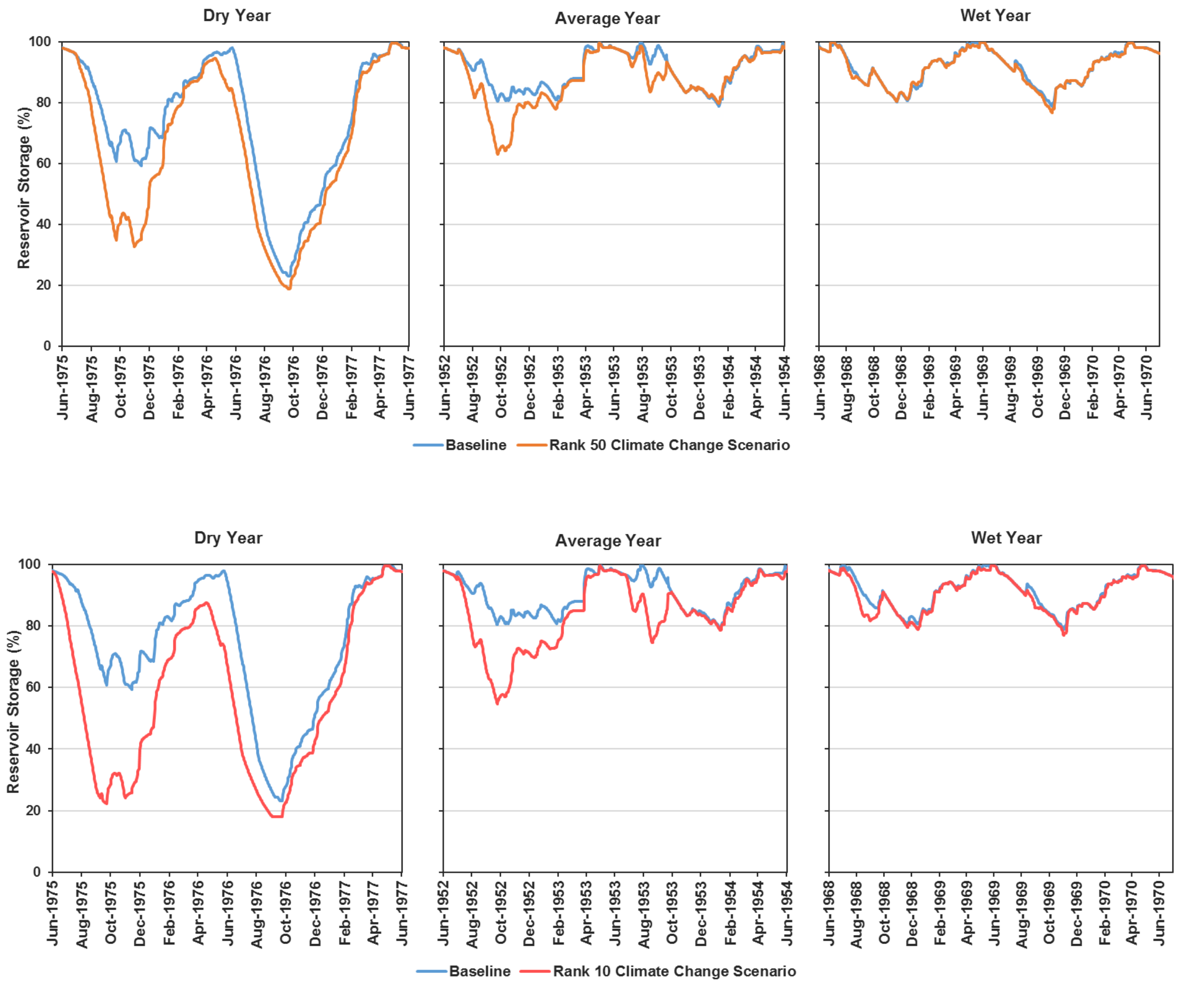


Figure A2.4 - Modelled drawdown of Clywedog Reservoir during different climate change scenarios

Scaling the climate change impact over planning horizon

Once we had the baseline DO impact for each WRZ, we could apply a scaling factor to forecast the impact over our planning period (2020-2045). We used the methodology set out in section 6 of Environment Agency's *Climate change approaches in water resources planning – overview of new methods* (2013). The resulting reductions in DO were entered into the WRMP tables. For Wrexham WRZ, it equates to 0.58 Ml/d reduction by 2045.

Our assessment has shown the Llandinam and Llanwrin WRZ is unlikely to be affected by climate change meaning it has is zero impact on deployable output. As Saltney and Llanfyllin WRZs are supplied by bulk supplies we have assumed that this water will continue to be available, with the climate change risk sitting with the donor WRZ or donor company.

A2.2 Resilience of Supply

A2.2.1 Drought Resilience

A key change for WRMP19 is a greater focus on drought resilience and improving the links between WRMPs and Drought Plans. The UKWIR (2016) *WRMP 2019 Methods – Risk Based Planning* document provides comprehensive guidance on the various drought resilience assessments water companies can undertake which are designed to be proportional to the scale and complexity of each companies' problem characterisation. It is suggested that water companies should, at a minimum, use the worst drought on record to assess drought risk; an approach that has been conventionally applied across the sector for previous WRMPs.

Wrexham WRZ

For our dWRMP the problem characterisation exercise we carried out identified that there is a low level of concern regarding the future water resources situation for Wrexham. Consequently, during our dWRMP our approach to drought resilience was proportional to this problem characterisation – we followed a "Risk Composition 1- conventionally tested plan" approach as defined in the UKWIR (2016) *WRMP 2019 Methods – Risk Based Planning* document. Therefore, the drought scenarios used to test our plan at dWRMP included only those observed in the historic records included in our baseline DO calculations (see previous sub-sections in A2). This baseline modelling period (1927 to 2015) captured a number of drought events including 1933-34, 1995-96 and 2010-2011.

However as part of the work carried out for our 2019 draft drought plan we have now carried out further work to look at droughts outside of the historic period, using stochastic drought scenarios we have outline this work and the outputs from it below and updated our fWRMP planning table 10 with this information.

Stochastic Drought Scenarios

In order to test how our water resources system responds to droughts that are worse than those observed in our baseline analysis we adopted an additional approach. The approach we selected was the creation of a number of stochastically generated drought 'what if' scenarios that haven't happened but plausibly could. The WRMP 2019 Methods – Risk Based Planning: Guidance (UKWIR, 2016) has informed the techniques we have used to develop these scenarios. We created 200 'what if' drought scenarios using a stochastic weather generator. This is 17,400 years of stochastic dataset, which can be considered as 200 alternative versions of the historic record. Stochastic weather generation is a modelling technique which uses the relationship between climate drivers and our observed rainfall data over the 20th Century. A rapid Catchmod model was then used to generate daily flows using these 17400 years of stochastic potential evapotranspiration and rainfall data. As a check, flow duration curves (FDCs) were generated for each of the River Dee catchments using both the stochastically generated flow and the historic flow sequences exported from the NRW Aquator model. As shown in Figure A2.5 below the fit between stochastically generated flow and historic flow data is very strong in all catchments.

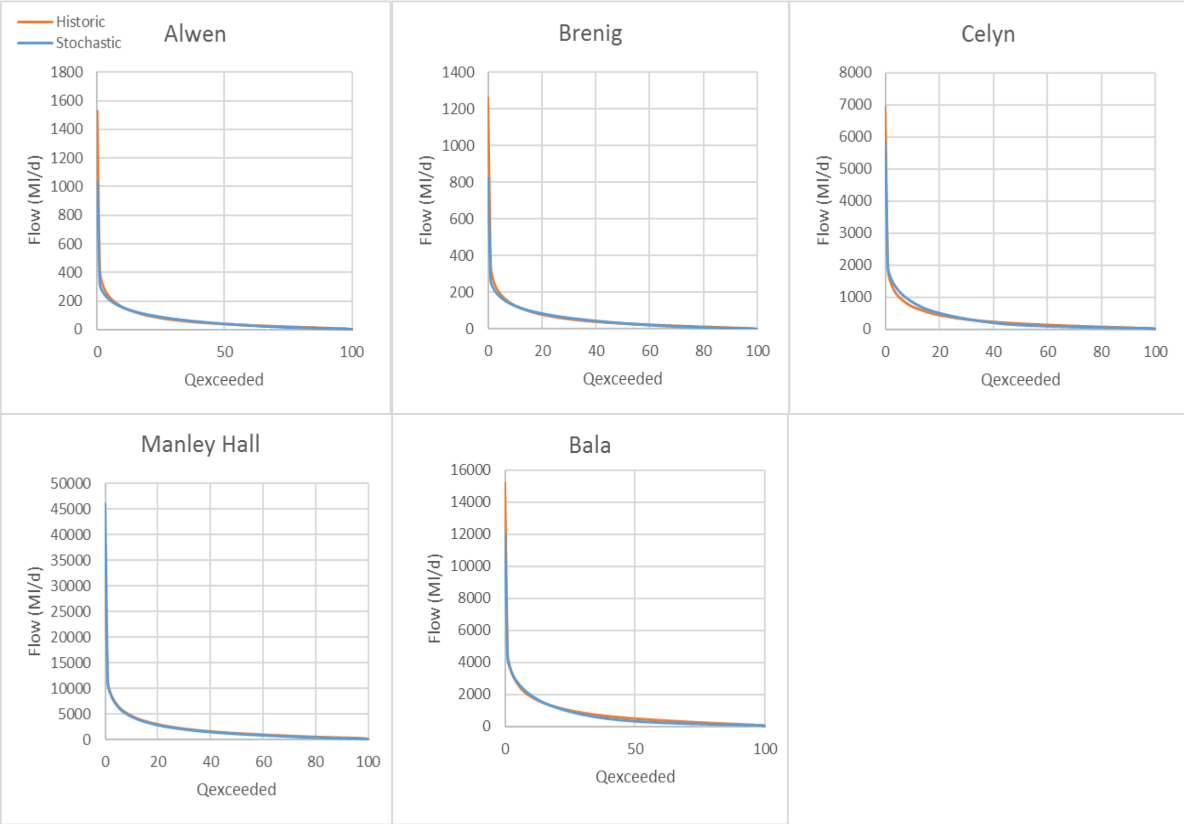


Figure A1.5 - Comparison of River Dee catchment stochastic and historic FDCs

The stochastically generated flows were then fed into the River Dee Aquator model, which was run to determine the corresponding daily Dee General Directions (DGD) permitted abstractions (safe yield or the stage 1 / 2/3 cut-backs). This time-series identifies periods of safe yield abstractions and stage 1/2/3 cutbacks across the stochastic years. Unlike previous climate change assessments undertaken by NRW, the DGD maximum yield, safe yield and cut-back amounts were not adjusted. The stochastic dataset is generated based on the same climatic conditions as the historic dataset (Figure A2.5), therefore there is no rationale to change any of the current DGD rules in the model.

We retained the NRW model assumption that all Dee abstractors always take their maximum DGD entitlement. In reality this is not the case as abstractors also take into account operational rules and costs. However, drought resilience modelling based on all Dee abstractors always taking their maximum DGD entitlement would help to account for the risk that might be caused by other abstractors altering their operating practices in the future.

Time-series of maximum / safe yield abstractions and cutback periods over the stochastic years were then loaded into the HD Aquator model as a boundary condition (i.e. available River Dee flow). The results from the River Dee Aquator model stochastic run have showed that, Wrexham WRZ abstractions from River Dee won't be affected by availability of water in the River Dee even under extreme drought conditions. However, whilst Wrexham WRZ is dominated by supply from the River Dee, its drought resilience can be affected by other sources and the ability of Pen-Y-Cae reservoir to augment the River Dee during drought events. In order to assess severe droughts, revised inflow sequences were also required for each of the reservoirs in the Wrexham WRZ. For our WRMP19 DO modelling, these flow time series for the Wrexham reservoir catchments were generated by sampling flow duration curves (FDC) from Low Flow Enterprise and a local gauge (67005 Ceiriog at Brynkinalt Weir). A similar approach was used to sample stochastic flows for the catchments of Wrexham upland reservoirs using the Dee stochastic record, the Dee stochastic flow duration curve and the Wrexham extended flow duration curve. Sampled stochastic flows for the Wrexham upland reservoir sources have showed that these sources have a high level of drought resilience, but not quite matching that of the River Dee. As such, low flow conditions during plausible drought events are likely to constrain the Wrexham DO rather than asset capability / licences.

Half of the stochastic dataset (8700 years of data) was run through the Wrexham WRZ Aquator model using the Scottish Method DO analyser in Aquator to derive the relationship between demand and frequency of failures (DO vs return period), as shown in Figure A2.6. The modelling results indicate that for a range of drought scenarios between 1 in 44 years return period (our current DO of 51.2) and 1 in 500 years return period (DO = 49.04) there is a small reduction in DO of 2.2 Ml/d. The 1 in 200 years return DO is 50.11 Ml/d, which is higher than the total of the highest dry year demand, target headroom and outage over the 25 year planning period for the Wrexham WRZ (46.44 Ml/d). The results do not include TUB and/or NEUB demand savings described in the DGD Stage 3 demand management actions. Thus, implementation of demand restrictions when the Dee Storage System drops into stage 3 is expected to provide higher DOs for each return periods and hence further increase the resilience of the resource zone to droughts.

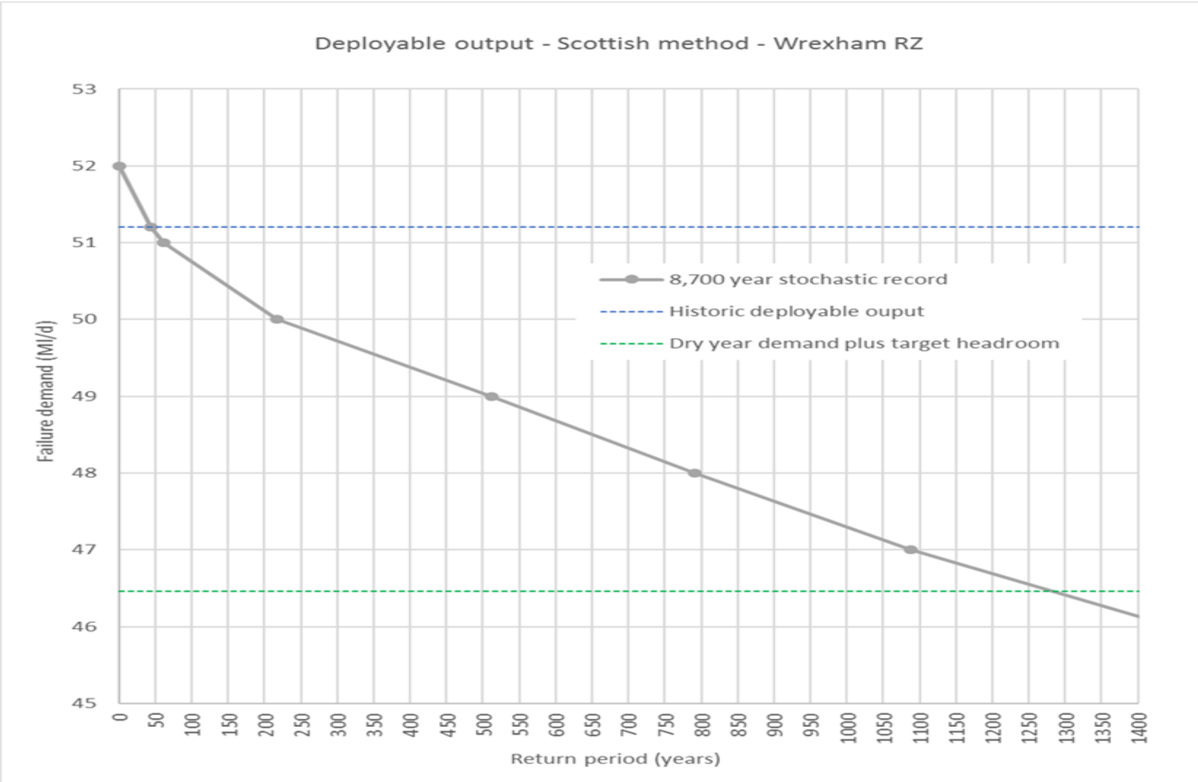


Figure A2.6 - Return periods of DOs estimated using stochastic modelling

Llandinam & Llanwrin WRZ

In preparing our draft WRMP we carried out an assessment of the vulnerability of each of our water resource zones to the potential impacts of drought. We did not carry out stochastic drought assessment for this WRZ as it has low vulnerability to drought, and is not typically constrained by water level but by other constraints, such as pump depth, due to the nature of the sandstone aquifers. Therefore, they have not been tested against extreme droughts outside of the normal groundwater deployable output (DO) calculations.

As discussed in section A2.1.6, our assessment of the Llandinam and Llanwrin zone indicates that given the location of the Llandinam source adjacent to the River Severn, it could be sensitive to the impacts of climate change and therefore potentially also drought as the boreholes are in hydraulic continuity with the river.

Clywedog Reservoir, the key regulation reservoir used to help maintain statutory flow requirements at Bewdley on the River Severn is in close proximity of Llandinam, approximately 11 km upstream. Compensation releases are made from Clywedog throughout the year. Regulation releases up to 500Ml/d are made during April to October when flows at Bewdley begin to drop. If appropriate, flood drawdown releases are also made from the reservoir during the winter months. Given the scale of releases and the proximity to the reservoir it was assumed that the river gravels would be well supported under drought and extreme drought events.

We have completed fWRMP Table 10 for the Llandinam and Llanwrin zone. Severn Trent Water's Aquator modelling showed that water resource zones directly reliant on the River Severn such as the Shelton and Wolverhampton zones have a very low vulnerability to the impacts of drought. Under all of their modelled historic and extreme drought scenarios, these zones showed zero change in DO. We can therefore assume that the Llandinam & Llanwrin zone, which is higher up the River Severn and close to Clywedog reservoir, will also have no change in DO for the same droughts.

Drought Resilience Statement

We have planned our system so that it can withstand the drought patterns and severities that have been seen over the last 89 years (with a suitable climate change allowance) without having to resort to the additional measures described in our Drought Plan. Furthermore our stochastic modelling has shown that our system is resilient to 1 in 200 and 1 in 500 year droughts scenarios with only a negligible drop in deployable output.

A2.2.2 Levels of Service

Reference Level of Service

The WRMP18 guidelines highlight the need for water companies in England to state their reference level of service to a 1 in 200 year (0.5% annual chance of occurrence) drought event to better understand each water companies' drought resilience. In this context, drought resilience refers to avoiding the use of emergency drought orders such as rota cuts and standpipes in the event of a 1 in 200 year drought.

As described in section A2.2.1 we have now completed stochastic modelling for our Wrexham zone. This modelling has enabled us to understand our deployable output and LoS for a full range of drought return periods including the reference LOS of 1 in 200, for this return period our Wrexham zone has a minor drop in Deployable Output from 51.2Ml/d at our baseline to 50.11Ml/d at 1 in 200. Throughout our planning period this this reduction in DO would still leave us with a surplus on our supply demand balance. Therefore our LoS of service would remain unchanged from our baseline LoS and we therefore would not require emergency drought orders at this return period.

Level of Service Statement

Based on our current Levels of Service (1 in 40 years) we have calculated our annual percentage risk of a TUB over the 25-year planning period to be 2.5%; we do not expect this to change over the planning period.

Table A2.9 below presents the annual average annual average risk of a Temporary Use Ban (TUB), Non-Essential Use Ban (NEUB) and Emergency Drought Orders (EDO).

Annual Average Risk of Drought Restrictions for each AMP	DGD Stage	Our levels of services	2020-25	2025-30	2030-35	2035-40	2040-45
Temporary Water Use Ban	Stage 2 /3	1 in 40 years (2.5% annual risk)	2.5%	2.5%	2.5%	2.5%	2.5%
Ordinary Drought Orders (Non-Essential Use Restrictions)	Stage 3	We do not anticipate the need for these	0.47%	0.47%	0.47%	0.47%	0.47%
Emergency Drought Orders	NA	We do not anticipate the need for these	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%

Table A2.9 - Annual average risk of drought restrictions for each AMP from 2020 to 2045

Decisions to impose ordinary demand management restrictions (TUB & NEUB) in the event of droughts in our Wrexham zone are made based on availability of water in the Dee Storage System as stated in the Dee General Direction. We have carried out drought resilience modelling of the River Dee catchment using stochastically generated weather datasets. Modelling results have been analysed to determine return periods using the number of times the different Dee Storage System's triggers would have been crossed and/or demand restrictions would have been implemented over the whole number stochastic years (17,400 years). These return periods have been used to inform estimation of annual risk of TUB and NEUB restrictions.

Stochastic modelling of the River Dee catchment has also showed that flow levels in the River Dee have high resilience to droughts and abstractions from River Dee are not affected by severe and extreme droughts. Moreover, augmentation from Pen Y Cae Lower reservoir was fully maintained throughout all plausible severe and extreme droughts in the 8700 years of stochastic dataset (for DO modelling we have only used half of the whole 17400 stochastic years). The modelling results have showed that Wrexham water resource zone abstractions from the River Dee will not be affected even if the Dee storage system drops into emergency storage due to flows from other upstream catchments. Thus, we are unlikely to implement emergency drought orders while a large percentage of the zonal supply is not affected even if the Dee storage system drops into emergency storage and hence we do not plan to use an emergency drought order and consider it unacceptable in this zone.

A2.2.3 Wider resilience

Our customers expect us to deliver a reliable service 24 hours a day, 365 days a year, and to plan and take decisions that mean we can do this reliably into the future at a price that is affordable to all.

Our PR19 Business plan includes aspects of resilience in the round. When developing the plan, we:

- Used our understanding of our assets and systems combined with external data and understanding of the broader challenges facing us and our communities over the long term. We have carried out hydraulic assessments of flood risk and drought risk.
- Embraced the requirements of the Well-being of Future Generations (Wales) Act and are forming relationships with organisations who all have a role to play in securing long-term resilience for the communities we serve.
- Talked to our existing and future customers about the biggest long term challenges and our plan reflects their views on how they expect us to balance these challenges with their bills today.

We have built on many existing business as usual approaches to identify and evaluate risks. We have applied good practice tools but made them specific to our business and region. In our PR19 business plan, we have set out the short, medium and long term developments – based on our analysis, discussions with colleagues, customers and stakeholders and inspired by Welsh policy ambition – that will help us ensure long term resilience.

We already have a resilient water supply system and in North Wales have managed to avoid any long duration interruptions (>12 hours) despite extreme temperatures (during the recent freeze thaw and drought), but we need to do more to improve the response and recovery aspects of our resilience capabilities. This will be a focus over the next five years and a key part of delivering the 38% improvement in supply interruptions identified in our PR19 business plan.

While risk from drought is considered the main threat to our ability to maintain our supply to customers, we also have to consider other risks that have the potential to adversely affect our water resource assets.

Dry weather events

We continue to see changes to our weather patterns, and it is likely that we will see more regular, non-drought dry periods like that experienced in 2018. The hot and dry weather during the 2018 summer has allowed us to test and confirm many of the assumptions made in our draft WRMP about water supply capability, and our ability to meet the demand for water without needing a Temporary Use Ban. However, we continue to explore the learning from this event and whether it changes our understanding of asset/operational performance and risks. We will use the annual WRMP review process to report on any amendments to our plan as a result of this work.

During the summer of 2018, private water supplies and agriculture were particularly badly affected in Wales. Working with Welsh Government, NRW, Dwr Cymru Welsh Water and other key stakeholders through the Wales Drought Liaison Group, we were able to support local authorities by providing bottled water to be given out to private water supply owners. We were also asked to consider possible alternative supplies for farmers such as disused reservoirs and offered up a number of options. Once the lessons learned of that group have been shared, we will consider what actions we could take to be more proactive in future similar situations.

Flooding events

Flooding can have a significant impact on water supplies, both in terms of physical damage to assets and reduction in water quality.

Flood impact assessments were carried out at our river abstraction point in Bangor on Dee in 2013. The primary reason for this work was to assess whether the flood defences in place at the site were still suitable in light of new guidance from Natural Resources Wales. The guidance suggested that the site should be protected against a 1 in 100 year flooding event.

The report suggested that additional defences were required and this work was carried out and completed in 2015. We are therefore confident that our river abstraction intake is resilient to at least a 1 in 100 year flood event. No significant risks from flooding have been identified at any of our other water resources assets.

Pollution events on the River Dee

Our bankside storage reservoir near Wrexham and treated water storage reservoirs at our Wrexham treatment works, provide us with sufficient 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.

Catchment solutions for improved reservoir water quality

Our AMP7 investment plan proposes to deepen our current catchment management programme. One of the key components will be investigation and mitigation of algal blooms and manganese issues in our impounding reservoirs that cause taste and odour issues and restrict the volume of water available.

The processes installed at our water treatment works mean that we cannot use sources if algal blooms are significant. Our current solution is therefore to reduce abstraction from these reservoirs when issues arise. Whilst this option avoids the risks of increased water quality complaints, it restricts our flexibility and makes our raw water system less resilient.

This is especially true when these issues are in the summer months should use these reservoir sources to supplement our river abstractions that may be under low flow restrictions.

We are confident that there are viable solutions available at catchment level to remove the taste and odour issues. We therefore intend to investigate the cause of the increasing manganese levels and algal blooms, and address the issues at source.

Catchment management to increase water resource yield and resilience

Another key component of our AMP7 catchment management programme will be a pro-active maintenance programme for leats and other infrastructure to improve capture rate of inflows to our upland impounding reservoirs.

Using the DO analysis carried out for the draft WRMP, a comparison between historical inflow data and modelled output revealed that there was potentially a much greater inflow of water into our reservoir catchments than we are currently capturing. Improving inflow into the reservoirs through catchment management interventions would mean that these lower cost, gravity sources would be available to us for longer in normal years and be more sustainable during dry weather.

While we are not forecasting a supply demand deficit, there is a great deal of uncertainty over climate change that could result in more severe droughts in the future. In addition, our current climate change modelling does not factor in possible impacts on water quality in the future which could also affect the resilience of our water resources. It is therefore essential that we 'future proof' our reservoirs and their catchments to ensure we can optimise their use.

Freeze-thaw events

We will consider the lessons learnt from the significant freeze-thaw event which occurred in March 2018 and the resulting actions that we need to put in place. Any interventions that we implement which affect our water resource assets will be reported on in the annual WRMP review.

A3. Imports and Exports

We operate a number of raw and treated transfers and bulk supplies, most of which are externally to and from third parties. For the purposes of this WRMP we only report on imports and exports that are of strategic importance. We use a threshold of 1 Ml/d to determine whether an import or export classes as strategic. We do not consider transfers below this magnitude to be strategic.

A3.1 Bulk supply agreements

Following the change to company boundaries, and creation of the new WRZs, there are now several new bulk supply agreements in place between Hafren Dyfrdwy and Severn Trent, in addition to the agreements previously in place between Dee Valley Water and neighbouring water companies, United Utilities and Welsh Water. Several 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 which account for less than 0.5 Ml/d.

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 that can be fed from the Wrexham Road pumping station and a new bulk supply agreement between Hafren Dyfrdwy and Severn Trent has been set up accordingly.

We have bulk supply agreements with United Utilities (UU), Severn Trent (ST) and Dŵr Cymru Welsh Water (DCWW). 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. The most significant transfers are those between Hafren Dyfrdwy and Severn Trent, which are summarised in table A3.1.

Donor WRZ	Receiving WRZ	Total quantity (Ml/d)
Severn Trent to Hafren Dyfrdwy		
Chester	Saltney	3.51
Shelton	Llanfyllin	6.75
Mardy	Llanfyllin	<0.01
Mardy	Wrexham	<0.1
Shelton	Llandinam	<0.5
Bishops Castle	Llandinam	<0.5
Hafren Dyfrdwy to Severn Trent		
Wrexham	Chester	0.7

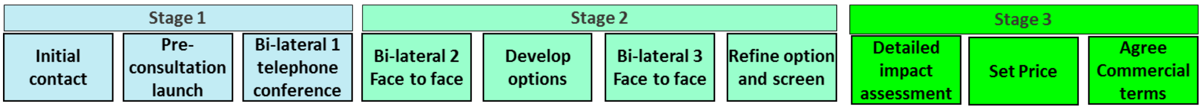
Llanfyllin	Mardy	<0.1
Llanfyllin	Shelton	<0.01
Llandinam	Bishops Castle	<0.5
Llandinam	Shelton	<0.5

Table A3.1 - Transfers of water between Hafren Dyfrdwy and Severn Trent

We also supply non-potable water to the Wrexham Industrial Estate. In the WRMP14 forecast, an average figure of 0.6 Ml/d was assumed until 2017/18, at which point it increased to 0.98 Ml/d. This was due to the expectation that a new power station would be commissioned during that period. As the power station is due to be commissioned by the end of AMP6, we have assumed this figure of 0.98 Ml/d for the duration of the planning horizon.

A3.2 Water trading

We used a three stage approach to identify third party water resource options. The approach covered both the potential imports and exports.



Stage 1 - communicate need and opportunities

We approached potential third party suppliers inside and outside our region to inform them of the opportunity. To do this we used multiple channels to ensure the broadest involvement, for example:

- through our pre-consultation letter;
- by invitation to water resource management plan technical workshops in Wales;

Stage 2 - develop technically viable options

- We met with all interested parties on a one to one basis to understand each other's specific needs and capability.
- We worked up options separately and then reviewed jointly to confirm the option was viable and to understand risks.
- We carried out further feasibility to determine the outline costs and benefits.
- We treated third party options in the same way as internal options in the screening approach.

Stage 3 - Agree which options to pursue and outline commercial and pricing arrangements

The outputs from our least-cost modelling exercise give a shortlist of options to be further reviewed between the draft and final version of our plan. During this time we will explore the commercial terms with our import and export partners.

We started this water trading engagement process in 2016 and completed the end of stage 2 by October 2017. As all our water resource zones are in surplus so there is little opportunity for new imports. The outcome of the discussions were;

- **Dŵr Cymru Welsh Water:**
  - No further imports are required over the resilience connection at Bretton that was commissioned in 2018.

    - The viability of a small export from our Llanwrin source near Machynlleth to Corris is being assessed.
- **Severn Trent:**
    - No viable transfers were identified following analysis of opportunities in north Shropshire.

There are no current plans to trade water from Hafren Dyfrdwy, notwithstanding that following the change in our company licence boundary, there will be transfer of water between England and Wales. This is due to the fact that the boundaries of the Wrexham and Chester WRZs have historically not followed the geographical boundary. Should this position change we will consult fully with NRW and Welsh Government.

A4. Outage

A4.1 Wrexham WRZ outage modelling approach

Outage is defined as a temporary short-term loss in deployable output. For WRMP14, the unplanned outage figures used in the headroom calculations were generated using the methodology detailed in the UKWIR document *Outage Allowance for Water Resource Planning.*

Between WRMP09 and WRMP14, we developed complex 'source to tap' models which calculated the loss of supply in hours per year for each District Metered Area (DMA). The components included in the model depicted the process that water is supplied through. All critical components are modelled and comprise, for example, a raw water source, an aqueduct or a single stage in a treatment works. Failure data was assigned to each and every 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). The outputs from the models showed that the 'source to treatment works systems' are inherently reliable. We have continued with this DMA approach since WRMP14, with the only significant change to the system being the decommissioning of our oldest treatment works, Legacy, by the end of the current AMP. The outages for Wrexham WRZ have been recalculated[6] to take account of this and the results are shown in Table A4.1.

Treatment works	Capacity (Ml/d)	Unavailability (hrs)	% Unavailability	Outage (Ml/d)
Pendinas	4.0	0.57	0.00654	0.0003
Llwyn Onn	47.5	0.22	0.00249	0.0012
Llangollen	3.0	4.82	0.02475	0.0017
			Wrexham WRZ	**0.0031**

Table A4.1 - Outage assessment for Dee Valley Water WRZs

We calculated our outage using an approach consistent with that used in WRMP14. However, with the creation of Hafren Dyfrdwy and our new PR19 performance commitments relating to outage, we will review our outage methodology for assets in the Wrexham WRZ and ensure alignment with the methodology used for Llandinam & Llanwrin (see section A4.2). We will report on the progress of this review in our annual WRMP reporting.

Outage in Saltney and Llanfyllin is zero as both WRZs are bulk import zones. Considering the relatively small amount of demand in Saltney and Llanfyllin, impact of outage on bulk imports to these zones is assumed to be negligible.

A4.2 Llandinam & Llanwrin outage modelling approach

We have used a risk based approach which follows the best practice principles set out in the UKWIR report *Outage Allowances for water resources planning* (UKWIR, 1995). This method uses Monte-Carlo analysis to assess the "allowable" outage (the probability distribution of the combined risks of the legitimate planned and unplanned outages occurring), with the output of the analysis enabling us to adopt a suitable level of risk.

Our outage model allows us to use a "bottom up" approach which utilises the operational outage data and information collated in our database for individual sources. We believe the use of site specific outage records results in a more appropriate assessment of future outage risk. The outage allowance models use data from our specially developed "Event Tracker" tool, which takes the data directly from our groundwater source outage databases. The outage allowance model uses triangular distributions for assessing the magnitude and duration of outage risks and a Poisson distribution for event frequency. The Event Tracker interrogates our outage databases to extract the outage events and consolidate the information into suitable distributions which are required to perform the Monte Carlo simulations in the outage allowance models.

Our outage allowance model has been developed with a user interface which enables a thorough audit trail to be maintained. The user interface captures key pieces of information, including a full set of input data and output data for the model run.

The outage allowance model has an additional function built in, which allows us to assess the impact of the outage in two ways:

[6] Treatment works capacity multiplied by % unavailability, divided by 100.

1. The outage is included in the model as a proportion of the full source deployable output.
2. The outage event is only recognised by the model if the severity of the event exceeds the buffer between the source deployable output and the maximum capacity of the source. Furthermore, when an outage event does exceed this buffer, its calculated magnitude takes this buffer into account. As a result, outage severity for a source is reduced when calculated against capacity (unless DO is equal to maximum capacity, in which case it will be equal).

We have used the second option in our modelling. In most cases, the deployable output of our sources is constrained by a factor other than the maximum treatment capacity of the treatment works, such as licence or infrastructure. Applying the outage impact to the full source deployable output in the modelling would result in a higher Outage Allowance. Adopting the second option enables us to assess the impact the outage events would have on our dry year deployable output.

The following is a summary of the approach used to select which issues are to be included in the outage assessment:

- If an actual event has been identified by the Event Tracker then it has been included in the outage assessment unless it was an operational choice such as 'preserving raw storage' or 'works control';
- Due to the shorter length of the event records for groundwater, some generic issues have been included such as local and widespread power loss, pump failures, and planned maintenance.
- Any outage event that was removed during the WRMP14 process was also removed for this latest WRMP outage assessment as the issues had been fixed.
- Only 'legitimate' events have been included in the outage assessment. These events were identified through internal stakeholder consultation.
- Following the UKWIR 1995 guidance, any outage event that lasted longer than 90 days either needed to be removed (as this counts as a long term loss of deployable output) or treated with caution. We decided to cap the duration to 90 days as the updated deployable output assessment has taken these into account.

Planned outages

We have an ongoing programme of planned maintenance and capital enhancement activities at our water production sites in order to maintain the long run serviceability of our assets. To minimise the loss of output from maintenance activities we schedule work to be carried out in a way that limits risks to customers' supplies. Planned maintenance is avoided at peak demand periods and this is reflected in very low numbers of planned outages between June and August. Outages due to repair and maintenance activities will only affect average deployable outputs and are not expected to influence our ability to supply our customers during peak demand periods. Furthermore, where possible, planned maintenance is planned in so that works may be brought back into production at short notice if required.

For our groundwater sources, our records of the outage impacts of planned maintenance of our boreholes are shorter than the surface water sources. We have used actual data wherever it is available. Most of our water resource zone assessments include an element of planned outage due to process maintenance and capital improvement.

The UKWIR (1995) guidelines defines an unplanned outage as being "an outage caused by an unforeseen or unavoidable legitimate outage event affecting any part of the source works and which occurs with sufficient regularity that the probability of occurrence and severity of effect may be predicted from previous events or perceived risks". Their definitive list of unplanned events are:

- pollution of source
- turbidity
- nitrate
- algae
- power failure
- system failure

The main unplanned outage issues for groundwater sources are pump failures and power failures. There are also issues of flooding at some sources and occasional periodic quality problems, principally turbidity after heavy rain. Where unplanned outages have occurred and have been recorded on our groundwater outage database, we have used actual recorded data to inform the outage assessment. The types of issues included in the assessment are summarised below:

- Burst / Leak on the site (leading to a system failure)
- Electrical issues on site (leading to a system failure or caused by power failure)
- Flooding on site (leading to a system failure)
- Mechanical issues on site (leading to a system failure)
- Pump / Valve issues on site (leading to a system failure
- Quality issues (including pollution of source, turbidity problems)

Although our detailed site outage record for groundwater sources extends back to 2009, several of our sources have not been affected by outage events during this time. Therefore for groundwater sources we have included allowances for some key generic risks. These risks are:

- Pump failures: a frequency of 0.4 events per source per year; and a duration average of three days, between a minimum and maximum of one and five days respectively.
- Local power loss: a frequency of 1.2 events per source per year; and a duration average of eight hours, between a minimum and maximum of 0.1 and 24 hours respectively.
- Widespread power loss: a frequency of three events per year; and a duration average of eight hours, between a minimum and maximum of 0.1 and 24 hours respectively.

Annual average outage allowances to 2045

The output from the probabilistic analysis of outage risks we have undertaken is summarised in Table A4.2 below. The table shows the likelihood of different outage quantities occurring in the year. For example, our assessment shows that there is a 60% chance that in any given year, up to 0.82 Ml/d will be lost due to outage, and a 90% chance that up to 2.60 Ml/d will be lost due to outage in the Llandinam and Llanwrin zone.

WRZ Name	DO (Ml/d)	Outage (Ml/d)				
		60% (40% risk)	70% (30% risk)	80% (20% risk)	90% (10% risk)	100% (0% risk)
Llandinam & Llanwrin	19.86	0.00	0.00	0.02	0.24	5.54

Table A4.2 - Output from probabilistic analysis of outage risks

Consistent with WRMP09 and WRMP14 we have therefore used the 80th percentile values of the cumulative frequency distribution of outage probabilities in our water resources planning. Table A4.3 below shows the Outage Allowances we have adopted with the percentage of the zonal deployable output that is affected.

WRZ Name	Outage Allowance (Ml/d)	Percentage of Deployable Output (%)
Llandinam & Llanwrin	0.02	0.1

Table A4.3 - Outage allowances against % of DO affected

Components of Outage Allowance

The relative contribution of the various components of the overall outage risk have been estimated by running the outage model with different events excluded from the calculation. It should be noted that because a probabilistic model is used, the results from the analysis should be regarded as indicative rather than definitive. The results, as shown in Table A4.4 below, are useful in understanding the sources of outage and can guide management decisions on addressing that risk, and on improving the information base on which it is assessed.

WRZ Name	Relative contribution of cause of outage (%)					
	Quality	Process Maintenance	Burst / Leak	Capital Improvement	Electrical	Pumps / Valves
Llandinam & Llanwrin	12.3	0.0	0.0	0.0	17.4	70.3

Table A4.4 - Relative contribution of cause of outage (%)

A5. Drinking Water Quality

Providing a safe, wholesome supply of drinking water to our customers is our primary duty. We must ensure that the water we provide meets the standards set out by the EU Drinking Water Directive, plus any additional UK requirements and ensure the necessary protection is in place to prevent deterioration in the water quality, with a view to reducing the level of treatment required. In particular when developing our WRMP, we must consider how we will support the objectives for any drinking water protected areas within our supply area.

Drinking water protected areas or 'safeguard zones' are designated zones in which the use of certain substances must be carefully managed in order to prevent pollution of raw water sources that are used for drinking water. There are no safeguard zones within our supply area. However, the River Dee catchment from Snowdonia to the weir in Chester is designated under the Water Resources Act 1991 as a Water Protection Zone. This means that a consent is required where certain substances are used or stored at specific sites anywhere within this part of north east Wales. It helps prevent water pollution arising from activities that cannot be controlled using other permits. Although this designation is driven by environmental concerns, it also provides a level of protection for our abstractions from the River Dee. We have a number of Dee Protection Zone (DPZ) consents ourselves and have worked with NRW, through the Dee Catchment Protection Group (see below) to raise awareness with local businesses about the DPZ consent requirement.

All of our water treatment works are designed to address the challenges of the raw water from the relevant sources, to ensure a consistent wholesome supply. We use a Water Safety Plan[7] approach to proactively address risks and where unacceptable risks are identified, we agree legal programmes of work with the Drinking Water Inspectorate (DWI) to resolve them.

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), currently chaired by Oliver Twydell, Water Quality Improvement Lead for Severn Trent Water (formally Head of Quality and Environment for Dee Valley Water). In May 2017 the DSC sanctioned the setting up of a Dee Catchment Protection Group, a working group with representatives from Dee Valley / 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

[7] Drinking water safety plans - *"the most effective way means of consistently ensuring the safety of a drinking water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer."* (Bartram J, Corrales L, Davison A, Deere D, Drury D, Gordon B, Howard G, Rhinehold A, Stevens M Water Safety Plan Manual : Step-by-step risk management for drinking water supplies, World Health Organisation, Geneva 2009)

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 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.

A5.1 Treatment works losses and operational use

The figures input into the WRMP19 tables for treatment works losses and operational use are based on the calculations used for WRMP14, with a reduction of 0.5 Ml/d from 2017/18 to take account of the decommissioning of Legacy WTW in the Wrexham WRZ. The decision was taken to not revisit the calculations as there have been no significant changes to any of our treatment works since this work was last carried out.

For our Llwyn Onn works in Wrexham WRZ, the treatment works losses and operational usage was assessed based on the daily readings from the discharge meter at the works. This figure reduced between 2011/12 and 2013/14 due to a large rescale refurbishment of Llwyn Onn which was completed in 2013. The results are shown in table A5.1.

Treatment Works	Works losses / Operational Usage (Ml/d)		
	2011/12	2013/14	2020/21
Llwyn Onn	0.7	0.35	0.35
Legacy	0.5	0.5	-

Table A5.1 – Treatment works losses and operational usage