# Draft Water Resources Management Plan 2024
# Annex 8: Supply Forecast

October 2022
Version 1.0

# Contents

# Glossary

**Water Resource Zones (WRZs)**

| | |
|---|---|
| HAZ | Hampshire Andover |
| HKZ | Hampshire Kingsclere |
| HWZ | Hampshire Winchester |
| HRZ | Hampshire Rural |
| HSE | Hampshire Southampton East |
| HSW | Hampshire Southampton West |
| IOW | Isle of Wight |
| SNZ | Sussex North |
| SWZ | Sussex Worthing |
| SBZ | Sussex Brighton |
| KME | Kent Medway East |
| KMW | Kent Medway West |
| KTZ | Kent Thanet |
| SHZ | Sussex Hastings |

**Planning scenarios**

| | |
|---|---|
| NYAA | Normal Year Annual Average |
| DYAA | Dry Year Annual Average |
| DYCP | Dry Year Critical Period |
| 1:200 | 1-in-200 dry year |
| 1:500 | 1-in-500 dry year |

**Other**

| | |
|---|---|
| DI | Distribution Input |

# 1. Introduction to our Supply Forecast

The supply forecast refers to the how we determine the baseline water resources we have available to meet demands in each Water Resource Zone (WRZ) for each planning scenario, and for each year throughout the fifty-year planning period before the addition of any new schemes. This forecast is composed of several elements:

- Our Baseline Deployable Output
- The impacts of climate change on the water resources available in the environment
- Bulk imports and exports from other water companies or businesses
- Potential reductions in the amount of water we use in order to protect the environment
- Process losses due to water used during treatment
- A risk-based allowance for outage at our supply works,

Each of these components is summarised briefly below:

## 1.1. Deployable Output

Deployable output (DO) forms the majority of the water resource supply available in any WRZ. DO is defined as the water available from a source after taking account of (UKWIR, 2014):

- Source characteristics (e.g. hydrological or hydrogeological yield);
- Physical and infrastructure constraints (e.g. aquifer properties, pump capacity, distribution networks);
- Raw water quality and treatment constraints;
- Licence and other regulatory constraints on water abstraction; and
- Demand constraints and levels of service

Our methodology for estimating DO is summarised in Section 2. Section 3 sets out our climate change modelling approach, and the results are presented in Section 4.

## 1.2. Bulk Imports and Exports

The bulk imports and exports component reflects transfers of water in and out of a WRZ. This can reflect both within company inter-zonal transfers as well as exports and imports to other neighbouring water companies or other formal transfers. Our bulk imports and exports are summarised in Section 4.

## 1.3. Climate Change

The Water Resource Planning Guideline (Environment Agency and Natural Resources Wates, 2016) requires that water companies assess the impact of climate change on water supplies. The impacts of climate change uncertainties may materialise between possible drier futures in which water resources will become scarcer, and wetter futures where increased winter rainfall translates to increased resource availability. Therefore, climate change can act in both directions in terms of water resource yield assessments. Our assessment of impacts of climate change must account for these uncertainties.

## 1.4. Process Losses

Process losses relate to the treatment process of water and need to be considered, i.e. the net loss of water, excluding water returned to the source during treatment before it is put into distribution. Our analysis of process losses is described in Section 6.

## 1.5. Outage Allowance

"Outage" refers to the planning allowance made for the temporary loss of DO from a source. An allowance for outage is made in the supply-demand balance, calculated at the level of the WRZ. Outage reflects that sources are vulnerable to both unplanned events (e.g. mechanical failure) or may need to be temporarily removed from supply in order to perform maintenance or upgrades (planned outage). Our assessment of our outage allowance is presented in this Annex.

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## 1.6. Engagement on our Supply Forecast

In developing our supply forecast, we have engaged with the EA at both a regional and company level as summarised below:

- Discussions with the EA during Summer 2020 on the use of groundwater models.
- A series of engagement sessions in the first half of 2021 with the EA at WRSE level on the regional simulation modelling approach and supporting datasets, and
- An Overview discussion of supply forecast methods during pre-consultation in February 2022.

# 2. Deployable output assessment

Deployable Output (DO) refers to the amount of water we can take from the rivers and groundwater sources after taking account of the constraints that determine the maximum amount of water that can be taken from a source on a sustainable basis. The constraints vary at each site and include hydrological/hydrogeological yields, licence conditions, pump capacity, treatment works capacity, water quality etc. The DO varies during the year. Less water is available during the autumn when groundwater and river flow levels are typically at their lowest. It also varies year-on-year depending on the weather. DO is lower in dry or drought years that are characterised by lower-than-average rainfall. The DO decreases as the severity of the drought increases. Therefore, it is common to describe DO in terms of the return period of weather conditions, such as 1:2 (normal year), 1:10 (dry year), 1:200 (drought) etc. Average DO (ADO) is used for the volume that can be abstracted on average during the year, whereas Peak DO (PDO) is used for the volume that can be abstracted during period of peak demand which typically lasts for 2-3 weeks in the summer. ADO and PDO vary with the return period, for example an ADO in a normal year would be different from the ADO in a dry year.

Our DO assessment methodology follows a staged process through several different climates, water resources and behavioural modelling approaches.

1. Generation of stochastic rainfall and potential evapotranspiration (PET) climate data for drought simulation as inputs to water resource models
2. Water resource modelling to generate time series of river flows, groundwater levels and groundwater DO for use in the Regional System Simulation (RSS) behaviour model
3. Conjunctive use of the RSS models to estimate WRZ level system response DO up to a 0.2% (1:500 year) probability of failure
4. Perturbation of climate inputs to assess supply uncertainty associated with climate change and repeat of the above steps to determine DO impacts.

Each of these stages is described further below and the relationship between each step is summarised on the flow chart below (Figure 2.1). The figure also illustrates where we have followed common approaches to other WRSE companies in our model assessment through the steps coloured in green. This has been critical to ensure that out supply forecast is consistent and coherent with other companies in the region in order to appropriately assess combined options and transfers.

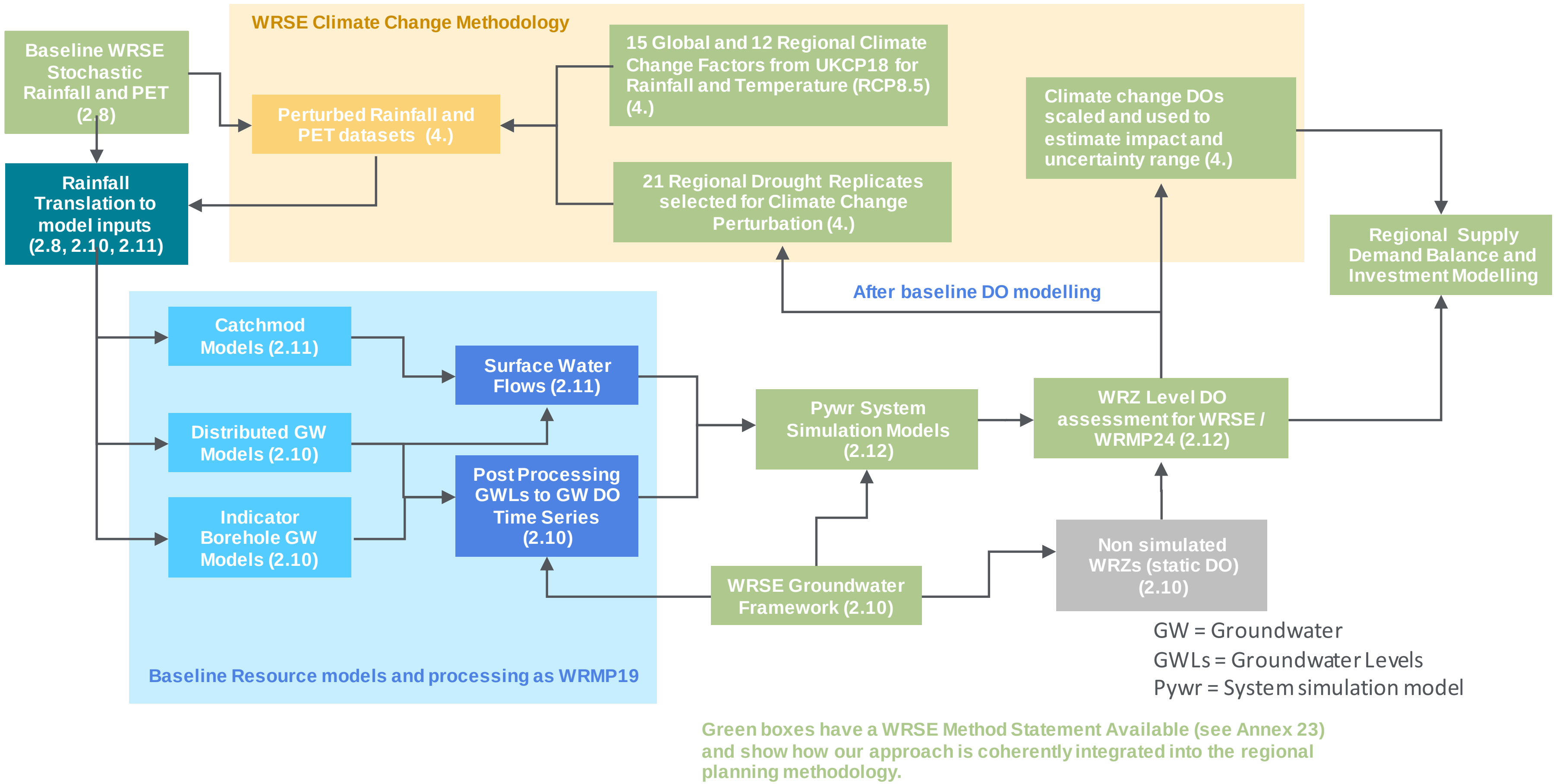


**Figure 2.1: Summary flow chart illustrating our DO assessment approach and alignment with the wider WRSE modelling approach to ensure coherent supply forecasts at a regional level. Numbers in brackets indicate relevant section numbers of this Annex which describe the methodology**

## 1.7. Overview of modelling approach

Figure 2.2 shows how our Hydrological and Hydrogeological modelling fits into the WRSE RSS modelling chain. With coherent climate data across the WRSE region feeding into company owned hydrological models, which feedback into a common set of regional system simulation models, which is used to produce outputs such as DO.

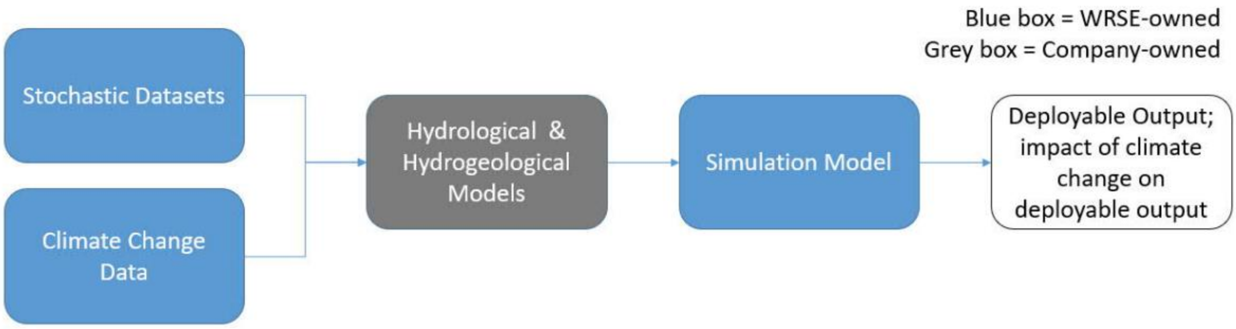


**Figure 2.2 Hydrological and groundwater models are used with the climate data to produce inputs to system simulation models which in turn as used to calculate DOs. The development of our supply forecast has been an integrated process with other WRSE companies and regional assessments, especially in the design of coherent stochastic climate data and climate change impacts.**

## 1.8. Stochastic Weather generation

Reliable historical records for rainfall and PET, two of the most important inputs to hydrological models, are generally no more than around 100 years long, and so to confidently supply capability under severe droughts equivalent to 0.2% annual probability or '1:500 year' droughts requires a significant amount of statistical analysis of climatic drivers and historical records.

We have used weather generators to produce stochastic, synthetic weather sequences of historically plausible droughts in each of our last three WRMPs. This allows us to consider the impact of more severe droughts than which have occurred in the past and apply them in our water resource modelling. The approach we have adopted is consistent across all WRSE companies (Atkins, 2020)[1] and allows for generation of a spatially coherent drought dataset at a regional level.

The current weather generator for rainfall is effectively a 3rd generation evolution of the weather generator we originally used for our WRMP14 stochastic modelling (Serinaldi and Kilsby, 2012)[2] and which was further

[1] WRSE, 2021. Method Statement: Regional System Simulation Model. Post consultation version (included in Annex 23)
[2] Serenaldi, F, Kilsby, C.G., 2012 A modular class of multisite monthly rainfall generators for water resource management and impact studies, Journal of Hydrology, 464-465, doi: 10.1016/j.jhydrol.2012.07.043

refined for our WRMP19. The model uses rainfall (based on the Met Office Had UK dataset) and associated regional climate teleconnections with variables including:

- North Atlantic Sea Surface Temperature and North Atlantic Oscillation (as WRMP14, WRMP19)
- Atlantic Multidecadal Oscillation (AMO)
- East Atlantic Index
- East Atlantic/West Russia Index
- Scandinavia Index

There have also been further improvements to model fits and bias correction at low rainfall accumulations (Atkins, 2020)[3]. A key change from data generated for WRMP19 is that these stochastic datasets are based on a greater range of climate drivers and have little bias correction. Data generated for WRMP19 only included NAO and SST as climate drivers, but several more climate drivers as shown above are now used. The inclusion of a greater range of climate drivers has resulted in a better model fit and with lesser need to bias correct the outputs. Where bias correction has been used, improved methods have been applied to reduce the production of implausible droughts.

The use of a greater range of climate drivers has also driven a change to the baseline period used on which to fit the models. For WRMP19, 1920-1997 was used as a baseline, but this has been updated to 1950-1997 due to better quality data as more climate drivers became available from 1950.

Rainfall locations (1km cells) were selected according to the following criteria (Atkins, 2020):
- Sites with good quality data from 1950 to the present, to match the availability of the improved ‘climate drivers’ data set), based on Met Office and CEH GEAR rainfall meta-data
- An improved spatial coverage in England and Wales, particularly in locations with important regional water supplies
- Water company preferences to add further sites to provides improved spatial coverage and sites at higher elevations

A total of 195 sites were selected and assigned to one or more of the UK wide regional groups. The assignment to groups ensured that there was good overlap between regions so that the data could be brought together for national assessments as required. Stochastic time series were generated for selected locations rather than for river basins for several reasons.
- The original methodology was designed for point data, and this scale highlights the high variability of rainfall which is lower when averaging over large catchment areas.
- It provides some flexibility to transpose these data to different spatial areas, whether these are catchments or water distribution zones for demand modelling.
- Previous assessments, including our WRMP19 assessments used point locations, so this approach provided a clearer audit trail from the WRMP19 work to the present study.
- Additional hydrological modelling strategies across the WRSE regions were developed in parallel to this study, so the full set of catchment boundaries were not available for all regions at the start of this study.

[3] Atkins, 2020, Regional Climate Data Tools Final Report, Sutton and East Surrey Water on behalf of WRSE, Report 5194482-2 (included in Annex 23)

Coherent Potential Evapotranspiration (PET) data in the weather generator is sub-sampled from historical data, largely as per previous WRMPs. This means that the PET generated is consistent with the input data, for example, if the Met Office MORECs PET data set[4] was supplied into the model, then MORECs consistent data would be generated as output. Daily data are matched to historical observations based on closest rainfall day and month (nearest neighbour) sampling. In summer months, PET is matched based on the 'nearest neighbour' summer rainfall total (April – August) rather than on a month-by-month basis. This was implemented as in previous versions of the stochastic weather generator summer persistence effects around PET were not being adequately simulated.

The key climate input and output data for each of our Water Resource Models are summarised in Table 2.1

By adopting this approach, we are aligning ourselves consistently with the water resource modelling undertaking by neighbouring water companies as part of the regional modelling approach. The final stochastic climate datasets represent a total of 19,200 years of modelled rainfall and potential evapotranspiration data for each site/model. However, the data are not a continuous sequence of 19,200 years but instead represents 400 different versions of what the 1950-1997 could have been, given the underlying climate drivers. This allows us to plan based on not only what we have experienced in the past, but also what we are likely to experience in the future. Further details of the weather generator are provided in Atkins (2020) and WRSE (2021a).[5]

**Table 2.1 Summary of Stochastic Climate Inputs for Water Resource Modelling**

| WRZ | Water Resource Model Type | Rainfall Input(s) | PET Input |
|---|---|---|---|
| HAZ, HRZ, HKZ, HSE, HSW, HWZ | Test and Itchen Groundwater Model (3 Rain Gauge MF96-VKD version as WRMP19, WRMP14) | Stochastic Rain Gauge inputs for Otterbourne, Boscombe Down and Rotherfield Park translated to model inputs via linear regression | Stochastic MOSES PET |
| IOW | Indicator Borehole model and coupled recharge model (as WRMP19, WRMP14)<br><br>Catchmod Model for Medina and Eastern Yar | Stochastic Rain Gauge inputs for Cowes Water Works translated to catchment inputs via spatial analysis and linear regression | Stochastic MORECS PET |
| SNZ | Catchmod Model for Western Rother, River Arun and Weir Wood Reservoir | Stochastic Rain Gauge inputs for Rotherfield Park, Hindhead Water Works, Balcombe and Bognor Regis apportioned to catchment inputs via spatial analysis and linear regression | Stochastic MORECS PET |
| SBZ, SWZ | Indicator Borehole model and coupled recharge model (as WRMP19, WRMP14) | Stochastic Rain Gauge inputs for Poverty Bottom, Mile Oak Pumping Station and Bognor Regis translated to 3 rain gauge model inputs through linear regression | Stochastic MORECS PET |

[4] Hough, M. N. and Jones, R. J. A.: The United Kingdom Meteorological Office rainfall and evaporation calculation system: MORECS version 2.0-an overview, Hydrol. Earth Syst. Sci., 1, 227-239, doi:10.5194/hess-1-227-1997, 1997
[5] WRSE, 2021. Method Statement: Stochastic Climate Datasets. Updated version (Included in Annex 23)

| | | | |
|---|---|---|---|
| KME, KMZ | Indicator Borehole model and coupled recharge model (as WRMP19, WRMP14)<br><br>Catchmod Models for River Medway and sub-catchments such as the Teise and Eden | Stochastic Rain Gauge inputs for Canterbury, East Malling Falconhurst, Goudhurst, Betsomes Hill, Dorking Pixham Lane and Barming Rain Gauges, apportioned to model inputs via spatial analysis and linear regression | Stochastic PENSE and MORECS PET |
| SHZ | Catchmod Models for Eastern Rother and River Brede | Stochastic Rain Gauge inputs for Great Dixter, Goudhurst, Balcombe, Rain Gauges, apportioned to model inputs via spatial analysis and linear | Stochastic MORECS PET |
| KTZ | East Kent Groundwater Model (as WRMP19, WRMP14) | Stochastic Rain Gauge inputs for Canterbiry Rain Gauge, apportioned to model inputs following same method as WRMP14, WRMP19. | EA Recharge Model |

## 1.9. Benefits of demand and supply side measures on DO

Supply side drought measures, such as environmental drought permits and orders to temporarily relax licence conditions and increase abstractions, have not been included in our baseline DO. This is consistent with the WRPG (Environment Agency, 2021a). Instead, these supply side drought measures are included as options within the supply-demand investment modelling.

Similarly, the beneficial supply and demand impacts of demand side drought measures such as TUBs (Temporary Use Bans) or NEUBs (Non-Essential Use bans)are not included in our baseline DO assessments but are also included as options within the supply-demand investment modelling.

## 1.10. Assessment of groundwater yields

### 1.1.1. Groundwater Framework

To determine the best way to include groundwater sources within the regional modelling approach we worked with WRSE to develop and apply a Groundwater Framework (WRSE, 2021b)[6].

Groundwater Resources are typically more complex and computationally intensive to model than surface water resources, as models must consider aquifer properties, variation in groundwater levels, antecedent operation, interference effects and asset and licence constraints.

To improve the efficiency of our water resource modelling approach, we worked with other WRSE companies to develop a common Groundwater Framework, the aim of this framework was to develop and select the most appropriate modelling method for including groundwater resources within the regional system simulation.

[6] WRSE 2021 Method Statement: Groundwater Framework (included in Annex 23).

The Groundwater Framework proposes a standard assessment approach to be applied across all WRSE Water Companies and Water Resource Zones. Application of the framework assigned a weighted score across different source characteristics and suggests the DO modelling approach and system simulator representation that should be employed. Generally, the higher scoring a source, the more suitable and the more benefit that would be gained from dynamic representation within the system simulator model.

The framework proposed a semi-quantitative characterisation of each groundwater source over three phases:

- Phase A: Background information. This includes the source name, type of source (e.g. single borehole, well and adit etc), the WFD Groundwater body from which it abstracts and if it is a confined or unconfined source. This information is not considered in the framework prioritisation scores but provides some context when considering appropriate modelling methodology and potential grouping of some sources.
- Phase B: Prioritisation criteria: This considers the prioritisation of sources for dynamic modelling based on their importance and potential value of their representation within the simulator. Four key criteria are considered in the scoring:
  - DO constraints and in particular the sensitivity of deployable output to climate factors, with a higher score being assigned to sources that have drought sensitive yields. DO and Climate change assessments for previous WRMPs
  - Conjunctive use benefits considers the interaction of a groundwater source with other downstream or downgradient sources or to the environment. It considers the extent to which groundwater source impacts on surface water and the designation of that impacted surface water under the Water Framework Directive (table 2). Sites score highly if there are downstream impacts on surface water or conjunctive use with surface water abstractions.
  - Sensitivity to antecedent conditions; this mostly considers the role of groundwater storage in providing a benefit to yields at a site. In particular it is concerned with whether operation of a source may have a later impact on groundwater yield
  - Proportionality/threshold benefit; the intention of this score was to provide an indication of the possible strategic importance of a site, primarily measured through its DO volume. This criteria was not used to determine if a source should be considered for dynamic modelling as it only provides an understanding of source size not of its other hydrogeological or environmental characteristics.
- Phase C Methodology: a review of current and available methodology, suitability of the sources as well as the outcome of the assessment and overall prioritisation assessment balancing the feasibility of implementation with the overall aim and methodology approach identified.

The final stage of the framework is to determine a proposed DO modelling approach for each groundwater source. At each stage of the framework assessment, including the suggested modelling approach the suggested modelling approach or score could be overridden. However, if this is done a comment to justify the change must be provided to have a track record of the manual adjustment to the framework outcome to ensure good governance.

The (anonymised) scores for all Southern Water Sources are presented in Appendix A.

### 1.1.2. Groundwater Modelling

We determined that the yield of three groundwater highest priority sources should be dynamically simulated within the regional system simulation model:

- River Itchen groundwater
- Twyford, and
- Pulborough

These sources are all constrained by Hands off Flow licence conditions in associated surface waters and where flow sequences were to be available within the RSS model.

For all other groundwater yields these were derived externally to the RSS using groundwater modelling approaches with variable time series of yield derived where sources were drought sensitive. This broadly followed the stochastic time series modelling approach we adopted in our previous plans (WRMP14 and WRMP19).

Table 2.3 sets out our approach in more detail.

For several sources and WRZs, our groundwater sources are asset or infrastructure constrained and are not sensitive to groundwater level variations or drought. The yield of these sources was supplied as a non-varying static DO time series of peak DO (PDO) and minimum DO (MDO) to the RSS model.

### *Groundwater DO Constraints*

In parallel to developing our water resource modelling, we undertook a company-wide review to understand the asset and infrastructure constraints of each source and where relevant these were used to constrain DO. If feasible, options to remove DO constraints have been considered as part of our options appraisal.

Following submission of data to support development of the ERP, which forms the basis of our dWRMP24, we have continued to work with WRSE to refine and update input data into the supply-demand balance. Some of the key changes to our supply forecast include the following.

A summary of groundwater DO constraints is presented in Table 2.2.

Overall, our approach for modelling dynamic groundwater yield follows the same approach as for our WRMP19. The key change being adoption of the new regionally consistent stochastic weather series as input data to our existing models. Where input locations differed, WRSE stochastic point rainfall time were converted to equivalent model rain gauge input time series via linear regression following the same approach as for our surface water models. PET data were resampled from existing model inputs, e.g. historic MOSES PET data is used to derive coherent stochastic MOSES through our stochastic generator (Section 1.8).

As mentioned previously, we employed a combination of groundwater modelling approaches depending on resource model availability and suitability for running the large stochastic datasets.

Model runs and time series were processed in batch scripts via Python in 1000s of runs to produce coherent stochastic inputs to the regional system simulation model. These comprised of time series source level groundwater DO (for PDO and MDO scenarios) or River Flows (for the Western area model). WRZ DO calculations, including assessment of average DO (ADO), were carried out within our Regional System Simulation models (Section).

Groundwater Model Outputs were validated against historical flows and groundwater levels, and the corresponding estimates of DO from WRMP19, accepting that some changes will be introduced because of the new stochastic climate data. When converting from indicator borehole groundwater level time series to DO, we followed the standard methodology outlined in UKWIR (2000), UKWIR (2014) and UKWIR (2016a).

### Table 2.2: Summary of constraints on groundwater DO.

| WRZ | No. of groundwater sources | Number of DO Constraints (1:500 year MDO/DYAA) | | | | | Number of DO Constraints (1:500 year PDO) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Groundwater level | Yield | Asset / Infrastructure / Demand | Abstraction licence | Water quality | Groundwater level | Yield | Asset / Infrastructure / Demand | Abstraction licence | Water quality |
| HKZ | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| HAZ | 5 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 1 | 3 | 1 |
| HRZ | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HWZ | 3 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 1 | 0 |
| HSE | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| HSW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IOW | 7 | 1 | 3 | 0 | 3 | 0 | 1 | 2 | 4 | 0 | 0 |
| SNZ | 6 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 4 | 2 | 0 |
| SWZ | 11 | 3 | 0 | 6 | 1 | 1 | 2 | 0 | 8 | 0 | 1 |
| SBZ | 13 | 5 | 1 | 4 | 1 | 2 | 4 | 1 | 6 | 0 | 2 |
| KMW | 9 | 6 | 0 | 3 | 0 | 0 | 6 | 0 | 3 | 0 | 0 |
| KME | 16 | 2 | 0 | 14 | 0 | 0 | 2 | 0 | 14 | 0 | 0 |
| KTZ | 11 | 6 | 0 | 4 | 1 | 0 | 6 | 0 | 4 | 1 | 0 |
| SHZ | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

**Table 2.3 Summary of groundwater resource modelling methods.**

| Aquifer Block | Water Resource Zones | Groundwater Modelling Approach | Rationale |
|---|---|---|---|
| Hampshire Chalk | HSE, HSW, HWZ, HKZ, HAZ, HRZ | The "Old" Test and Itchen EA Groundwater model (i.e. MODFLOW96-VKD) as per 2013 calibration used with the 400 WRSE climate and PET sequences to generate naturalised flows and groundwater levels. Naturalised flows are then used as time series input to Pywr and denaturalised using lumpy groundwater factors which account for abstraction impacts on the rivers. We have recently updated the lumpy groundwater factors to reflect the outcome of the more recent WINEP investigations in Hampshire.<br><br>We have used the "old" MODFLOW96-VKD as it has a much faster run time than the new MODFLOW-6 model which allows us to simulate all 19k stochastic years from the WRSE climate data. We consider this is necessary because of the high DO sensitivity of our major sources in this aquifer block and for coherence with the wider WRSE methodology. Secondly, we consider the "old" model calibrates better to low flows for the key MRF compliance points on the lower Test and lower Itchen than the new model.<br><br>The head calibration of the old model is inferior, however, the DO for most of our Hampshire sources outside the Lower Itchen is not level dependent and so do not need to be modelled dynamically as they are insensitive to drought. For the Lower Itchen GW sources, we can use an indicator borehole (Chalk Dale) along with modelled GWL's and established curve shifting relationships to estimate rest water level variations. We can then estimate dynamic DO via standard curve shifting methods. For WRMP24 we have applied additional regression to bias correct groundwater level fit to observed data for the old model.<br><br>Validation of the assessments for a sub-sample of climate replicates against both the EA River Test Catchmod model and the "new" MODFLOW6 groundwater model (as carried out assessment of the Candover Scheme) indicate that the old model is more drought sensitive than the new MODFLOW6 model with river flows during severe droughts being around 10-15Ml/d lower. This will help constrain our uncertainty estimates. | Method covers all sources in WRZ. As most are drought insensitive, having static profiles they can be used coherently with other datasets. Flow sequences for River Test and Itchen and MRF dependant DO are based on WRSE coherent climate data so are temporally compatible with modelling elsewhere.<br><br>Output flow sequences for River Itchen also supplied to Portsmouth Water for use in their DO assessments for the Lower Itchen.<br><br>Impacts of SEW source in the Candover Stream Catchment are included in Lumpy Groundwater Impact factors applied to River Itchen Flow within System Simulation Models. |
| IOW Chalk | IOW | Following AMP6 WINEP WFD ND investigations DO for drought sensitive sources has become less hydrogeologically sensitive as many licence changes have capped DO and source output in general at severe drought MDO. | A subset of these assessments could be validated against the full new IoW groundwater model, however, run time of this model as such will not allow the |

| Aquifer Block | Water Resource Zones | Groundwater Modelling Approach | Rationale |
|---|---|---|---|
| | | Where there is still some dynamic response (e.g.Newport, Lukely Brook, Knighton), a lumped parameter model based on BGS Aquimod code is used to simulate groundwater levels for an indicator borehole where we have existing RWL curve shift relationships (as used in WRMP19, WRMP14). The 400 WRSE climate sequences provide inputs to the lumped parameter model. | full ~19k years of WRSE climate data to be run in a reasonable timescale hence our assessments used lumped parameter model as a "rapid" tool.<br><br>Method covers all sources in Isle of Wight Resource Zone. Climate sequences are coherent so DO time series are temporally and spatially coherent with other WRZs. |
| Brighton and Worthing Chalk | SBZ, SWZ | The 400 WRSE Stochastic climate data are used with 4R recharge model from B&W Groundwater model) and an indicator borehole (Whitelot Bottom) regression model to predict rest water Level shifts at SWS abstractions. | Similar methodology used for WRMP09 and WRMP14 (though recharge model has evolved) and same stochastic approach as WRMP19 (stochastic).<br><br>As for WRMP19 a subset of these assessments could be validated against the full B&W groundwater model, however, run time of this model as such will not allow the full ~19k years of WRSE climate data to be run in a reasonable timescale hence our assessments used past validated regression relationship as a "rapid" tool (there is still significant run time for 4R recharge model alone). |
| North Kent Chalk | KME, KMW | As WRMP14/19, Stochastic simulation with EA Recharge code to Indicator Borehole Model for DO Curve Shifting to produce groundwater level and yield time series. | Same methodology as used in WRMP09 (with historic hind cast data and NK model outputs), WRMP14 (stochastic) and WRMP19 (stochastic).<br><br>New North Kent and East Kent Extended model still under |

| Aquifer Block | Water Resource Zones | Groundwater Modelling Approach | Rationale |
|---|---|---|---|
| | | | development will eventually replace this process with a single groundwater model assessment for all Kent Sources.<br><br>Method covers all sources in Kent Medway East and West WRZs. Climate sequences are coherent so DO time series are temporally and spatially coherent with other WRZs. |
| East Kent and Thanet Chalk | KTZ | WRSE Stochastic data used with Naturalised EA East Kent Groundwater Model (used under licence) to predict rest water Level shifts at SWS abstractions.<br><br>Although there are surface water impacts, we have no groundwater sources which have coupled surface water MRF conditions | Same methodology as used in WRMP09 (with historic hind cast data), WRMP14 (stochastic) and WRMP19 (stochastic).<br><br>New North Kent and East Kent Extended model still under development will eventually replace this process with a single groundwater model assessment for all Kent Sources.<br><br>Method covers all sources in Kent Thanet Water Resource Zone. Climate sequences are coherent so DO time series are temporally and spatially coherent with other WRZs. |

# 1.11. Surface Water Hydrology

To understand the availability of supplies from our river sources such as the Rother and the Medway, we use hydrological modelling. We have used several hydrological models developed using the EA 'Catchmod' catchment modelling code implemented in Python ('PyCatchmod')[7]. These models primarily cover our Central and Eastern areas, river flows in the baseflow dominated River Test and River Itchen in our Western area were simulated using a regional groundwater model.

The hydrological models we used were largely unchanged from those used for our WRMP19. We updated our River Rother hydrological characterisation to improve low flow fits and to an include enhanced representation of groundwater impacts on the river.

Our hydrological modelling approach is consistent with that set out in WRSE (2021a)[8] and the regional modelling methodology. Hydrological models may be used to assess the potential impacts of drought on river flows. We have used CATCHMOD (Greenfield, 1984) rainfall-runoff hydrological models to model river flows since 2005.

Our flow models are calibrated against observed data and are used to simulate the likely river flows which would occur in a catchment given a particular sequence of weather. The models have been developed to produce flow sequences from the synthetic stochastic rainfall and PET sequences (section 1.8), as well as the historic records of rainfall and PET.

## 1.1.3. Climate Data

Analysis of WRSE rain gauge apportionment was carried out for all the surface water catchments. There were a limited number of rainfall assessment points with rainfall sequences developed for WRSE. This analysis identified nearest climate data rain gauges to the existing Catchmod surface water catchments, and then undertook goal-seek regression analysis to apportion the contribution of each rain gauges site (instead of Thiessen polygon approach).

As with the Groundwater models coherent Potential Evapotranspiration (PET) data in the weather generator is sub-sampled from model historical input data, largely as per previous WRMPs.

## 1.1.4. Flow Naturalisation

Flow naturalisation is the term given to the process of determining the 'natural' flow within a river. Naturalised flows represent the flows that would have occurred in the river without the influences of artificial abstractions and discharges within the catchment. The naturalised flows are then used to calibrate the hydrological models, so that the models simulate flows without these influences.

Flow naturalisation by decomposition involves estimating flows as might have occurred without the artificial influences through the re-addition of abstracted water to the gauged flow and the removal of discharges. Flow naturalisation was undertaken in line with EA guidance (2001).

[7] Tomlinson, J, Arnott, J and Petch, L, pycatchmod: A Cython implementation of the rainfall runoff model CATCHMOD (Wilby, 1994), Version 1.1

[8] WRSE, 2021. Method Statement: Hydrological Modelling. Post consultation version (included in Annex 23).

A dataset of abstractions in each catchment was collated from information shared by the EA. The largest 99% of abstractions based on licence volume were extracted for analysis and missing data were infilled. The impact of groundwater abstractions was represented using the 'lumpy groundwater factor' methodology described in Environment Agency (2001). Time series of discharges were developed using estimates of dry weather flows (DWFs), based on either measured discharge date, or consented-DWFs.

Using the procedures outlined above the catchment abstraction and discharge time series datasets were used to generate naturalised flow sequences from the observed gauged daily flows.

Reservoir inflows were assessed using two methods, by back calculating inflows based on reservoir water balance, and by using nearby gauged catchments which were generally unaffected by artificial influences as a proxy. Inconsistencies and anomalies in the reservoir water balance datasets meant that proxy flow data from nearby catchments was preferred for estimating historical reservoir inflow sequences.

### 1.1.5. Flow denaturalisation

We applied Bespoke WRMP19 Medway flow denaturalisation to consider non-simulated HoF constraints and interaction of Bewl, River Medway Scheme and Bough Beech reservoir.

Our Catchmod rainfall-runoff models simulate 'natural' catchment flows. To estimate the yield of surface water systems, we need to take account of the abstractions and discharges which would normally occur in the catchment. "Denaturalisation" is the procedure by which these artificial influences are added back to the simulated natural flows.

Denaturalisation represents a sub-set of the abstractions and discharges in the catchment. The Southern Water surface water abstractions and reservoir releases are not represented in the denaturalisation process. These are modelled instead in the Pywr System Simulation model for which the denaturalised flows are a key input.

Actual historical abstraction data were analysed, and the 'peaky worst year' (PWY) selected to use denaturalisation, being the year with the greatest aggregate abstraction. Discharge data we updated to use recent actuals.

Denaturalisation was carried out using a bespoke script written in Python. This procedure accounted for the licenced HOF condition for each abstraction with a dynamic denaturalisation process which checked the amount of water available above the HOF for each licence, and only accounted for an abstraction if there was sufficient water available.

### 1.1.6. Outputs

Flow outputs from our Catchmod modelling comprise 400 x 48-year time series of river flows for each model consistent with the stochastic climate input data. Output flows were validated by comparison against the equivalent stochastic flow series from our WRMPO19 hydrology modelling.

Once validated outputs are then passed to our regional system simulation models where they provide input time series for both reservoir refill and/or river flows to be used in the calculation of Water Resource Zone Deployable Output (Table 2.4).

**Table 2.4 Link between hydrological model output and System Simulation**

| Area/WRZ | Catchmod Flow Series | System Simulation Sub-Model |
|---|---|---|
| Western | N/A River Test and Itchen Flows come from T&I Groundwater Model | Hampshire |
| IoW | Medina and Eastern Yar | N/A (New IoW model under development) |
| Sussex North | Western Rother, Arun at Pallingham, Weir Wood | Sussex North (Central) |
| Kent Medway East and West | Bewl, Teise, Teston, Allington, Stonebridge, Boughbeech, Powdermill, Brede, Udiam, Eden | River Medway Model (Outputs for River Medway Scheme yield are passed to Kent Medway-Thanet model |

# 1.12. Regional system simulation

To derive water resource zone level estimates of our DO, as required by the WRPG, we have used a regional system simulation model which has been developed collaboratively with WRSE and neighbouring water companies. The overall approach is set out in WRSE (2021c)[9] and is summarised below.

Our regional system simulation (RSS) models have been used to produce both our baseline DO assessments and assessments of uncertain future impacts of climate change. The first stage of model use involves using the model to produce values to feed into the WRSE investment model and Water Resource Planning tables. Specifically, outputs to be produced by the RSS model are:

- Baseline DO (see WRSE (2021d) [10]
- Impact of climate change on DO (See Section and WRSE (2021e) [11]

The regional level RSS is a combined model composed of many coupled sub-models. A key requirement of the RSS is that methods and models used are, where reasonable, consistent with existing company assessments. As such, the initial sub-models are being built to represent company WRZs and sub-region models.

The sub-models were constructed in Pywr to a similar level of detail as our existing Aquator system simulation models although some demand centres were aggregated, and sources grouped to simplify the model and speed up run time. New models were developed in Pywr because it offers improved functionality for handling stochastic flow and climate sequences and more efficient run times, especially when scaled up to a regional level model.

We also updated our demand profiles to be more consistent with recent patterns of consumption. Some additional constraints were also added to model groundwater DO to mimic operational usage of the sources. Where relevant, some abstraction licence changes, network enhancements were also included.

[9] WRSE, 2021. Method Statement: Regional System Simulation Model. Post consultation version. (Included in Annex 23)
[10] WRSE, 2021. Method Statement: Calculation of Deployable Output. Post consultation version (Included in Annex 23).
[11] WRSE, 2021. Method Statement: Climate Change – Supply Side Methods. Updated version (Included in Annex 23).

During developed of our models, sub-model performance was validated against our existing Aquator models where possible to ensure system behaviours and source operation was modelled appropriately.

The Southern Water components of the RSS model were constructed from five sub-models:

- Western area model encompassing four WRZs (HWZ, HRZ, HSE and HSW).
  - This was constructed to a similar level of detail to existing well validated Aquator model
  - Validation undertaken against the existing Aquator model (e.g. from WRMP19)
  - Updated to include:
    - Section 20 licensing agreement,
    - Hampshire grid schemes, and
    - Revised Wastewater discharges
- SNZ model (Central area)
  - This was constructed to a similar level of detail to existing well validated Aquator model.
  - Validation undertaken against the existing Aqautor model (e.g. from WRMP19).
  - Updated to include improved impact pathway between Hardham groundwater abstraction and the River Rother.
- Brighton and Worthing WRZ model (Central area)
  - A model incorporating network constraints and disaggregated demands and sources developed from an existing Aquator model, but not one that had been used for DO assessment.
  - For WRMP19 DO was totalled for source inputs into these WRZs. No final simulation model from WRMP19 was available for validation.
  - Validation undertaken against the DO supply forecasts.
  - Additional constraints added to the groundwater DO to mimic operational usage of the sources.
- River Medway model including SHZ (Eastern area)
  - Similar level of detail to our existing Aquator model.
  - Validation undertaken against the Aquator model.
  - Updated to include new licensing arrangements around Bewl and SEW arrangements.
- Kent Medway-Thanet model encompassing KME, KMW and KTZ (Eastern area)
  - A model incorporating network constraints and disaggregated demands and sources developed.
  - For WRMP19, DO was totalled for source inputs into KTZ. No final model available for validation.
  - Validation undertaken against the DO supply forecasts.
  - Additional constraints added to the groundwater DO to mimic operational usage of the sources.

Three of the WRZs in the Western area (HAZ, HKZ and IOW) were not included as sub-models within the RSS model.

HAZ and HKZ are relatively small groundwater dominated WRZs with sources that are asset and licence constrained and hence DO does not vary with drought severity or groundwater levels. The DO for these WRZs have therefore been determined using the standard unified method and does not require system simulation. However, we are currently constructing a sub-regional system simulation model for Hampshire to include these zones jointly with PWC.

For the IOW we calculated DO additively, but this was simulated through our combined groundwater modelling using the coherent stochastic WRSE climate dataset to determine a probabilistic estimate of drought severity and associated DO following the standard unified method. This WRZ was modelled as a single demand node within our Western area sub-model. We are currently constructing our own in-house Pywr system simulation model for this WRZ.

### 1.1.7. Calculation of Water Resource Zone Deployable Output

DO at a WRZ (system response level) level was estimated using the 'Scottish DO Method'[12], excluding the effect of transfers both external and internal.

By this approach the system model repeatedly runs through the full hydrological and groundwater sequences (400 x 48-years for the stochastic sequences) for a range of different overall demand levels. As the overall demand levels are changed, the individual demands for selected demand centres are incrementally increased. The analyser counts and reports the number of days with failures (i.e. when there are insufficient resources to meet demand) in each year for each demand level.

The DO is defined as highest level of demand which can be applied where emergency drought orders would not be imposed more often than once every 'X' number of years, where 'X' ranges from 1 in 2 years to 1 in 500 years.

This method does not attempt to calculate individual source DOs, it is focused only on "system" (WRZ) level DO. However, in estimation of our This method does not attempt to calculate 1:500 source DOs, it is focused only on WRZ level DO groundwater deployable outputs. We have used estimates of source DOs to validate and compare the approach to our WRMP19 assessments.

For all of our Water Resource Zones, we set the failure condition to be after four consecutive days of a failure to meet demand. This condition was consistent with other WRSE companies again to ensure a coherent approach to resource modelling.

### 1.1.8. MDO scenario modelling considerations

For our groundwater sites in Pywr, we included as a baseline rate source level MDO assessments and PDO profiling, i.e. our groundwater site yields have stochastic time series constrained by MDO constraints so that they drop off in the autumn and with drought severity, but with factors that allow peaking up to PDO during critical periods in July and August.

The Pywr DO assessments effectively constrain DO when there has been four days of consecutive failure at a given level demand. The key distinction and why we effectively call this an DYAA DO, even though there is at no point any kind of annual averaging involved (especially in zones without significant storage), is because the supply failures can occur at any point in the year outside the critical period and are not constrained to just those which would occur only at the time of minimum flow. However, as the greatest stress between supply and demand will typically occur at the time of lowest supply the DO effectively becomes a de-factor MDO failure anyway. We've validated this by looking at supply failures in Hampshire Southampton Zones (which are the most MDO sensitive of all zones) and all of them occur at the time of minimum flow in the two rivers (i.e. between September and November) and is equivalent to MDO failures.

Comparison of the WRMP24 'DYAA' DOs with the equivalent WRMP19 MDOs (Table 2.5) show that in all cases the WRMP24 DO's are roughly equal to-or lower than our equivalent MDO scenario from WRMP19,

[12] UKWIR, 2014, Handbook of Source Yield Methodologies, Report Ref. No. 14/WR/27/7

through a combination of the changes to stochastics and network/system factors so that the current DYAA scenarios are a 'higher stress' than our WRMP19 MDO scenario.

Although other companies within the South East region have similar water resources to us, i.e. drought sensitive groundwater sources and river abstractions constrained by Hands Off Flow conditions, none have, to date, considered or required a specific MDO scenario. Therefore, even if we were to run a dedicated MDO scenario it would not be coherent with the deployable outputs from other companies, nor would the data be available to properly determine option yield and utilisation. Furthermore, the development of new transfer and storage options and overall reduction in the role of groundwater (due to expected licence changes) are likely to reduce our overall risk to MDO scenario droughts.

**Table 2.5: Comparison of WRMP19 MDO Scenario deployable output with our updated WRMP24 DYAA scenario for a 1:500 year drought.**

| WRZ | WRMP19 1:500 MDO (Ml/d) | WRMP24 1:500 DYAA DO (Ml/d) | Comment |
|---|---|---|---|
| HK | 8.68 | 8.75 | Static non drought sensitive DO, scenario agnostic |
| HA | 21.43 | 22.86 | Static non drought sensitive DO, scenario agnostic |
| HR | 12.3 | 10.35 | Static non drought sensitive DO, scenario agnostic |
| HW | 23.88 | 22.52 | Static non drought sensitive DO, scenario agnostic |
| HSE | 0 | 20.49 | DYAA scenario effectively represents MDO failure condition |
| HSW | 0 | 0 | DYAA scenario effectively represents MDO failure condition |
| IoW | 27.14 | 23.96 | GW yields based on MDO constrained time series anyway |
| SNZ | 17.5 | 17.6 | Effectively MDO failure anyway (Rother yield) |
| SWZ | 53.87 | 45.78 | GW yields based on MDO constrained time series |
| SBZ | 88.2 | 77.5 | GW yields based on MDO constrained time series |
| Eastern area WRZs | N/A | N/A | Due to reservoir storage we've not previously considered MDO scenario for Kent |

The range of uncertainty due to climate change, population growth and environmental destination, there are a number of other combinations of discrete forecasts that can also produce similar levels of deficits (e.g. an MDO scenario). Therefore, the solutions being presented in our plan should be considered as not just answering these 9 specific combinations of uncertainty drivers, but also a more general point that a given level of supply-demand deficit is best solved using this combination of solutions via our best value decision making. Although based on our assessment above, we do not expect MDO deficits to be significantly greater than the DYAA scenario, our adaptive approach would therefore cover any higher deficits driven by use of MDO.

### 1.1.9. Apparent network constraints

Consistent with the WRPG (Environment Agency, 2021a) and following the WRSE approach, we have produced WRZ level DO assessments using the behaviour RSS model that reflect potential supply failures up to a 1:500-year system response. Through this approach, several apparent conjunctive use and infrastructure constraints on our DO compared to the standard unified approach in our groundwater dominated WRZs were identified.

To estimate the conjunctive use losses, we compared the calculated DO from our RSS model with an additive assessment of DOs calculated using the same climate dataset but following the standard unified methodology for individual sources (UKWIR, 2002[13]). We have not been able to estimate system losses for some WRZs. For example HSE, SNZ are inherently conjunctively linked within those WRZs (e.g. through common licence conditions). We will continue to investigate the cause of these apparent system level DO constraints through our system simulation modelling.

[13] UKWIR, 2000. A Unified Methodology for The Determination of Deployable Output. Ref. 00/WR/18/1.

### Table 2.6: Summary of Baseline DO at the WRZ level.

| WRZ | DO by return period (DYAA/MDO) - Ml/d | | | | DO by return period (PDO) - Ml/d | | | |
|---|---|---|---|---|---|---|---|---|
| | 1:500 year | 1:200 year | 1:100 year | 1:2 year | 1:500 year | 1:200 year | 1:100 year | 1:2 year |
| HKZ | 8.75 | 8.75 | 8.75 | 8.75 | 9.28 | 9.28 | 9.28 | 9.28 |
| HAZ | 22.86 | 22.86 | 22.86 | 22.86 | 24.80 | 24.80 | 24.80 | 24.80 |
| HRZ | 10.35 | 10.35 | 10.35 | 10.35 | 10.35 | 10.35 | 10.35 | 10.35 |
| HWZ | 22.52 | 22.52 | 22.52 | 22.52 | 24.40 | 24.40 | 24.40 | 24.40 |
| HSE | 20.49 | 32.46 | 45.65 | 77.97 | 41.00 | 58.38 | 78.36 | 108.42 |
| HSW | 0 | 0 | 0 | 73.54 | 0 | 0 | 11.85 | 78.8 |
| IOW | 23.96 | 25.89 | 26.07 | 26.58 | 30.54 | 34.09 | 34.33 | 34.65 |
| SNZ | 17.6 | 21.46 | 54.84 | 83.94 | 20.81 | 57.32 | 70.6 | 99.16 |
| SWZ | 45.78 | 46.26 | 46.69 | 51.73 | 54.96 | 55.52 | 56.05 | 62.11 |
| SBZ | 77.5 | 80.05 | 81.57 | 86.94 | 93.82 | 96.88 | 98.74 | 105.33 |
| KMW | 72.98 | 74.16 | 75.98 | 77.09 | 79.70 | 80.79 | 82.61 | 83.32 |
| KME | 85.37 | 86.15 | 86.71 | 89.13 | 97.65 | 98.62 | 99.47 | 103.93 |
| KTZ | 44.71 | 46.50 | 47.98 | 51.42 | 52.86 | 54.71 | 55.52 | 59.68 |
| SHZ | 19.75 | 20.90 | 21.98 | 32.84 | 23.90 | 27.14 | 29.15 | 41.25 |

**Table 2.7: Estimate of apparent conjunctive use constraints on DO at the WRZ level by comparison with WRMP19 DO.**

| WRZ | DO by return period (DYAA/MDO) - Ml/d | | | | DO by return period (PDO) - Ml/d | | | |
|---|---|---|---|---|---|---|---|---|
| | 1:500 year | 1:200 year | 1:100 year | 1:2 year | 1:500 year | 1:200 year | 1:100 year | 1:2 year |
| HKZ | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| HAZ | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| HRZ | -1.28 | -1.28 | -1.28 | -1.28 | -0.22 | -0.22 | -0.22 | -0.22 |
| HWZ | -1.31 | -1.31 | -1.31 | -1.31 | -1.27 | -1.27 | -1.27 | -1.27 |
| HSE | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| HSW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IOW | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| SNZ | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| SWZ | -5.52 | -5.35 | -5.27 | -8.25 | -1.15 | -1.03 | -1.80 | -7.02 |
| SBZ | -5.34 | -4.38 | -4.84 | -12.57 | -12.12 | -10.67 | -11.02 | -13.06 |
| KMW | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| KME | 1.89 | 2.51 | 2.94 | 0.83 | 2.04 | 2.39 | 2.39 | 1.61 |
| KTZ | 2.18 | 2.53 | 2.84 | -6.02 | 4.91 | 3.97 | 2.50 | -3.65 |
| SHZ | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

# 3. Impacts of Climate change on Water supplies

## 1.13. Climate Change Vulnerability

Our 2019 WRMP assessed the outturn climate change vulnerability, following from our water resource modelling for all our WRZs up to 2045, the end of a conventional 25-year planning period. This vulnerability assessment found the following:

1. We have a few zones which are highly vulnerable to climate change where both the 'mid-range' forecast impacts and the uncertainty between 'wet' and 'dry' scenarios is large. This generally applies to WRZs with minimum residual flow constraints are either imposed already, or forecast, on surface water abstractions, specifically HSW, HSE and SNZ WRZs. KTZ was also considered to be highly vulnerable owing to the range of uncertainty of climate change impacts between wet and dry scenarios.

2. Our Medium Vulnerability Zones were those WRZs where the most likely mid-range impact was small (<5% of WRZ DO) but where the range of predictions between the 'wet' and 'dry' suggested substantial uncertainty (up to 15% of WRZ DO). This included SWZ, SBZ, SHZ and KMW WRZs. These zones tend to have a higher proportion of drought or yield constrained sources vulnerable to the effects of climate change.

3. Several of our WRZs were Low Vulnerability, where the impacts of climate change are small and the uncertainty between 'wet' and 'dry' scenarios is also low (<5% of total WRZ DO). These WRZs are therefore considered to be low vulnerability, generally echoing the predictions of our initial (pre-modelling) WRMP19 vulnerability assessment. This classification includes HKZ, HAZ, HRZ, HWZ, IOW and KME WRZs. The vulnerability of these WRZs is typically lower as a greater proportion of their sources are licence or infrastructure constrained, reducing their overall sensitivity to drought and climate change.

For the most sensitive WRZs (Hampshire Southampton East, Hampshire Southampton West and Sussex North), the high vulnerability arises primarily due to existing flow conditions on abstraction licences for the Rivers Test, Itchen and Rother. The DO of these zones is directly related to available flow above the flow constraint. Changes in flow due to climate change perturbations therefore directly translate to impacts on DO. This is exacerbated under the more severe or extreme low probability droughts where the DO is already small, or even zero. The magnitude of the flow changes can therefore account for a large percentage shift in DO.

For severe droughts, especially for the River Test, the sensitivity to climate change in the severe or extreme drought conditions becomes less significant as no water is available at all under the licence conditions during these events. Under these circumstances, climate change impacts are still felt for less severe (1 in 20 year) drought events and can still be large (10's of Ml/d).

# 1.14. Climate Change Impact Assessment and Modelling

To assess the uncertain impact of climate change on water supplies, we have followed a consistent approach with all WRSE companies, as set out in WRSE (2021e)[14]. Accordingly, we have followed a 3-tier climate change assessment approach in the context of current guidance, even for our previously established medium and low vulnerability water resource zones using consistent methods, models, and datasets with the other companies in our region.

Following the initial baseline water resource model assessment and DO assessment, a sub-set of the stochastic climate replicates were selected through agreement with neighbouring companies that were considered to contain a series of representative significant drought events across the WRSE region with probabilities generally between 1% and 0.2%.

Change factors were derived from the 28 Global Circulation Models (GCMs) included in the 2018 United Kingdom Climate Projections (UKCP) were provided by WRSE alongside the climate (rainfall and PET) datasets (Atkins, 2020). Spatial coherence across the region was an essential required feature of the assessment for coherent regional water resources planning and the regional and global projections were adopted by WRSE. At the time of production, the spatially coherent projections were only available for RCP8.5, the highest emissions scenario. Our approach is broadly equivalent to the ’High Climate Change’ PR24 Ofwat reference scenario. Alongside WRSE, we are currently considering lower emissions scenarios (e.g. RCP2.6) and associated uncertainty to support a Ofwat’s low climate change reference scenario for PR24.[15]

These climate change factors were used to perturb the baseline input time series of rainfall and evapotranspiration to our water resource models. The resource models and RSS were then re-run following the same sequence as for baseline DO to determine the change in DO for each of the 28 climate replicates and hence the impact of climate change.

We have applied the standard linear scaling approach suggested by the WRPG (Environment Agency, 2021a) to climate change in all our WRZs. The range in forecast impacts on climate change on our 1 in 500-year DO are shown in Table 3.1.

The data indicate that Hampshire Southampton East is the most vulnerable zone with the greatest potential climate change impacts on DO. This reflects the vulnerability of river flows and therefore DO which is constrained by the river flow available to abstract above the hands-off flow condition. Median climate change impacts in nearly all zones are neutral (near zero) or show a small positive gain. This reflects that, in general, winters are expected to get wetter under climate change (Met Office, 2022)[16] and hence our models show that groundwater and river yields to slightly increase.

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[14] WRSE, 2021 Method Statement: Climate Change – Supply Side Methods Updated version August 2021 (Included in Annex 23)
[15] Ofwat, 2021, PR24 and beyond: Long-term delivery strategies and common reference scenarios
[16] Met Office, 2022, UK Climate Projections, Headline Findings, ukcp18_headline_findings_v4_aug22.pdf (metoffice.gov.uk)

### Table 3.1 Summary of forecast climate change impacts and uncertainty by WRZ

| WRZ | 2040 | | 2060 | | 2075 | |
|---|---|---|---|---|---|---|
| | Median (Ml/d) | Uncertainty (% of Baseline) | Median (Ml/d) | Uncertainty (% of Baseline) | Median (Ml/d) | Uncertainty (% of Baseline) |
| HKZ | 0.00 | 0% | 0.00 | 0% | 0.00 | 0% |
| HAZ | 0.00 | 0% | 0.00 | 0% | 0.00 | 0% |
| HRZ | 0.00 | 0% | 0.00 | 0% | 0.00 | 0% |
| HWZ | 0.00 | 0% | 0.00 | 0% | 0.00 | 0% |
| HSE | -17.92 | -62.5% to 38.6% | -25.08 | -87.5% to 54% | -30.46 | -106.3% to 65.6% |
| HSW | 0.00 | 0% | 0.00 | 0% | 0.00 | 0% |
| IOW | 0.24 | -1.3% to 2.3% | 0.34 | -1.9% to 3.3% | 0.41 | -2.3% to 4% |
| SNZ | -6.30 | -14.9% to 3.1% | -8.82 | -20.8% to 4.4% | -10.70 | -25.3% to 5.3% |
| SWZ | 0.33 | -14.9% to 1.7% | 0.46 | -20.8% to 2.3% | 0.55 | -25.3% to 2.8% |
| SBZ | 0.16 | 1.9% to 2.8% | 0.22 | 2.7% to 3.9% | 0.27 | 3.3% to 4.7% |
| KMW | 0.00 | -8.7% to 0% | 0.00 | -12.2% to 0% | 0.00 | -14.8% to 0% |
| KME | -7.56 | -1.3% to 0.3% | -10.59 | -1.9% to 0.4% | -12.86 | -2.3% to 0.5% |
| KTZ | 1.96 | 1.9% to 8.5% | 2.74 | 2.7% to 11.9% | 3.33 | 3.3% to 14.4% |
| SHZ | -1.73 | -14.9% to -0.2% | -2.43 | -20.8% to -0.3% | -2.95 | -25.3% to -0.4% |

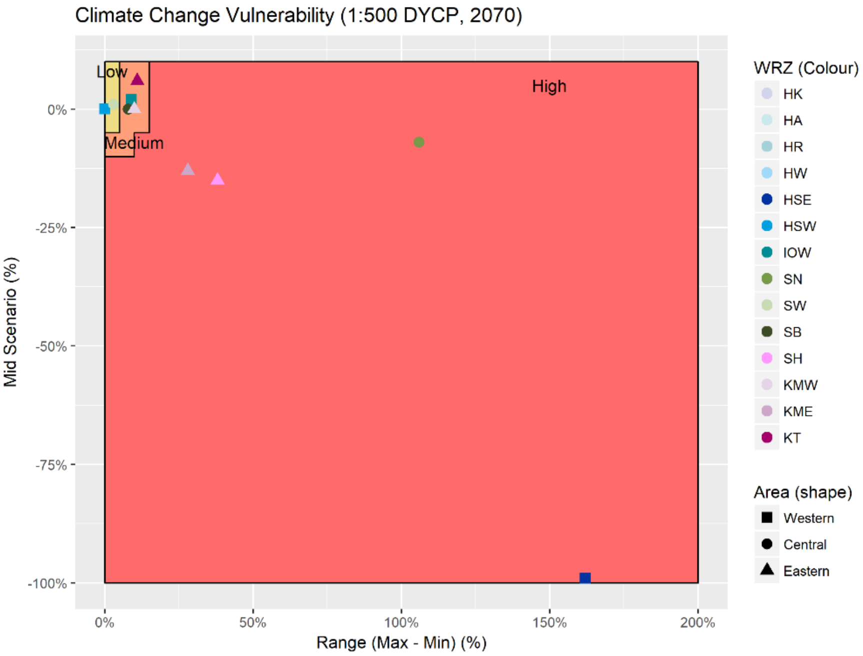
Following our updated water resource modelling, we have considered the final climate change vulnerability of our WRZs by 2070 – see Figure 3.1. The year 2070 represents the mid-point of the UKCP18 regional and global climate projections (which cover the 2060-2079 time slice), using this year in our water resource modelling and hence no scaling is applied to these forecasts. This review shows that across our supply areas, the forecast impacts of climate change fall into three broad categories, like our WRMP19 assessment:

- Highly vulnerable WRZs where both the 'mid-range' forecast impacts and the uncertainty between 'wet' and 'dry' scenarios is large. As previously this generally applies to WRZs with minimum residual flow constraints are either imposed already, or forecast, on surface water abstractions. As with specifically HSE, SNZ, KME and SHZ. KME is now considered to be highly vulnerable owing to the range of uncertainty of climate change impacts between 'wet' and 'dry' scenarios. Compared to our WRMP19 assessment, HSW has moved to low vulnerability, primarily because after confirmed 2027 licence changes, there is no DO available under any climate change condition. KTZ has moved to medium vulnerability as the uncertainty has reduced.
- Medium vulnerability WRZs include those WRZs where the most likely mid-range impact is small (<5% of WRZ DO), but where the range of predictions between the 'wet' and 'dry' scenarios suggests substantial uncertainty (up to 15% of WRZ DO). This group includes IOW, SWZ, SBZ and KTZ.
- Low vulnerability WRZs are those where the impacts of climate change are small and the uncertainty between wet and dry conditions is also low (<5% of total WRZ DO). This group includes HAZ, HKZ, HWZ and HSW. The vulnerability of these WRZs is typically lower as a greater proportion of their sources are license or infrastructure constrained, therefore reducing their overall sensitivity to drought and other effects of climate change.

For the majority of the most sensitive WRZs (HSE, SNZ and SHZ), the vulnerability arises due to the dominance of surface water over groundwater, of which the former is less robust in responding to climate change. The final highly vulnerable zone, KME, is dominated by groundwater; however, within the system simulator model, it sees greater conjunctive benefit from Bewl Water due to an internal transfer from KMW and hence has a greater degree of climate change vulnerability as a result.

Figure 3.2 to 3.4 visualise the modelled change in baseline DO due to climate change and present the associated uncertainty. The greatest uncertainty is shown for HSE, here the majority of impacts are negative from a decline in river flows but are weakly positive for the Isle of Wight, possibly reflecting a small increase in groundwater recharge.

SNZ shows the next greatest uncertainty, followed by KME. For these zones which possess the greatest uncertainty, the PDO shows a slightly greater uncertainty than average. Of all the WRZs, SWZ and IOW show the least uncertainty regarding climate change vulnerability, meaning we have the greatest confidence in forecasting future supply for these zones. The range of climate vulnerability reflects the sensitivity of the sources to changes in rainfall patterns, their location in a catchment and the type of abstraction licence.



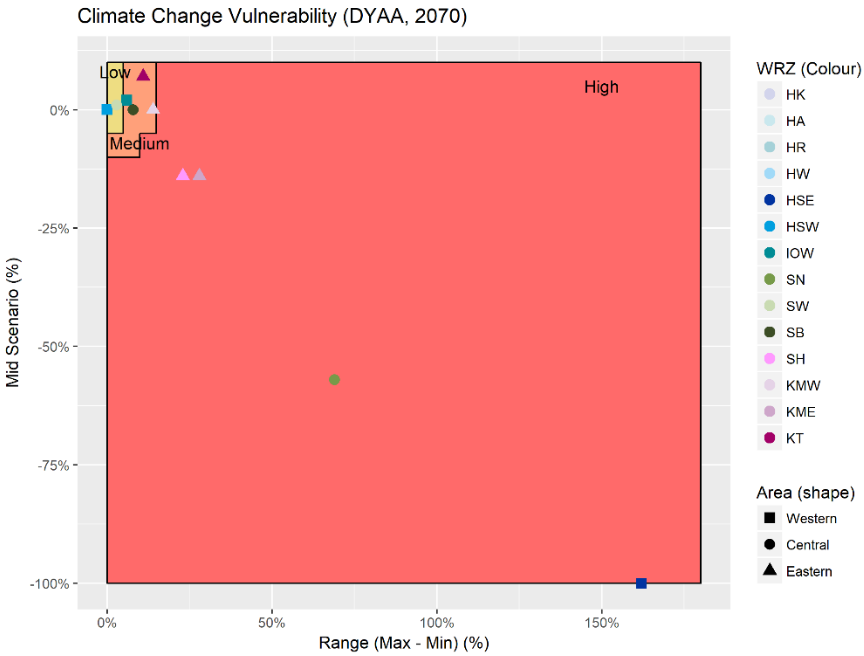




**Figure 3.1: Climate change vulnerability assessments for Dry Year Annual Average and Critical Period Scenarios.**

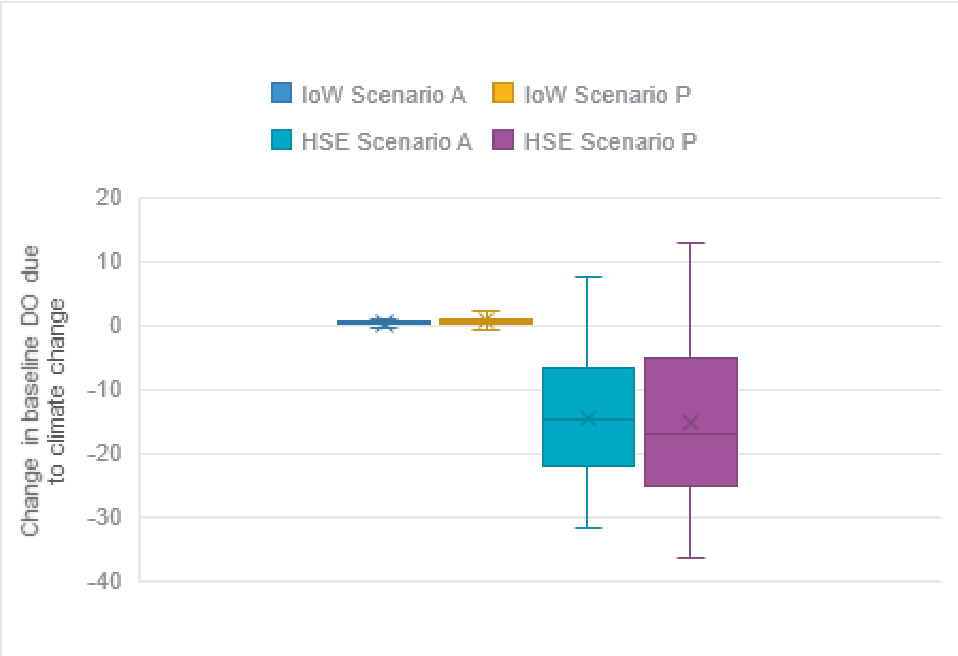



**Figure 3.2: Western Area 2070 modelled change in baseline DO due to climate change (1 in 500yr)**

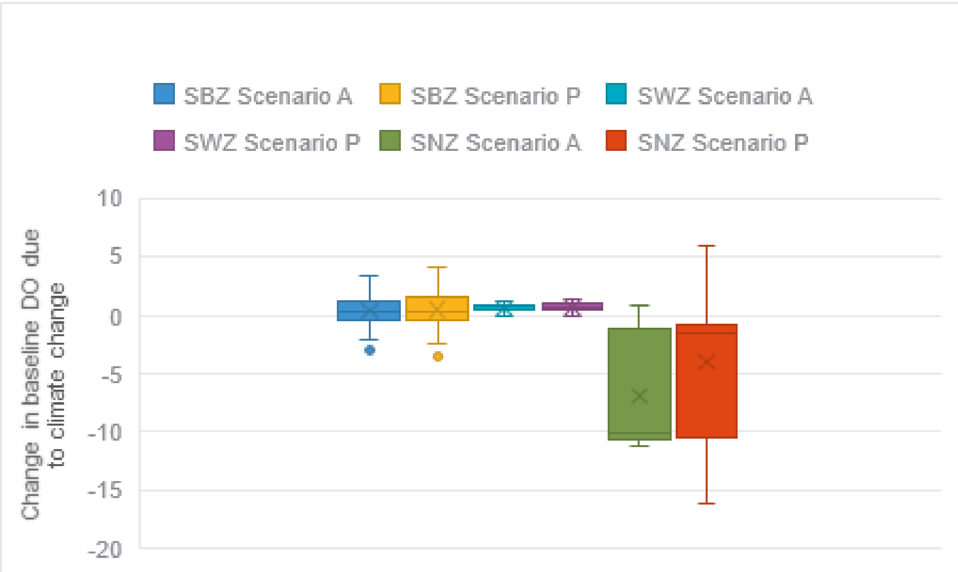



**Figure 3.3: Central Area 2070 modelled change in baseline DO due to climate change (1 in 500yr)**

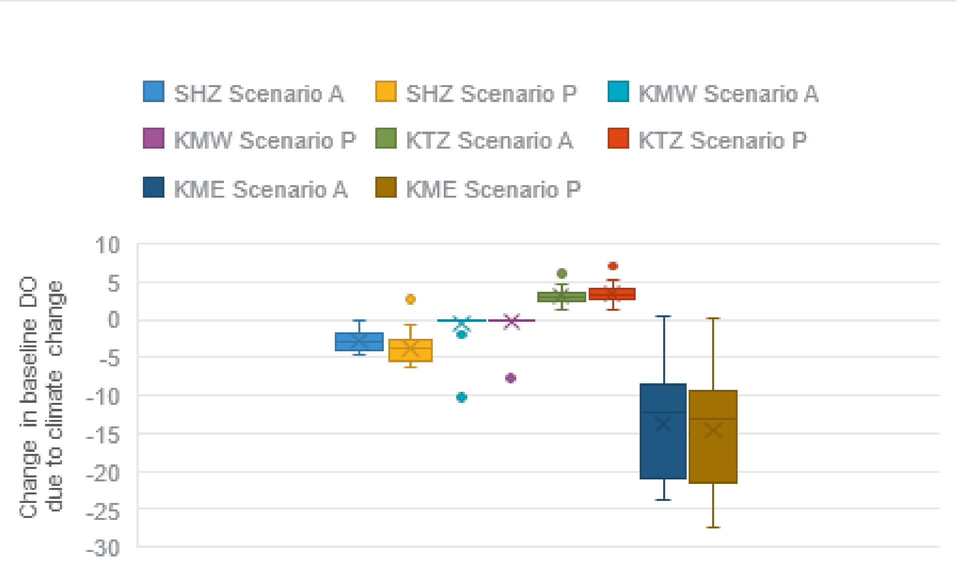



**Figure 3.4: Eastern Area 2070 modelled change in baseline DO due to climate change (1 in 500yr)**

# 4. Transfers and bulk supplies

We have several bulk transfer agreements with our neighbouring water companies (Table 4.1). We also transfer water across our WRZs (Table 4.2). In addition, we also provide non-potable supplies to two large industrial users; one in HSW and the other in SHZ.

For this plan, we have assumed that all of our existing transfers will continue, unless there is a specific option to modify any of them. Bulk transfer agreements with our neighbouring water companies are included as options in our options appraisal investment modelling upon the expiry of their current contractual term.

**Table 4.1: Existing bulk transfers with neighbouring water companies.**

| Type | Donor WRZ | Recipient WRZ | Potable or Raw | Maximum volume (Ml/d) | Contract Expiry |
|---|---|---|---|---|---|
| Export to AFW (Deal) | KTZ | RZ7 | Potable | 1.24 | |
| Export to SEW (Belmont) | KME | RZ6 | Potable | 7.8 | |
| Export to SEW (Bewl) | KMW | RZ7 | Potable | 12.3 | |
| Export to SEW (Burham) | KMW | RZ7 | Raw | | |
| Export to SEW (Darwell) | SHZ | RZ3 | Raw | 8/17th of the Bewl/ Darwell Yield | |
| Export to SEW (Matts Hill) | KME | RZ6 | Potable | 7.5 | |
| Export to SEW (Pitfield) | KMW | RZ6 | Potable | 0.5 | |
| Export to SEW (Weir Wood) | SNZ | RZ5 | Potable | 5.4 | 2031 |
| Export to WSX (Ibthorpe) | HAZ | | Potable | 0.41 | |
| Import from AFW (Napchester) | RZ7 | KTZ | Potable | 0.1 | |
| Import from SES (North Sussex) | SES | SNZ | Potable | 0.8 | 2026 |
| Import from PWC (Eastleigh) | PWC | HSE | Potable | 15.0 | |
| Import from PWC | PWC | SNZ | Potable | 15.0 | 2026 |
| SEW bulk supply near Canterbury | SEW | KTZ | Potable | 2 | tbc* |

*This transfer is in development for 2025 as part of our preferred WRMP19 delivery

**Table 4.2: Existing interzonal transfers**

| Donor WRZ | Recipient WRZ | Link | Potable or Raw | Maximum volume (Ml/d) |
|---|---|---|---|---|
| HRZ | HSE | Abbotswodd | Potable | 5.1 |
| HSE | IOW | Cross-Solent main | Potable | 20.0 |
| HSE | HWZ | Olivers Battery | Potable | 9.6 |
| HSW | HSE | Woodside | Potable | 16.8 |
| HSW | HSE | Gover Road | Potable | 2.7 |
| HSW | HSE | Rownhams | Potable | 5.6 |
| HSW | HRZ | Broadlands | Potable | 3.1 |

| Donor WRZ | Recipient WRZ | Link | Potable or Raw | Maximum volume (Ml/d) |
|---|---|---|---|---|
| SNZ | SWZ | Rock Road | Potable | 11.8 |
| SWZ | SNZ | Tenants Hill | Potable | 13.1 |
| SWZ | SBZ | V6 | Potable | 16.8 |
| KME | KTZ | Selling transfer | Potable | 12.0 |
| KMW | KME | Nashenden | Potable | 37.1 |

In addition to our existing interzonal transfers, our supply forecast for the Western area has been developed assuming implementation of the 'Hampshire Grid' transfers which were selected as preferred options in WRMP19. The transfers are planned to improve connectivity between our Hampshire Water Resource Zones (HAZ, HRZ, HSE and HSW), these transfers are still in development as part of our Water for Life Hampshire, but their assumed benefits are summarised in Table 4.3.

As discussed in our water resource zone integrity assessment, these new transfers are expected to improve the connectivity across our Hampshire supply area and reduce drought risks. We will revisit our water resource zone arrangement in Hampshire in future plans to reflect the benefits of these transfers.

**Table 4.3: Hampshire Grid Transfer Options currently being developed.**

| Donor WRZ | Recipient WRZ | Link | Potable or Raw | Maximum volume (Ml/d) |
|---|---|---|---|---|
| HSE | HWZ | Hampshire grid (reversible link HSE-HW) | Potable | 78.0 |
| HWZ | HSE | Hampshire grid (reversible link HSE-HW) | Potable | 78.0 |
| HSE | HAZ | Hampshire grid link (HSE-HA) | Potable | 15 |
| HSW | HSE | Southampton link main (reversible link HSW-HSE) | Potable | 30 |
| HSE | HSW | Southampton link main (reversible link HSW-HSE) | Potable | 30 |
| HSW | HRZ | Romsey Town and Broadlands valve (HSW-HR reversible) | Potable | 10 |
| HRZ | HSW | Romsey Town and Broadlands valve (HSW-HR reversible) | Potable | 10 |

These transfer options would increase the interconnectivity and move towards a single, larger zone underpinned by a water grid.

# 5. Outage

Outage refers to the temporary unavailability of DO from a source. Outages can be unplanned or planned. Unplanned outages can occur for a variety of reasons, such as, mechanical failures or water quality issues. These can be either full outage, where an entire source is unable to produce water, or partial outage, where a site can produce water but not at the maximum DO. Planned outages occur where we need to undertake maintenance or improvement works. We include a provision for outages within our supply-demand forecast.

An outage allowance is a planned volume of unavailable DO that we have allocated within our WRMP in recognition that outages will occur as part of day-to-day operation. This ensures that when outages do occur, our customers are not at increased risk during the time required to resolve it.

For WRMP19, our outage allowance followed a profile of outage recovery throughout AMP7 and then remained constant from 2025 onwards. For this plan, we have followed a consistent methodology for determining our outage allowance as the other WRSE companies (WRSE, 2021f)[17]. This ensures we are aligned with the RBVP and consistent in our approach.

The calculation method first involves collating and checking our historical outage data. We looked in detail at the previous 5 years' data to ensure that outage events were valid and whether outage experienced in the recent past is likely to be reflective of potential future levels.

We applied statistical distributions to the historic data to deduce the probability of these outages occurring again. For example, a normal distribution is applied if the data follows a standard bell curve shape or a fixed distribution if the outage has only occurred once in the past and there is no other information to build on. These distributions are then run through a Monte Carlo statistical model to produce thousands of simulations of outage volumes, which then picks the 95$^{th}$ percentile as the outage allowance. In effect this means that if our calculated outage allowance was 5Ml/d, then 95% of the time we would expect our outage volumes to actually be less than or equal to that total.

Due to historic high levels of outage and our current recovery plan to bring outage down to the end of AMP7 target level, we consider that the 95$^{th}$ percentile is an appropriate allowance. We also looked at the 90$^{th}$ percentile for sensitivity testing but this was significantly lower and more likely to be unachievable which would put our customers at increased risk (i.e. a greater chance that outage would be higher than that volume).

Since publishing our WRMP19, we have been constantly improving our outage data collection. These improvements involve a more accurate capturing of partial outages, more clarity around the reasons for outage and a breakdown of different types of outages (planned, unplanned and asset constrained). This improved data collection is allowing us to pinpoint cost-efficient outage recovery as well as improving our estimation of outage.

Following the agreed and consistent regional approach, the outage allowance from 2025-26 by WRZ for each of the planning scenarios is shown in Table 5.1. Figure 5.1 shows the historic reported outage up to March 2022, the WRMP19 outage recovery plan up to March 2025 and then the WRMP24 forecast outage allowance for the DYAA scenario which is used for the draft Regional Plan from April 2025 onwards. This shows that since 2018, our outage levels have been reducing significantly. We are still slightly behind the outage allowance but have plans in place to continue reducing outage in line with the recovery plan.

The Supply Demand Balance Index (SDBI) has increased focus on delivering the outage recovery plan and addressing new outages when they occur. At the monthly executive level Water Leadership Team, current

[17] WRSE, 2021. Method Statement: Outage. Version 2 (included in Annex 23)

outage levels are assessed, and investment decisions taken to manage outage levels below the forecast allowance. This includes asset maintenance activities to reduce the risk of new outages occurring.

**Table 5.1: Estimated outage allowance by WRZ.**

| WRZ | 2025-26 DYAA Outage (Ml/d) | 2025-26 DYCP Outage (Ml/d) | 2025-26 MDO Outage (Ml/d) |
|---|---|---|---|
| HAZ | 0.10 | 0.30 | 0.14 |
| HKZ | 1.07 | 1.80 | 1.20 |
| HWZ | 0.20 | 0.09 | 0.61 |
| HRZ | 1.53 | 1.50 | 0.36 |
| HSE | 0.51 | 0.00 | 0.70 |
| HSW | 0.17 | 1.34 | 0.000 |
| IOW | 3.01 | 3.28 | 1.53 |
| SNZ | 2.42 | 8.12 | 1.67 |
| SWZ | 5.33 | 2.75 | 1.55 |
| SBZ | 7.54 | 3.04 | 3.05 |
| KME | 3.64 | 4.05 | - |
| KMW | 6.78 | 2.97 | - |
| KTZ | 3.43 | 2.20 | - |
| SHZ | 0.06 | 0.00 | - |
| SWS | 35.77 | 31.43 | 10.81 |

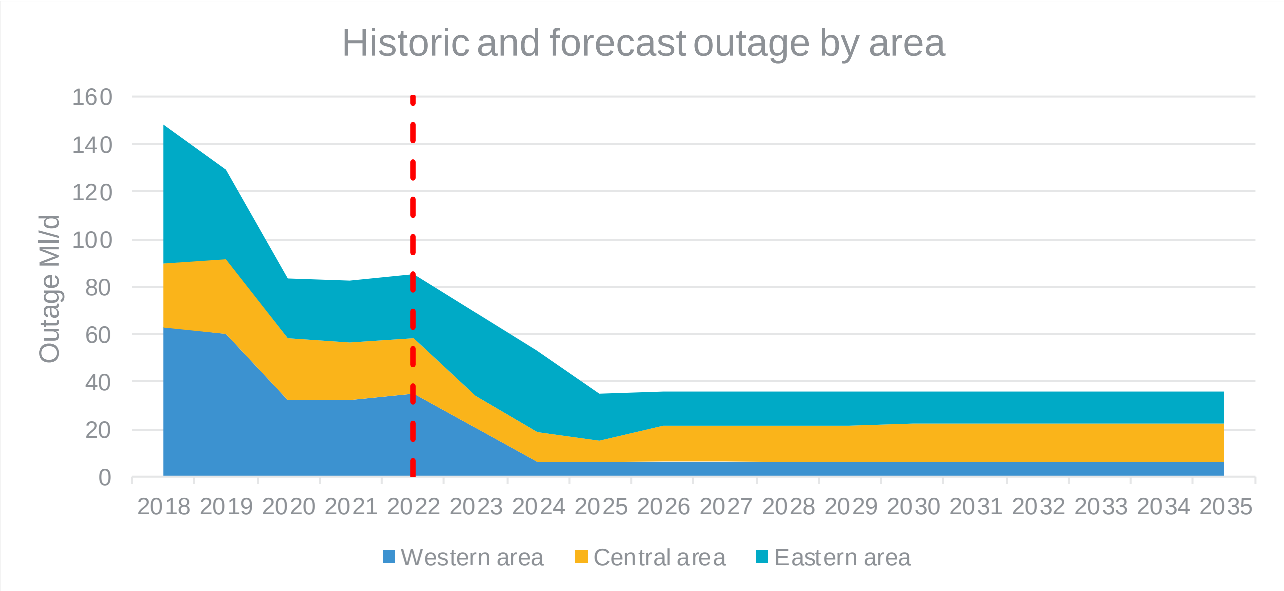



**Figure 5.1: Historic outturn (to March 2022) and forecast outage allowance figures (from April 2022) for the DYAA planning scenario by supply area**

# 6. Process losses

When we treat water, there are some limited process and operational losses. We account for these in our supply forecast. Process losses, in this context, refer to the volume of water that is recycled back into the environment between the point of abstraction from the environment, and where treated water enters the distribution network, due to water treatment processes. Typically, groundwater sources have a simpler treatment process (in some cases only chlorination is required) than surface water sources and so process losses in groundwater dominated WRZs will tend to be lower.

To calculate the process losses, we look at all our surface water and groundwater sites to estimate how much process losses they incur. Where available, we look at the difference between the volumes of water recorded on our abstraction meters against those recorded on our distribution meters to provide this information. This allows us to calculate a percentage process loss figure that can then be used at sites with similar treatment processes (e.g., groundwater) where we do not record both flows. We then validate the process loss volumes with our Process Scientists to ensure these figures are appropriate for the types of treatment technology used on each site.

The average process loss percentage for sites where data is consistent and reliable is around 5%. This assumption was applied where necessary to estimate process losses by WRZ for our WRMP19 and the same values were adopted for the ERP and this dWRMP24 submission. We are currently undertaking a further review of our process losses with our Process Scientists and will provide any amendments for the next iteration of investment modelling to update the Regional Plan. We will provide an update on any amendments to our process loss figures in our revised dWRMP24.

The estimates of process losses we have adopted in the dWRMP24 are summarised for each WRZ in Table 6.1.

**Table 6.1: Estimated process losses by WRZ.**

| WRZ | Average (Ml/d) | Peak (Ml/d) |
|---|---|---|
| HAZ | 0.13 | 0.13 |
| HKZ | 0.08 | 0.08 |
| HWZ | 0.09 | 0.09 |
| HRZ | 0.07 | 0.07 |
| HSE | 2.33 | 2.33 |
| HSW | 5.25 | 5.25 |
| IOW | 2.23 | 3.23 |
| SNZ | 1.88 | 1.14 |
| SWZ | 0.84 | 0.84 |
| SBZ | 0.52 | 0.52 |
| KME | 0.65 | 0.65 |
| KMW | 3.65 | 1.90 |
| KTZ | 0.44 | 0.44 |
| SHZ | 1.72 | 1.89 |

# 7. Water Available for Use

## 1.1.10. Water Available For Use (WAFU)

Once DO has been calculated, planning allowances ( outage, process losses etc.) and net exports are subtracted, net imports are added, to calculate the total Water Available for Use (WAFU).

In order to effectively prepare our WRMP, we need to forecast what water supplies will be available over the planning period. This is our water available for use (WAFU), which is calculated based on:

- Water available from our resources,
- Bulk imports and exports,
- Climate change,
- Sustainability reductions,
- Process losses, and
- Outage

**The WAFU chart**s at company level (Figure 7.1 Forecast Water Available for use – Situation 4 Company Level) show similar overall trends to those at an area level through the planning period.

For our Baseline Deployable Output, there are generally reductions through time in all areas as we improve our drought resilience to achieve 1 in 500 (the fall in baseline DO represents the fact that under a 1 in 500 year drought less resources are available).

Our baseline imports and exports are relatively stable through time in all areas where changes occur, this reflects the nature of our current bulk supply agreements and that some existing and new transfer options are instead included in our investment modelling as options rather than being fixed in the baseline.

We only have one, relatively small (3.02Ml/d), confirmed further licence change which has a DO impact (at Andover in our HAZ zone in 2027 – see Annex 9). However for our potential, but presently unconfirmed, licence changes which are possible through our Environmental Destination scenarios, there are significant reductions forecast through to 2050, especially for situation 4 which represents the High Environmental Destination scenario.  We are undertaking a considerable amount of environmental investigation through to 2027 to help to reduce the uncertainty around the possible magnitude of any licence changes required to achieve our environmental ambition.

Climate change presents the next largest possible reduction in WAFU, primarily the zones most vulnerable (HSE, SNZ) are also amongst the most environmentally sensitive. Hence the Western and Central area WAFU declines significantly.

The key supply side uncertainties of our adaptive plan is designed to hedge against are the loss of supply due to climate change, and the loss of supply due to licence changes (we may need to make to protect the environment). Both drivers can potentially lead to large reductions in WAFU depending on which future "situation" we progress towards. However, whilst the drivers of each change are to a large degree independent variables, i.e. the degree of climate change will not directly influence the degree of environmental protection, we must provide (though the two are indirectly related) the way that the adaptive branches are constructed. We need to be careful to avoid double counting deficits (i.e. we can't lose deployable output to climate change if that deployable output has already been lost to climate change). However, since both impacts have been calculated independently during our resource modelling, we have included DO adjustments which offset under scenarios where both climate change and environmental destination act in combination to reduce deployable output to avoid double counting, leading to greater water losses than is available to lose (i.e. leading to negative WAFU). This is most obvious in our Hampshire Southampton East and Sussex North zones both of which are highly vulnerable to climate change and at risk of needing significant licence reductions to protect the environment. Although both are expected to occur, in some combination it is likely (for the purposes of our monitoring plan) than any changes in deployable output from licence changes are likely to be primary, and most obvious cause of WAFU loss, and will proceed the loses due to climate change.

## Figure 7.1 Forecast Water Available for use – Situation 4 Company Level

## Figure 7.2 Forecast Water Available for use – Situation 4 Western Area

## Figure 7.3 Forecast Water Available for use (Ml/d) – Situation 4 Central Area

## Figure 7.4 Forecast Water Available for use (Ml/d) – Situation 4 Eastern Area

# Appendix A – Groundwater Framework Scores

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Central Area -North Sussex, 1 | 5 | 4 | 5 | 4 | 5 | 5 | Internal representation | Dynamic |
| Southern Water SWS, Central Area -Worthing, Sussex, 4 | 4 | 4 | 3 | 3 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 4 | 3 | 4 | 3 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 7 | 3 | 4 | 3 | 3 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Worthing, Sussex, 5 | 3 | 3 | 3 | 3 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Thanet, Kent, 11 | 3 | 2 | 3 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 1 | 3 | 1 | 3 | 3 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Western Area -Southampton East, Hampshire, 1 | 5 | 5 | 1 | 4 | 5 | 5 | Internal representation | Dynamic |
| Southern Water SWS, Western Area -Southampton East, Hampshire, 2 | 5 | 5 | 1 | 4 | 5 | 5 | Internal representation | Dynamic |
| Southern Water SWS, Western Area -Winchester, Hampshire, 1 | 1 | 4 | 1 | 3 | 5 | 5 | External representation - annual profile | External timeseries |
| Southern Water SWS, Central Area -Worthing, Sussex, 9 | 5 | 3 | 1 | 2 | 5 | 5 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 7 | 5 | 3 | 1 | 2 | 5 | 5 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 8 | 5 | 3 | 1 | 2 | 5 | 5 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Brighton, Sussex, 2 | 3 | 3 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Central Area -Worthing, Sussex, 10 | 3 | 3 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Thanet, Kent, 6 | 3 | 3 | 1 | 3 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Medway East, Kent, 16 | 5 | 2 | 1 | 1 | 5 | 5 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 6 | 3 | 2 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Thanet, Kent, 10 | 3 | 2 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 6 | 3 | 1 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 9 | 3 | 1 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Medway East, Kent, 14 | 3 | 1 | 1 | 2 | 5 | 5 | External representation - timeseries | External timeseries |
| Southern Water SWS, Western Area - IoW, 1 | 1 | 3 | 3 | 1 | 0 | 0 | External representation - annual profile | External timeseries |
| Southern Water SWS, Western Area - IoW, 3 | 1 | 3 | 3 | 3 | 0 | 0 | External representation - annual profile | External timeseries |
| Southern Water SWS, Eastern Area - Medway East, Kent, 2 | 1 | 2 | 3 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 1 | 2 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 7 | 2 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Western Area - IoW, 5 | 2 | 3 | 1 | 1 | 0 | 0 | External representation - annual profile | External timeseries |

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Eastern Area - Thanet, Kent, 1 | 2 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 4 | 2 | 3 | 1 | 1 | 0 | 0 | External representation - timeseries | External timeseries |
| Southern Water SWS, Eastern Area - Thanet, Kent, 7 | 2 | 3 | 1 | 3 | 0 | 0 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 10 | 1 | 3 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Brighton, Sussex, 12 | 1 | 3 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 2 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 6 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 11 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Western Area -Kingsclere, Hampshire, 1 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Winchester, Hampshire, 2 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area - IoW, 7 | 1 | 3 | 1 | 1 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 2 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 1 | 1 | 3 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 13 | 1 | 3 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Eastern Area - Medway East, Kent, 15 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 2 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 3 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 5 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 8 | 1 | 3 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 1 | 2 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 3 | 2 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 4 | 2 | 2 | 1 | 1 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Thanet, Kent, 9 | 2 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -North Sussex, 3 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Central Area -North Sussex, 4 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - annual profile | External timeseries |
| Southern Water SWS, Western Area -Andover, Hampshire, 1 | 1 | 2 | 1 | 3 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area - IoW, 2 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - annual profile | External timeseries |
| Southern Water SWS, Western Area - IoW, 4 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - annual profile | External timeseries |

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Eastern Area - Medway West, Kent, 5 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 6 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 7 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 8 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway West, Kent, 9 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 3 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 4 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 5 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 9 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 10 | 1 | 2 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 11 | 1 | 2 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Medway East, Kent, 12 | 1 | 2 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Eastern Area - Hastings, Sussex, 1 | 1 | 2 | 1 | 1 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Central Area -Brighton, Sussex, 5 | 2 | 1 | 1 | 3 | 0 | 0 | External representation - timeseries | External timeseries |

| | Prioritisation assessment | | | | | | Proposed modelling methodology | |
|---|---|---|---|---|---|---|---|---|
| Groundwater source | Criteria 1: DO constraint | Criteria 2: Conjunctive benefit | Criteria 3: Sensitivity to antecedent conditions | Criteria 4: Proportionality / threshold of benefit | Ranking (auto) | Ranking (final) | Internal/External boundary condition | Selected methodology |
| Southern Water SWS, Central Area -Brighton, Sussex, 3 | 1 | 1 | 1 | 3 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Brighton, Sussex, 8 | 1 | 1 | 1 | 3 | 0 | 0 | External representation - timeseries | External timeseries |
| Southern Water SWS, Central Area -Brighton, Sussex, 11 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 3 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -Worthing, Sussex, 8 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - timeseries | External profile |
| Southern Water SWS, Central Area -North Sussex, 2 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Kingsclere, Hampshire, 2 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Winchester, Hampshire, 3 | 1 | 1 | 1 | 1 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Rural Hampshire, 1 | 1 | 1 | 1 | 3 | 0 | 0 | External representation - single value | External timeseries |
| Southern Water SWS, Western Area -Rural Hampshire, 2 | 1 | 1 | 1 | 1 | 0 | 0 | External representation - single value | External profile |
| Southern Water SWS, Western Area - IoW, 6 | 1 | 1 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Andover, Hampshire, 2 | 1 | 0 | 1 | 2 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Andover, Hampshire, 3 | 1 | 0 | 1 | 1 | 0 | 0 | External representation - annual profile | External profile |
| Southern Water SWS, Western Area -Andover, Hampshire, 4 | 1 | 0 | 1 | 1 | 0 | 0 | External representation - annual profile | External profile |