Water Resources Management Plan 2019
Annex 5: Baseline Supply-Demand Balance

December 2019

Version 1

from Southern Water

Contents

Southern Water

1. Executive summary

This Annex sets out our baseline supply-demand balance (SDB). The baseline SDB is one of the key inputs to the plan and consists of a number of components:

- Deployable output (DO) forecast
- Demand forecast
- Impacts on DO due to climate change
- Bulk supplies
- Short term losses of supply and source vulnerability (outage)
- Operational use of water or loss of water through the abstraction-treatment process (process losses)
- Reductions in DO due to nitrate and pesticide impacts
- Modelled impacts of different sources of uncertainty, including:
  - Uncertainty in the impact of sustainability reductions
  - Uncertainty in the impact of climate change on DO
  - Uncertainty in the availability of bulk imports
  - Uncertainty in the accuracy of distribution input (DI) meters
  - Uncertainty in the accuracy of DO estimates
  - Uncertainty in the demand forecast
  - Natural annual variability in supply and demand

The structure of this Annex, and links to other Annexes, can be summarised as follows:

- The first section, “Existing imports/exports and inter-zonal transfers”, provides a summary of current bulk supply agreements
- The second section, “Water Available for Use”, summarises forecast impacts on supply due to climate change, outage, process losses, bulk supplies, sustainability reductions and nitrate and pesticide issues
- The third section, “Headroom and uncertainty”, describes the assessment of risk and uncertainty within the plan
- The final section, “Supply-demand balance”, presents the overall baseline SDBs that are used as inputs to the real options analysis
- Annex 2 provides further detail on the demand forecast
- Annex 3 provides further detail on DO and forecast impacts due to climate change, outage, process losses, sustainability reductions and nitrate and pesticide issues.

1.1 Assessment of risk and uncertainty

A ‘problem characterisation’ assessment was undertaken by the company at the start of the development of the Water Resource Management Plan (WRMP), the method for which is set out in in recent UKWIR (2016a, 2016b) guidance. This highlighted a number of complexity factors and concerns in each of the company’s supply areas, and indicated that the plan would benefit from using a more complex 'extended' decision-making approach (see Annex 1). As a result of the assessment, the company has chosen to develop a ‘fully risk based’ plan that uses a ‘real options’ analysis method to recognise risk and uncertainty, and to make appropriate 'no-regret' investments.

As part of the development of a ‘fully risk based’ plan, the baseline SDB forecast has been generated as a series of probabilistic distributions, from which Southern Water can select different percentiles to represent a range of possible futures. This represents an innovation in the company’s treatment of risk in the SDB, commensurate with the strategic challenges and uncertainties faced by the company at the present time.

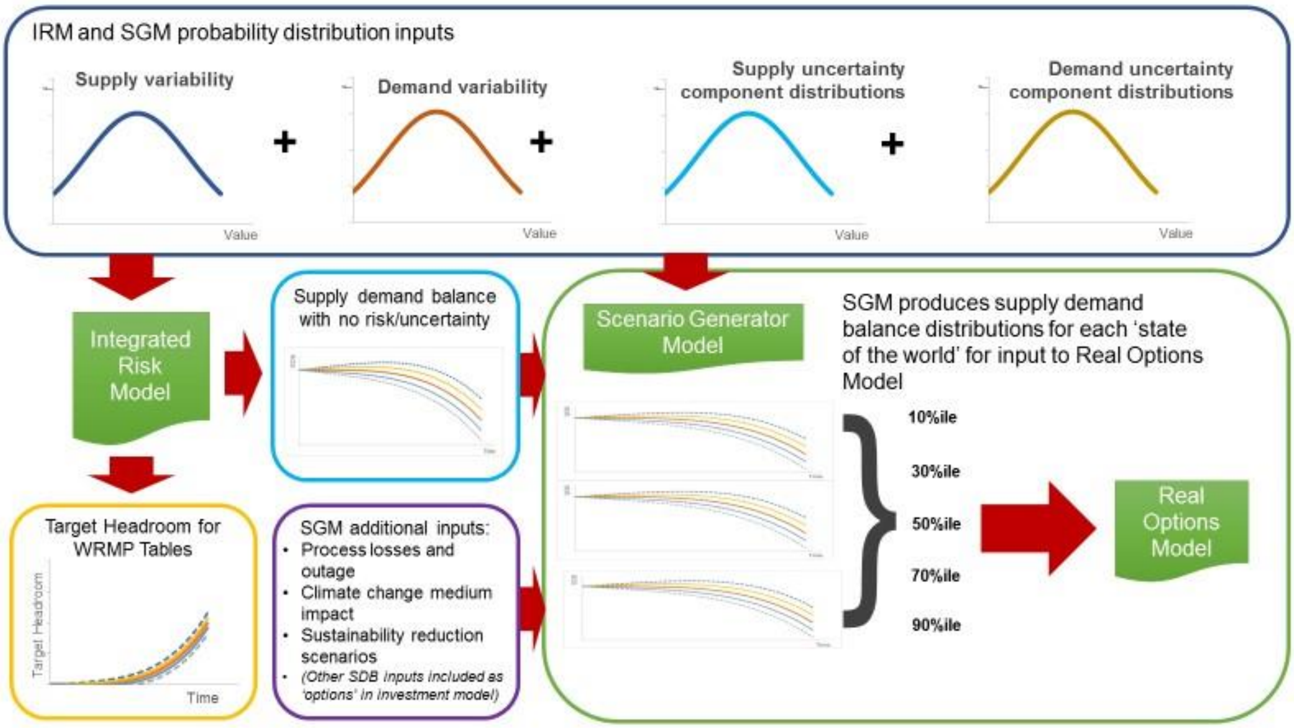
The baseline SDBs at different percentiles are used as the input to the real options decision-making model. The SDB used prior to 2027 is based on the 50th percentile. Beyond this there is a greater degree of uncertainty in the SDB and therefore the 10th, 30th, 50th, 70th and 90th percentiles are used as inputs to the real options model. This ensures that a realistic range of plausible future deficits can be planned for. Annex 8 provides further detail on how the branches have been applied in the real options model.

We have developed a two-stage modelling process to produce the baseline SDB distributions, each of which uses a Monte Carlo simulation approach. The two stages are as follows:

1. Use of Southern Water’s Monte Carlo ‘integrated risk model’ (IRM) that was developed for WRMP14 to develop an estimate of (i) target headroom (used for the WRMP tables only) and; (ii) to generate a SDB profile that takes into account the variability of supply and demand that can occur in a given year.
2. The full modelling of future uncertainty in the SDB at different levels of drought severity within a ‘scenario generator model’ (SGM). The SDB profiles that are generated by this model are used as inputs to the real options investment model, described in Annexes 6 and 8. The baseline SDB profiles are shown below.

Figure 1 below provides an overview of the headroom and uncertainty modelling process.

Figure 1 Overview of the IRM and SGM



The SGM produces an estimate of the water resource zone (WRZ)-level SDB at seven 'states of the world' across the planning period (2016-17 to 2069-70). These are as follows:

- Normal year annual average (NYAA);
- 'Drought': 1 in 20 year drought at Minimum Deployable Output (MDO) (Central and Western areas) or Average Deployable Output (ADO) (Eastern area) and Peak Deployable Output (PDO) (all areas);
- 'Severe drought': 1 in 200 year drought at MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas); and
- 'Extreme drought': 1 in 500 year drought MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas).

The definitions of the supply and demand forecasts at NYAA, MDO, ADO and PDO are summarised in Annexes 2 and 3.

For the Western area the baseline SDB was based on the assumption that the Itchen and Lower Test sustainability reductions would be implemented in the base year. For the revised draft WRMP, the baseline SDB included an additional sustainability reduction on the Itchen in 2024, which followed evidence presented by the Environment Agency (EA) in the Western area Public Inquiry from March 2018 (see below).

For the final WRMP, as instructed by Defra in its letter dated 19 March 2019, we have revised this assumption, and have instead included the uncertainty associated with this further sustainability reduction. This is consistent with the consideration of other uncertain and unconfirmed sustainability reductions in our plan, across all supply areas. This scenario is referred to within this Annex as 'Scenario A', which represents the planning conditions used for deriving the plan for the Western area,

For the draft plan on which we consulted, we had four alternative scenarios, each making different assumptions about the timing and scope of the EA's proposed licence changes (also referred to as sustainability reductions). These were defined before the Public Inquiry was held and so before the outcome of that Public Inquiry was known. This was to enable us to explore the sensitivity of the strategy to these different assumptions. Strategy A, our core strategy for the Western area, assumed the EA's proposed licence changes would be implemented in full and immediately. This was identified, during preparation of our statement of response and revised draft WRMP, as the most likely outcome. Scenarios B, C and D were considered as alternative scenarios to demonstrate the impact on option selection and the relative costs of the different solutions based on alternative licence change assumptions.

The licence changes on the Test and Itchen have now been implemented (as of March 2019), and so scenarios B, C and D serve only to show how the strategy would have looked if more time had been given to implement the sustainability reductions.

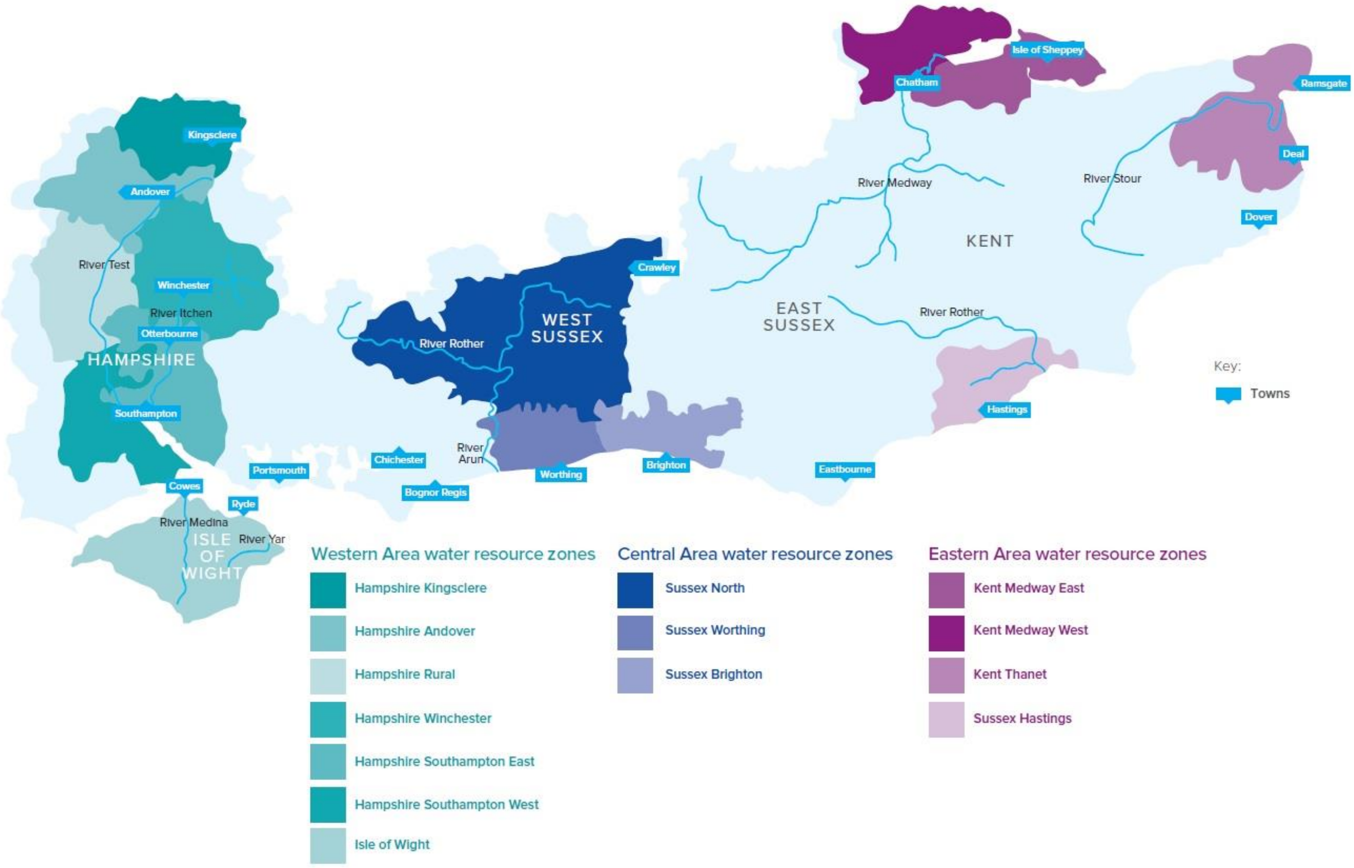
Our preferred plan in our final plan is therefore based on what was previously known as 'Strategy A' in the draft WRMP.

The additional sustainability reduction on the Itchen in 2024 is based on the outcome of the Western area Public Inquiry in March 2018. At the end of the Inquiry the EA referred in their closing statements to the prospect of further review of the proposed hands off flow conditions on the River Itchen licences at the point of intended renewal in 2024. Whilst these revisions still have to be investigated during the next AMP (2020-2025) the last independent review of the hands off flow conditions (Wilby, 2010) proposed a flow condition of 224Ml/d, which is higher than the current conditions of 198Ml/d. Therefore in order to have long-term regard to an anticipated further reduction in abstraction we have used this estimate of 224Ml/d as the potential new hands off flow condition on the River Itchen licence in order to assess the likely impact on the supply forecast post 2024. Further information is provided in Annex 9.

1.2 Baseline supply-demand balance

Our supply area is shown in Figure 2 for reference. Figure 3 to Figure 11 show the baseline SDB distributions at the 'severe drought' (1 in 200 year) level that feed into the decision-making model. The percentile bands shown in these 'plume plots' represent the likelihood that the SDB will be equal to or lower than a certain value. It should be noted that except where indicated, these do not include bulk supplies or DO write-downs due to nitrate and pesticide impacts, as these have been included within the investment model as options.

Figure 2 Map of Southern Water's supply area



1.2.1 Central area

Figure 3 and Figure 4 show the baseline SDB distribution at MDO and PDO respectively. The results show that at the 50th percentile, there is a deficit of -16.5Ml/d in 2020-21 at MDO and a surplus of 7.7Ml/d at PDO, reducing to -42.2Ml/d at MDO and -32.2Ml/d at PDO by the end of the planning period. The sharp reduction in the SDB in 2027-28 is due to the modelled impact of potential sustainability reductions.

The 50th percentile 1 in 200 year SDB is slightly lower at MDO at the start of the planning period than the equivalent WRMP14 SDB forecast for 2020-21, which was -11.2Ml/d, and slightly higher at PDO, which was -4.5Ml/d. The reduction in the forecast SDB at MDO and slight increase at PDO at the start of the planning period compared to WRMP14 is due to the net impact of a number of individual SDB components. The reasons for the changes in each component are discussed in Annexes 2 and 3.

In the Central area, the net impact of bulk supplies is positive (+9.6Ml/d) throughout the planning period at MDO and PDO. This is the same value included in the WRMP14 baseline SDB. The WRMP19 baseline SDB distribution including bulk supplies is shown in Figure 5 below. This partially reduces the deficit; however, at the 50th percentile there is still a deficit at from start of the planning period at MDO. There are several Drought Orders and Permits available to address this, although these have not been included in the baseline SDB as they are included within the feasible options set.

Figure 3 Baseline SDB distribution at the 'severe drought' level for Central area MDO

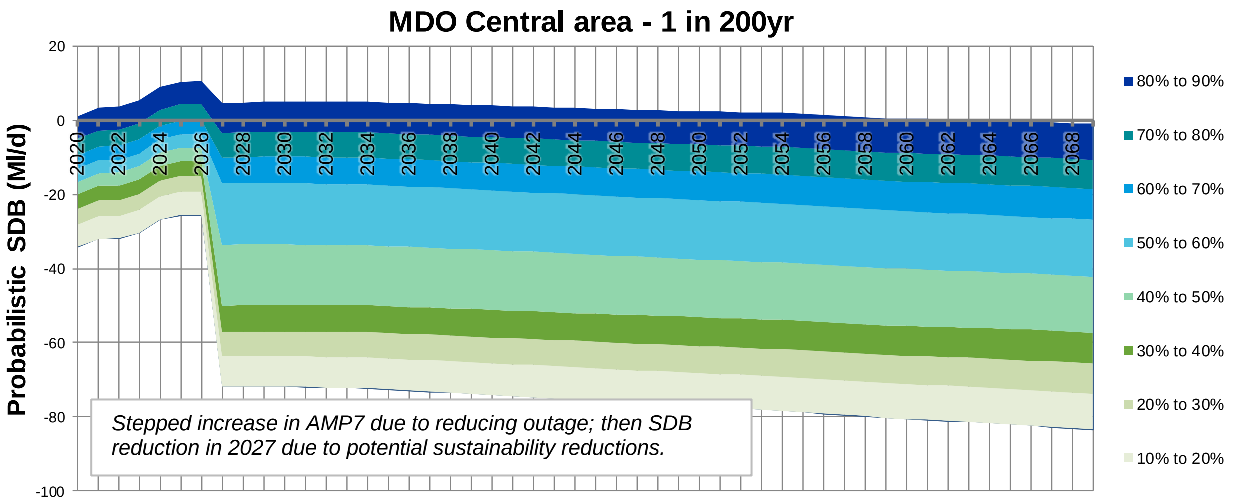


Figure 4 Baseline SDB distribution at the 'severe drought' level for Central area PDO

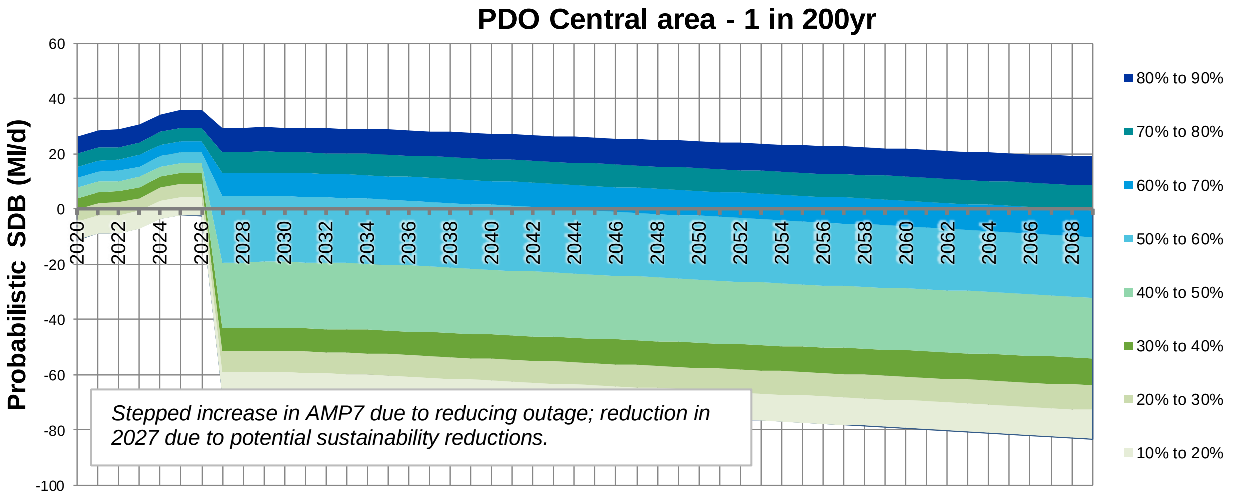
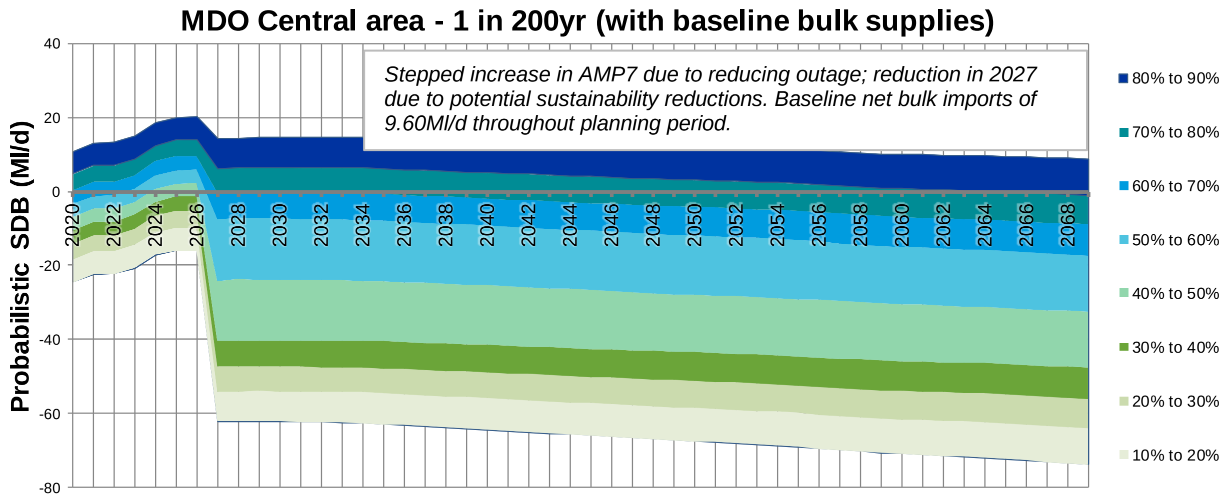


Figure 5 Baseline SDB distribution at the 'severe drought' level for Central area MDO with baseline bulk supplies



1.2.2 Eastern area

Figure 6 and Figure 7 show the baseline SDB distribution at ADO and PDO respectively. The results show that at the 50th percentile, there is a surplus of 12.6Ml/d at ADO in 2020-21, which increases until 2026-27 and then decreases until the end of the planning period, with a deficit from 2064-65. At PDO there is a surplus throughout the planning period at the 50th percentile until 2027-28, when the SDB reduces significantly due to the modelled impact of potential sustainability reductions.

The 1 in 200 year SDB is higher at the start of the planning period than the equivalent WRMP14 SDB forecast for 2020-21, which was 29.1Ml/d at ADO and 59.6Ml/d at PDO. The increase in the forecast SDB compared to WRMP14 is due to the net impact of a number of individual SDB components. The reasons for the changes in each component are discussed in Annexes 2 and 3.

In the Eastern area, the net impact of bulk supplies is negative throughout the planning period at (-27.2Ml/d at ADO and -34.7Ml/d at PDO in 2020-21). The WRMP19 baseline SDB distribution including bulk supplies is shown in Figure 8 below. This reduces the surplus such that there is a forecast deficit from 2020-21 to 2023-24 and from 2027-28 onwards at the 50th percentile at ADO.

Figure 6 Baseline SDB distribution at the 'severe drought' level for Eastern area ADO

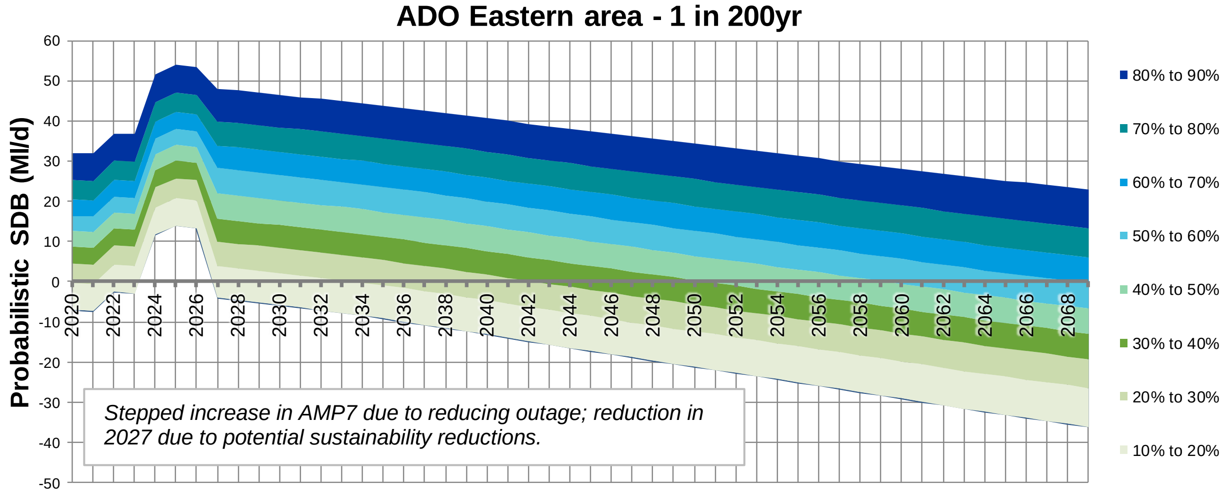


Figure 7 Baseline SDB distributions at the 'severe drought' level for Eastern area PDO

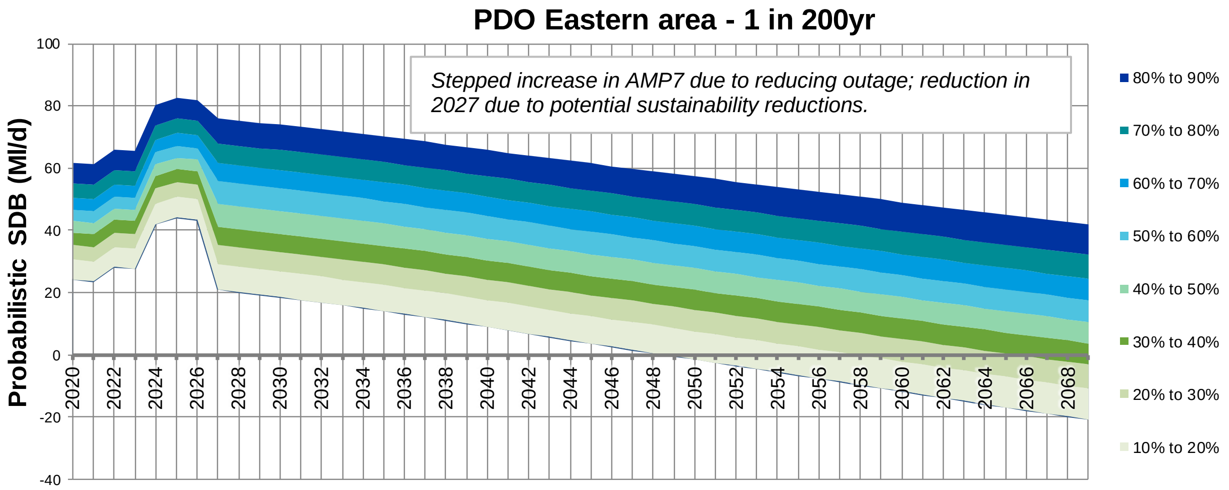
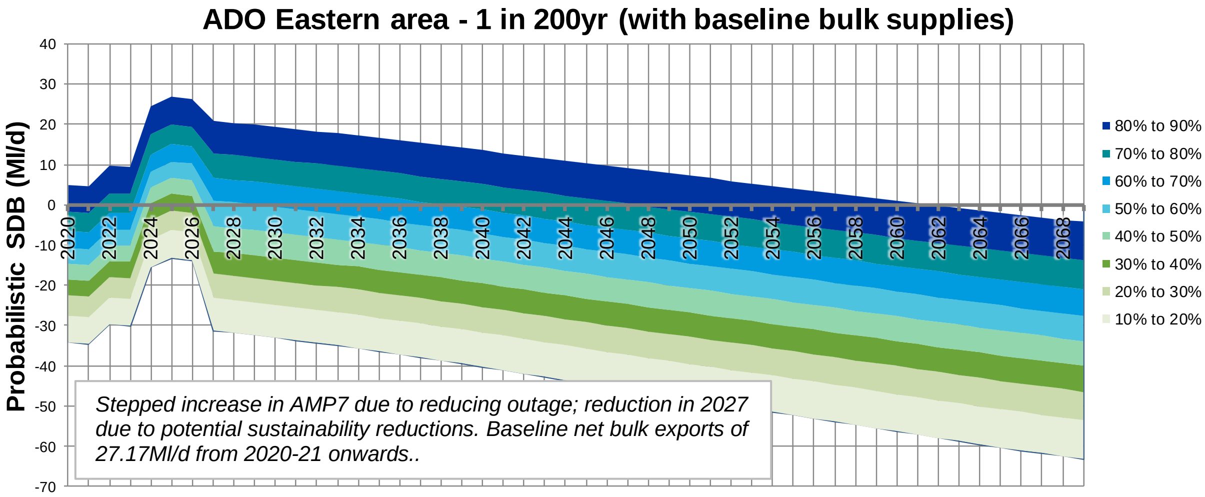


Figure 8 Baseline SDB distributions at the 'severe drought' level for Eastern area ADO with baseline bulk supplies



1.2.3 Western area

Figure 9 and Figure 10 show the baseline SDB distributions for Western area Scenario A at MDO and PDO. The results show that for the Scenario A (which now corresponds with the Section 20 Operating Agreement and licence changes), there is a deficit throughout the planning period at all percentiles at both MDO and PDO. At the 50th percentile there is a deficit of -92.7Ml/d at 2020-21 at MDO and -59.9Ml/d at PDO.

The 1 in 200 year SDB for the Scenario A is significantly lower throughout the planning period than the equivalent WRMP14 SDB forecast, which was -7.5Ml/d at ADO and -25.9Ml/d at PDO in 2020-21. The difference in the forecast SDB compared to WRMP14 is due to the net impact of a number of individual SDB components. The reasons for the changes in each component are discussed in detail in Annexes 2 and 3.

The most significant impact is from the immediate implementation of the Lower Test sustainability reduction (applied in 2019 following licence changes) under the Scenario A and a potential additional Itchen sustainability reduction in 2024-25, which were not included in the WRMP14 baseline forecast.

In the Western area, the net impact of existing bulk supplies is positive throughout the planning period (4.7Ml/d at MDO and 4.6Ml/d at PDO). The WRMP19 baseline SDB distribution including existing bulk supplies is shown in Figure 11 below for the Scenario A. This slightly reduces the deficit such that the forecast deficit at 2020-21 at the 50th percentile at MDO is -88.0Ml/d. There are several Drought Orders and Permits available to address this, although these have not been included in the baseline SDB presented in this Annex, as they are included within the feasible options set.

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Figure 9 Baseline SDB distributions at the 'severe drought' level for Western area MDO under Scenario A

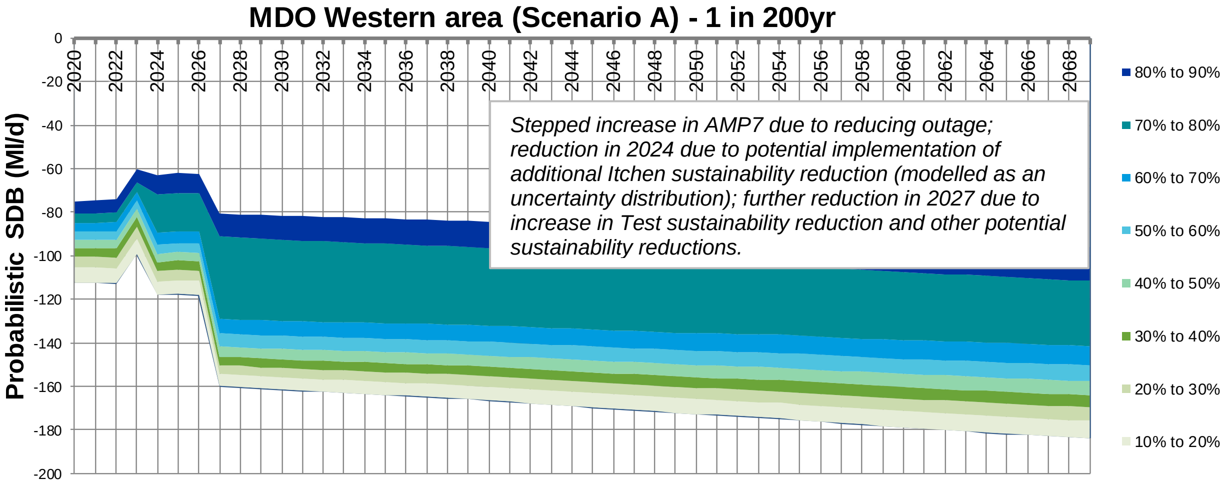


Figure 10 Baseline SDB distributions at the 'severe drought' level for Western area PDO under Scenario A

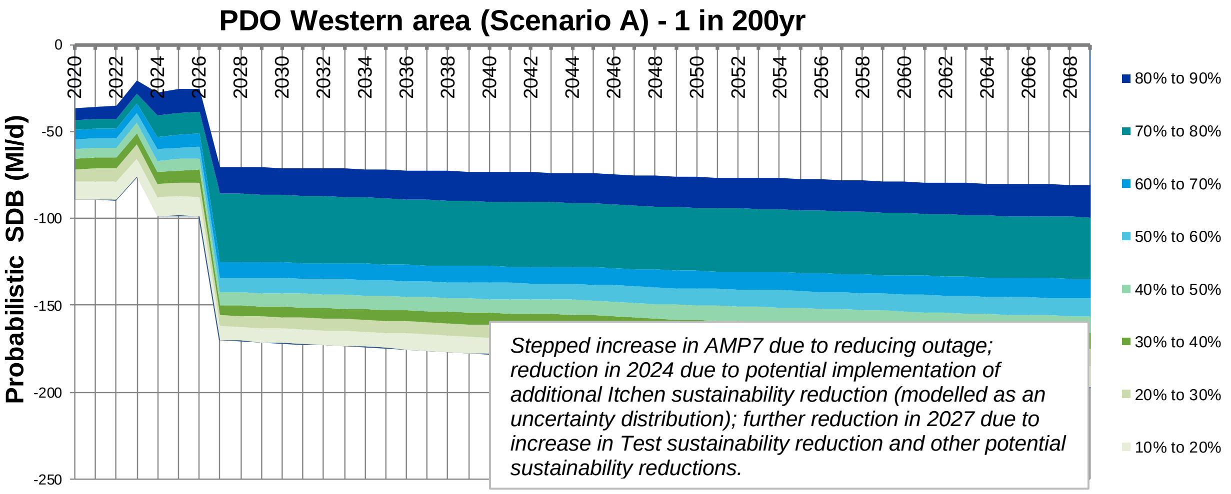
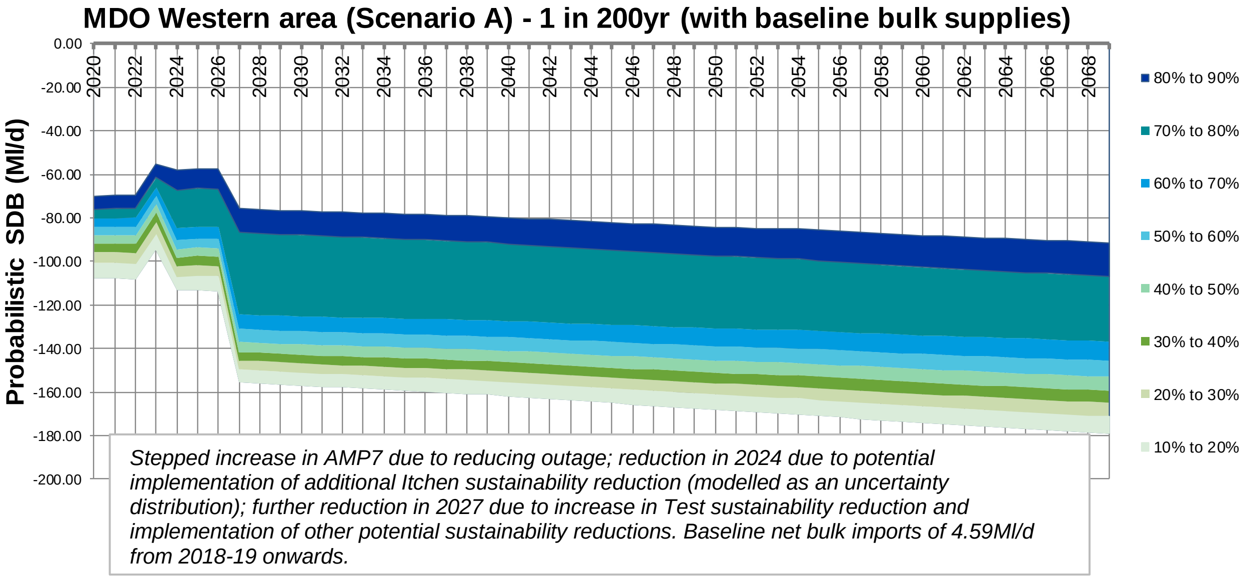


Figure 11 Baseline SDB distributions at the 'severe drought' level for Western area MDO under Scenario A with baseline bulk supplies



2. Existing imports/exports and inter-zonal transfers

This section summarises Southern Water's existing bulk supply agreements with neighbouring water companies that cover bulk imports and exports. The terms and conditions of these bulk supplies are set out in bulk supply agreements with those companies. Table 1 provides a summary of the bulk supply agreements and inter-zonal transfers included in the investment model.

Table 1 does not include additional options for bulk imports from neighbouring companies, which are instead considered as part of the options appraisal and investment modelling process for the WRMP. Bulk supply and inter-zonal transfer options that are selected by the investment model feed into the final plan supply-demand balance (SDB) for the WRMP.

The following notes are relevant to Table 1 below:

- Export volumes/capacities are shown as negative values; import volumes/capacities are shown as positive
- "(cap)" designates that the value is the total capacity of the transfer. The utilisation of the transfer capacity will be set to minimise any deficits and is carried out in the investment model

Our supply area is shown in Figure 12 below for reference.

Figure 12 Map of Southern Water's supply area

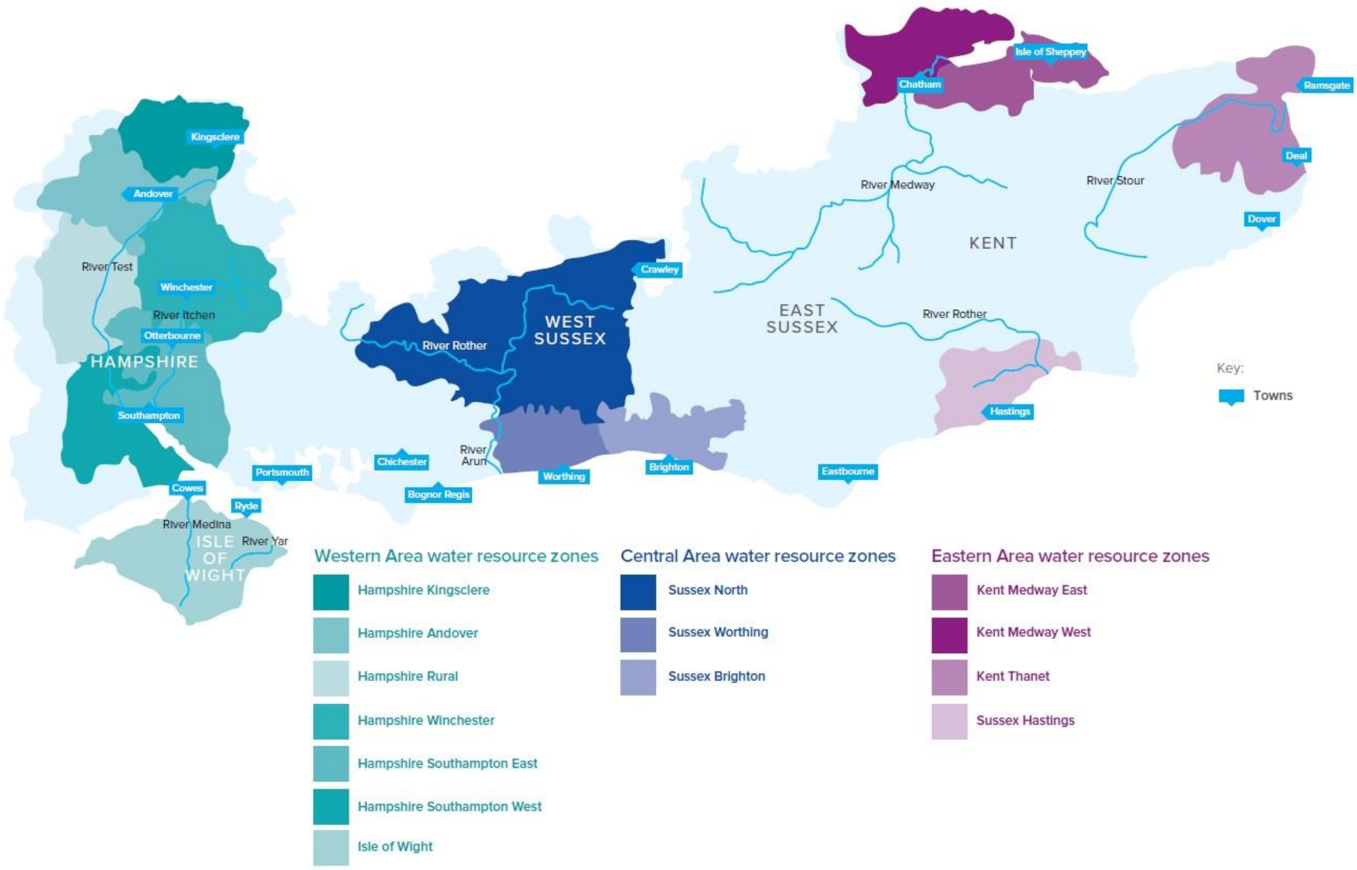


Table 1 Detailed summary table of current bulk supplies (external) and inter-zonal transfers (internal) by water resource zone (WRZ) (HA = Hampshire Andover; HR = Hampshire Rural; HSE = Hampshire Southampton East; HSW = Hampshire Southampton West; IoW = Isle of Wight; SN = Sussex North; SW = Sussex Worthing; SB = Sussex Brighton; KME = Kent Medway East; KMW = Kent Medway West; KT = Kent Thanet; SH = Sussex Hastings)

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
	Western area					
HSW	Export to Esso	-10.0	-10.0	-10.0	Contract ends in 2027, although assume contract extension to end of planning period	Contract in place since AMP5. In the event of a drought, the company would hold discussions with major customers with regards to the resources position and their supply.
HSW to HSE	*Internal*: Current transfers from Southampton West to East	24.0 (cap)	24.0 (cap)	24.0 (cap)	Throughout the planning period	Values are for operational capacity of transfer. The investment model optimises the volume of water transferred. Combines several separate inter-zonal transfers for investment modelling purposes.
HSW to IoW	*Internal*: Cross-Solent main export to IoW	18.0 (cap)	18.0 (cap)	18.0 (cap)	Throughout the planning period	Values are for assumed operational capacity of transfer at end of AMP6. Investment model optimises the volume of water transferred. Constraint is on one specific main. Cross-Solent pipeline has theoretical capacity of 25Ml/d, so there is an option to improve infrastructure to allow full utilisation of this capacity.
HSW to HR	*Internal*: Romsey Town & Broadlands valve (bi-directional)	3.1 (cap)	3.1 (cap)	3.1 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred. This is bi-directional.
HR to HSW	*Internal*: Romsey Town & Broadlands valve (bi-directional)	3.1 (cap)	3.1 (cap)	3.1 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred. This is bi-directional.
HR to HSE	*Internal*: Abbotswood	1.1 (cap)	1.1 (cap)	1.1 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred.
HSE to HW	*Internal*: Winchester South West	7.5 (cap)	7.5 (cap)	7.5 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred.
HSE	Import from Portsmouth Water	15.0 (assume 7.5 in	15.0 (assume 7.5 in	15.0 (assume 7.5 in	From 2017-18 through the planning period	New import from Portsmouth Water to Southern Water at Moor Hill reservoir. Availability of this bulk supply was confirmed by Portsmouth Water during discussions in

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
		extreme drought)**	extreme drought)**	extreme drought)**		AMP5. Portsmouth Water confirmed that their forecast surplus was sufficient to provide this bulk supply without the need for additional resource developments. It is assumed that the bulk supply could be at risk in an extreme (1 in 500 yr) drought event, unless supported by Drought Order for Itchen.
HA	Export to Wessex Water near Andover	-0.41	-0.31	-0.33	Throughout the planning period	The volume of the transfer reflects the take over recent years. In the event of a drought we would discuss with Wessex Water the relative resource position in the Hampshire Andover WRZ and agree what action is required to mitigate the impact of the drought.
	Central area					
SN	Import from Portsmouth Water at Pulborough	15.0 (assume 7.5 in extreme drought)**	15.0 (assume 7.5 in extreme drought)**	15.0 (assume 7.5 in extreme drought)**	From 2016-17 to 2026-27	Southern Water would seek to maximise its import from Portsmouth Water during a drought event, subject to the terms of the contract. Alternatively, Portsmouth may seek to reduce it. This reflects the different impacts that a drought of different severity or duration can have on different supply areas which have different mixes of water sources and demand pressures. As a drought situation develops the companies hold regular discussions to agree the volumes of bulk supplies. There is no pain share clause; upon entering a drought the companies would open up dialogue to agree the approach that would be taken. There is uncertainty with regards to the availability of the bulk supply in an extreme (1 in 500 yr) drought event.
SN	Export to South East Water from Weir Wood	-5.4 (assume -1.9 in extreme drought)***	-5.4 (assume -1.9 in extreme drought)***	-5.4 (assume -1.9 in extreme drought)***	From 2015-16 to 2020-21	The agreed contractual volume in the WRMP is 5.4Ml/d for the average day and peak day condition. However, during drought periods, the volumes will be the subject of the process stated below. No pain share clause; companies must operate in a reasonable manner, typically when the company(ies) enters a drought, a dialogue will take place between the donor/recipient companies as to the operation of the transfer. It is assumed that there would be a reduction in export volume during an extreme drought event.

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
						A renewal of this agreement is currently being renegotiated between SEW and SWS and is due to be complete by March 2020.
SN to SW	*Internal*: Bi-directional transfer between SN & SW	15.0 (cap)	15.0 (cap)	15.0 (cap)	Throughout the planning period	Rock Road bi-directional transfer. Values are for capacity of transfer. Investment model optimises the volume of water transferred.
SW to SN	*Internal*: Bi-directional transfer between SN & SW	15.0 (cap)	15.0 (cap)	15.0 (cap)	Throughout the planning period	Rock Road bi-directional transfer. Values are for capacity of transfer. Investment model optimises the volume of water transferred.
SW to SB	*Internal*: Export to SB at v6 valve	17.0 (cap)	17.0 (cap)	17.0 (cap)	Throughout the planning period	Trunk main (“v6”). Values are for capacity of transfer. Investment model optimises the volume of water transferred.
SW to SB	*Internal*: Additional capacity in v6 valve trunk main (SW to SB)	13.0 (cap)	13.0 (cap)	13.0 (cap)	From 2026-27 onwards	V6 (Worthing to Brighton) is has a maximum capacity of 21.6Ml/d at peak and this is limited by the head of Tenants Hill WSR. The plan is to install a bi-directional booster to allow more water (30Ml/d) to be moved in either direction along with localised mains reinforcements. This investment is currently planned for completion in 2026-27.
SB to SW	*Internal*: Reversing the v6 main (SB to SW)	30.0 (cap)	30.0 (cap)	30.0 (cap)	From 2026-27 onwards	
SW	Import from Portsmouth Water via North Arundel rather than Pulborough*	0	0	0	Throughout the planning period	Resilience option only: There is a bulk supply agreement from Portsmouth Water (15Ml/d, generally supplies Pulborough, when used), which can be brought into the WRZ directly at North Arundel, but this is intended only for use in extreme conditions – ie modelling suggests that DO failures occur in either SN or SB, not SW; this capability would therefore only be required during outage events and not under normal system operation. If transfer were used it would mean that the 15Ml/d import to SN from Portsmouth Water was not available. Instead the import to North Arundel could be up to 8Ml/d, but the DO at North Arundel (4Ml/d) would itself be lost. Furthermore, the remaining 7Ml/d of the total 15Ml/d Portsmouth Water import would not then be achievable to Pulborough – only around 2-3Ml/d would likely be achievable. Therefore, there is little net gain from this transfer as it

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
						would result in the loss of most of South Arundel and North Arundel sources. This is why it would be considered as a resilience option only to provide the company with flexibility. There is no pain share clause; upon entering a drought the companies would open up dialogue to agree the approach that would be taken.
	Eastern area					
SH	To South East Water at Darwell	-12.0	-8.0	-8.0	From 2015-16 to <u>2024-25</u>	Under the terms of the contract South East Water is permitted to abstract up to 8Ml/d over any rolling 28 day period and up to 12Ml/d during any period as long as it does not exceed the condition above. South East Water will aim to take only 8Ml/d in the peak period; however, because the contract allows abstraction of up to 12Ml/d we have included the full volume in our peak scenarios for this interim period to the end of AMP7. The abstraction takes place from the Darwell reservoir. Pain share clause in contract: the yield of the enhanced Bewl-Darwell transfer scheme is split between the two companies such that Southern Water are entitled to 9/17ths of the transfer and SEW 8/17ths of the transfer. For the purposes of the WRMP we have aimed to honour the full bulk supply contract volumes (referred to above) in the 1 in 500 extreme drought scenario for the AMP7 period. However, for the purposes of our respective drought plans we had previously agreed with South East Water to assume a limit of 4Ml/d in extreme droughts. We will review this assumption as we update our respective drought plans during 2020. There is intention to alter the Bewl-Darwell transfer to remove the risk of transfer of invasive species into Darwell but the transfer into Darwell is to be maintained until 2025 when South East Water will implement an alternative.
KME to SH	*Internal*: Bewl-Darwell transfer	35.0 (cap)	35.0 (cap)	35.0 (cap)	Bewl-Darwell transfer may be impacted by WFD	Optimised using the Aquator water resources model to look at the combined system DO of the reservoirs. Note

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
	From 2023-24 this will become the Bewl to Rye / Beauport transfer*	As part of DO only	As part of DO only	As part of DO only	driver to reduce risk of invasive species transfer in AMP7 or AMP8.	that there is a Water Framework Directive (WFD) driver to change this transfer to prevent the risk of invasive species transfer. From 2025 this transfer will instead go from Bewl to Beauport and Rye WSWs rather than Darwell reservoir.
KM	Export to South East Water*	0	0	0	No longer required	There is no specific contract for this small supply which is covered under the general terms and conditions of the licence conditions. No pain share clause; companies must operate in a reasonable manner, typically when the company(ies) enters a drought, a dialogue will take place between the donor/recipient companies as to the operation of the transfer. This supply is no longer required at South East Water's request (required for emergency use only), so is a potential resilience option for South East Water only.
KMW	Export to South East Water	-0.5	-0.1	-0.1	Throughout the planning period	There is no specific contract for this small supply which is covered under the general terms and conditions of the licence conditions. No pain share clause; companies must operate in a reasonable manner, typically when the company(ies) enters a drought, a dialogue will take place between the donor/recipient companies as to the operation of the transfer.
KMW	Export to South East Water at Bewl Water reservoir; and Export to South East Water at WSW near Rochester	-18.80 (combine d Bewl & near Rochester export). (no change in extreme drought) DO includes planned	-12.30 (combine d Bewl & near Rochester export). (-11.03 in extreme drought) DO includes planned capacity	-12.30 (combine d Bewl & near Rochester export). (-11.03 in extreme drought) DO includes planned capacity	Throughout the planning period.	Under the terms of the River Medway Scheme agreement, South East Water can take their entitlement at Bewl Water and a WSW near Rochester. The maximum volume of water that South East Water can take at Bewl Water is governed by the abstraction licence which was issued to Southern Water. The relevant maximum volumes are 4750Ml/a and 20Ml/d. The overall amount available to South East Water from the supplies at Bewl and near Rochester is defined as 25% of the yield of the River Medway Scheme (RMS). The yield is the DO calculated for WRMP19 and subsequently shared with South East Water. As a drought situation develops the companies hold regular discussions to agree any restrictions or concessions for bulk supplies. The nature

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
		capacity increase at WSW near Rochester will provide additional 3.8	increase at WSW near Rochester will provide additional 2.2 (up to 1 in 20 year drought only)	increase at WSW near Rochester will provide additional 2.2 (up to 1 in 20 year drought only)		of the bulk supply will depend on how both companies are affected by any given drought. There is no pain share clause; companies must operate in a reasonable manner, typically when the company(ies) enters a drought, a dialogue will take place between the donor/recipient companies as to the operation of the transfer. It has been assumed that the extreme drought event DO will be used to derive South East Water's potential take – also at 25% of total DO in 1 in 500 yr drought. Planned works to increase capacity at a WSW near Rochester in early AMP7 will provide additional peak supply to South East Water.
KME	Export to South East Water at Sheldwich	-7.39 (no change in extreme drought)	-6.80 (no change in extreme drought)	-6.80 (no change in extreme drought)	Throughout the planning period	As part of the Sheldwich scheme, South East Water can take its entitlement at Hartlip. There is also the provision for South East Water to pump water into the Eastling main in one location and take water out at another. However, the net maximum daily and annual average volumes that South East Water is entitled to remain the original volumes given in the Sheldwich scheme agreement. No pain share clause, companies must operate in a reasonable manner, typically when the company(ies) enters a drought, a dialogue will take place between the donor/recipient companies as to the operation of the transfer. It is assumed that there is no change in export volume under extreme drought conditions.
KME to KT	*Internal*: Faversham4-Fleet main transfer	14.0 (cap)	14.0 (cap)	14.0 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred. Although the main capacity is actually 22Ml/d, the amount of water that could be transferred to KT is limited to the DO of the Faversham4 source.
KMW to KME	*Internal*: Current transfers from KMW to KME	44.7 (cap)	44.7 (cap)	44.7 (cap)	Throughout the planning period	Values are for operational capacity of transfer. Investment model optimises the volume of water transferred. Combines several separate inter-zonal transfers for investment modelling purposes: Chatham

WRZ	Name of bulk supply	Volume (or capacity) (Ml/d)			Time constraints	Description
		Peak	MDO	ADO		
						West WBS to Borstal, and Chatham West WBS to Woolmans Wood.
KT	Export to Affinity Water at Deal	-0.07	-0.07	-0.07	Throughout the planning period	Agreed with Affinity in AMP6. Figures from 2025-26 onwards have been updated for the final plan as confirmed in discussions between the company and Affinity Water.
KT	Import from Affinity Water near Dover	0.1	0.1	0.1	Throughout the planning period	There is no specific contract for this small supply which is covered under our general terms and conditions of licence conditions.

*Resilience option / tentative supply

**This are assumed to reduce by 50% to 7.5Ml/d under the extreme drought states of the world to reflect uncertainty in what Portsmouth Water would be able to supply in extreme droughts – e.g. whether there may be reduced abstractions or the need for drought orders relating to Portsmouth Water's Lower Itchen abstraction, and consequently their ability to provide a full supply to us

***Based on assumed maximum DO available under the 1 in 500 year extreme drought scenario.

3. Water Available for Use

This section presents the company's baseline Water Available for Use (WAFU). WAFU is defined within the Technical Water Resources Planning Guidelines (Environment Agency and Natural Resources Wales, 2016) as the combined total of:

- Deployable output (DO)
- Future changes to DO from sustainability changes, climate change and any other changes
- Transfers and any future inputs from third parties
- Short term losses of supply and source vulnerability known as outage
- Any operational use of water or loss of water through the abstraction-treatment process

The WAFU at the start and end of the planning period for each of our three supply areas during a 1 in 200 year drought is shown in Figure 13 to Figure 24 below.

There are several aspects to note:

- The DO write-downs are the result of forecast nitrate and pesticide impacts on sources of supply
- Three different climate change scenarios were used in the uncertainty modelling process (see Annex 3 for further details): 'dry', 'medium', and 'wet'. These are calculated for each individual water resource zone (WRZ), and are expressed as a change in DO. The medium scenario is considered to represent the most likely impact on DO, whilst the 'dry' and 'wet' scenarios represent the 90th and 10th percentiles of the distribution of UKCP09 scenario impacts respectively. The figures below show the 'medium' impact. Where this is positive, this means that under the medium climate change scenario there is a gain in water
- Three sustainability reduction scenarios, which we have called 'cases', have been developed for this plan ('Lower', 'Middle' and 'Upper'). The sustainability reductions shown in this section are those that are in the Lower case only (i.e. the confirmed sustainability reductions on the Itchen and Lower Test). The assumptions used to develop the three cases are covered in the Headroom and Uncertainty section (4) below
- For the Western area the baseline supply forecast was based on the assumption that the Itchen and Lower Test sustainability reductions would be implemented in 2017. For the revised draft WRMP, the baseline SDB included an additional sustainability reduction on the Itchen in 2024, based on the outcome of the Public Inquiry in March 2018

- For the final WRMP, as instructed by Defra in its letter dated 19 March 2019, we have revised this assumption, and have instead included the uncertainty associated with this further sustainability reduction. This is consistent with the consideration of other uncertain and unconfirmed sustainability reductions in our plan, across all supply areas. We have called this 'Scenario A', which represents the planning conditions used for deriving the plan for the Western area. This was developed prior to the Public Inquiry on the Test, Itchen and Candover abstraction licences, the Section 20 Operating Agreement and the licence changes, and provides consistent terminology between the draft and final WRMPs. Scenarios B, C and D were considered as alternatives to demonstrate the impact on option selection and the relative costs of the different solutions of alternative licence change assumptions. These have been retained in Annex 9 only for the purposes of scenario testing of the preferred plan

The additional sustainability reduction on the Itchen in 2024 is based on the outcome of the Western Public Inquiry in March 2018. At the end of the Inquiry the Environment Agency (EA) referred to in their closing statements, the prospect of further review of the proposed hands off flow conditions on the River Itchen licences at the point of intended renewal in 2024. Whilst these revisions still have to be investigated during the next AMP (2020-2025) the last independent review of the hands off flow conditions (Wilby, 2010) proposed a flow condition of 224Ml/d, which is higher than the current conditions of 198Ml/d. Therefore in order to have long-term regard to an anticipated further reduction in abstraction we have used this estimate of 224Ml/d as the potential new hands off flow condition on the river Itchen licence in order to assess the likely impact on the supply forecast post 2024. Further information is provided in Annex 9.

3.1 Central area

Figure 13 and Figure 14 show the WAFU available at the start of the planning period (2020-21) in the Central area at MDO and PDO. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage and process losses equates to a reduction in WAFU compared to DO of 8.3Ml/d at MDO and 14.8Ml/d at PDO in 2020-21.

Figure 15 and Figure 16 show the WAFU available at the end of the planning period (2069-70) in the Central area at MDO and PDO. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage and process losses equates to a reduction in WAFU compared to DO of 21.7Ml/d at MDO and 34.0Ml/d at PDO in 2069-70.

Figure 13 WAFU in the Central area at the start of the planning period for a 1 in 200 year drought at MDO

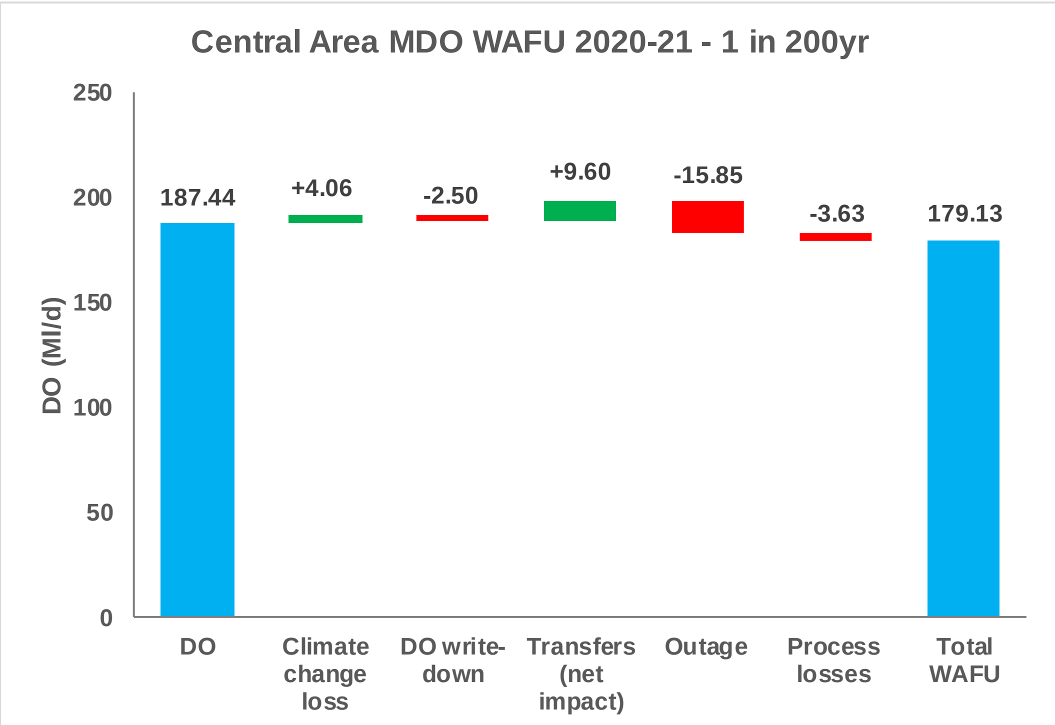


Figure 14 WAFU in the Central area at the start of the planning period for a 1 in 200 year drought at PDO

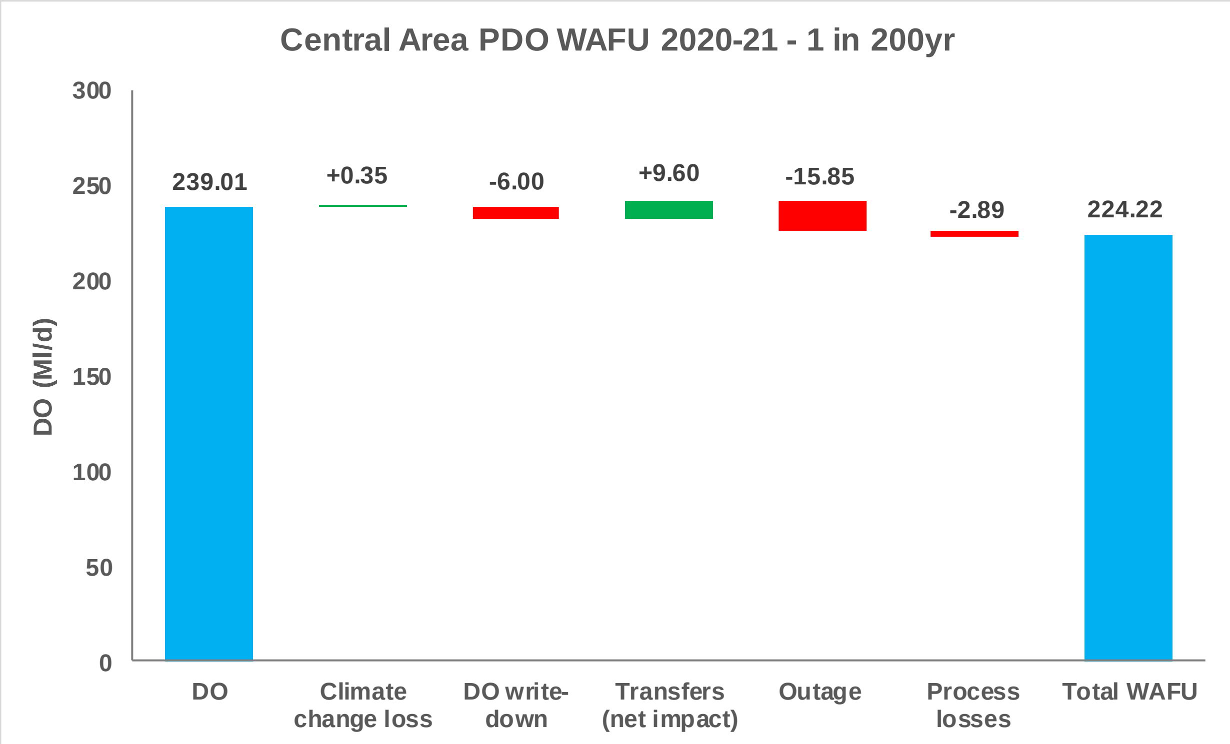


Figure 15 WAFU in the Central area at the end of the planning period for a 1 in 200 year drought at MDO

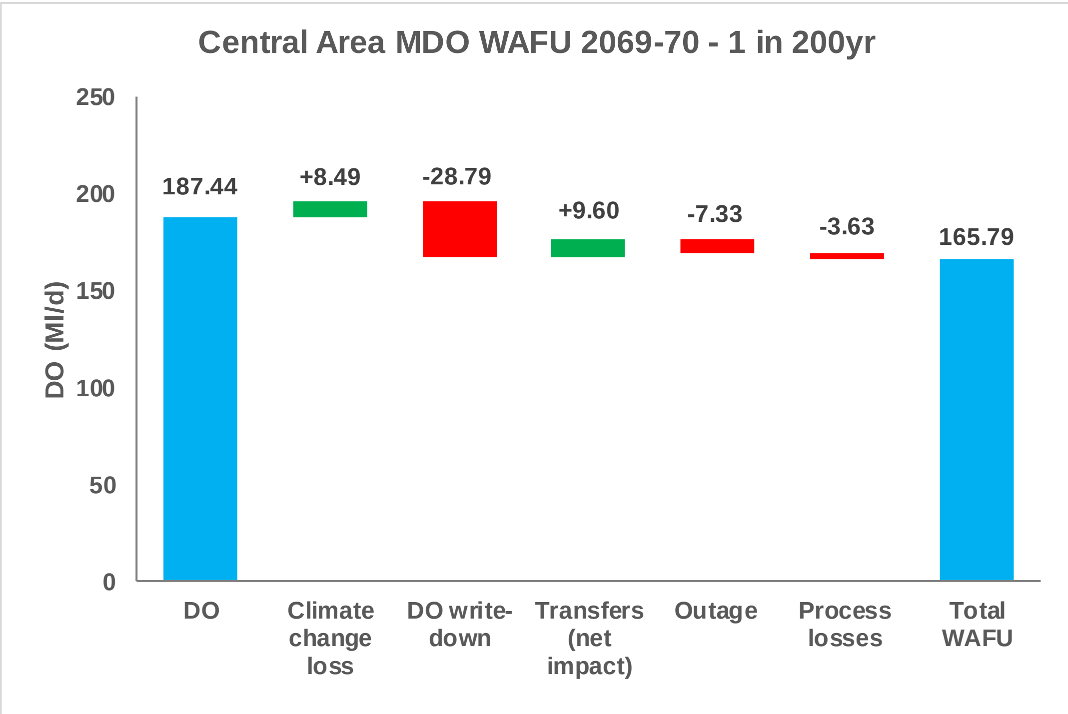
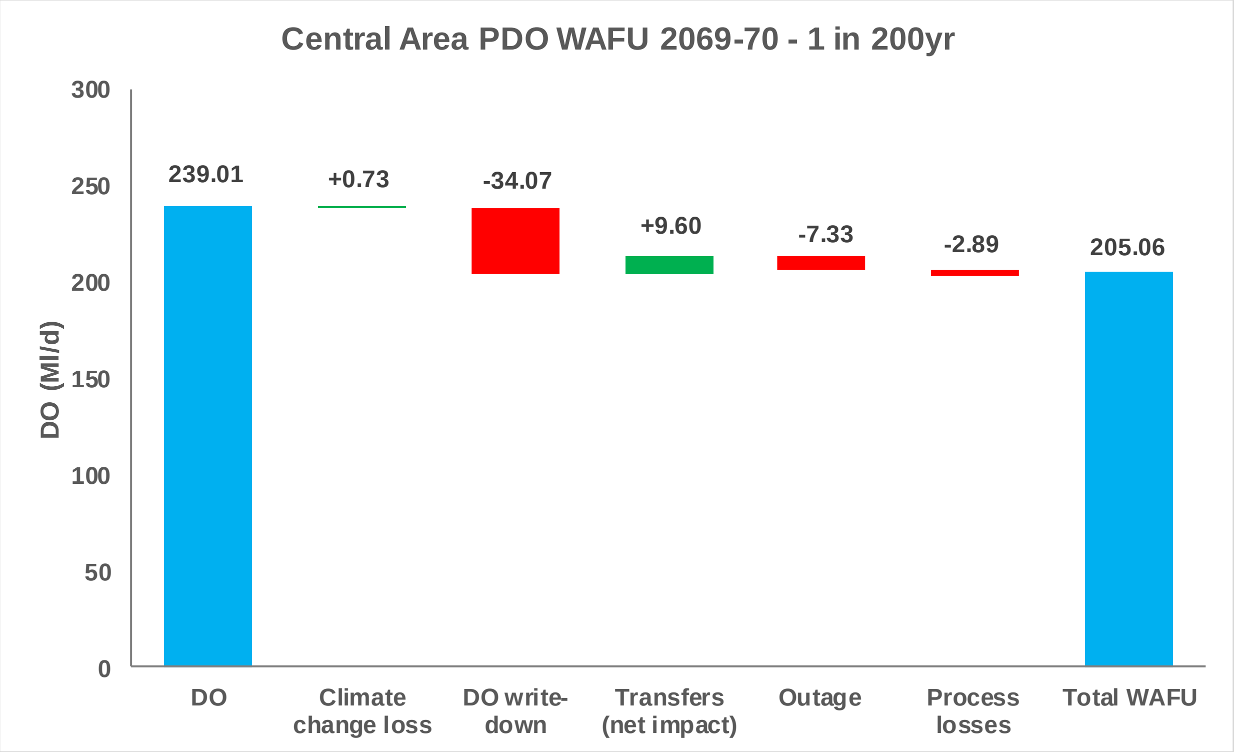


Figure 16 WAFU in the Central area at the end of the planning period for a 1 in 200 year drought at PDO



3.2 Eastern area

Figure 17 and Figure 18 show the WAFU available at the start of the planning period (2020-21) in the Eastern area at ADO and PDO. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage and process losses equates to a reduction in WAFU compared to DO of 73.6Ml/d at ADO and 84.1Ml/d at PDO in 2020-21.

Figure 19 and Figure 20 show the WAFU available at the end of the planning period (2069-70) in the Eastern area at ADO and PDO. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage and process losses equates to a reduction in WAFU compared to DO of 95.3Ml/d at ADO and 100.5Ml/d at PDO in 2069-70.

Figure 17 WAFU in the Eastern area at the start of the planning period for a 1 in 200 year drought at ADO

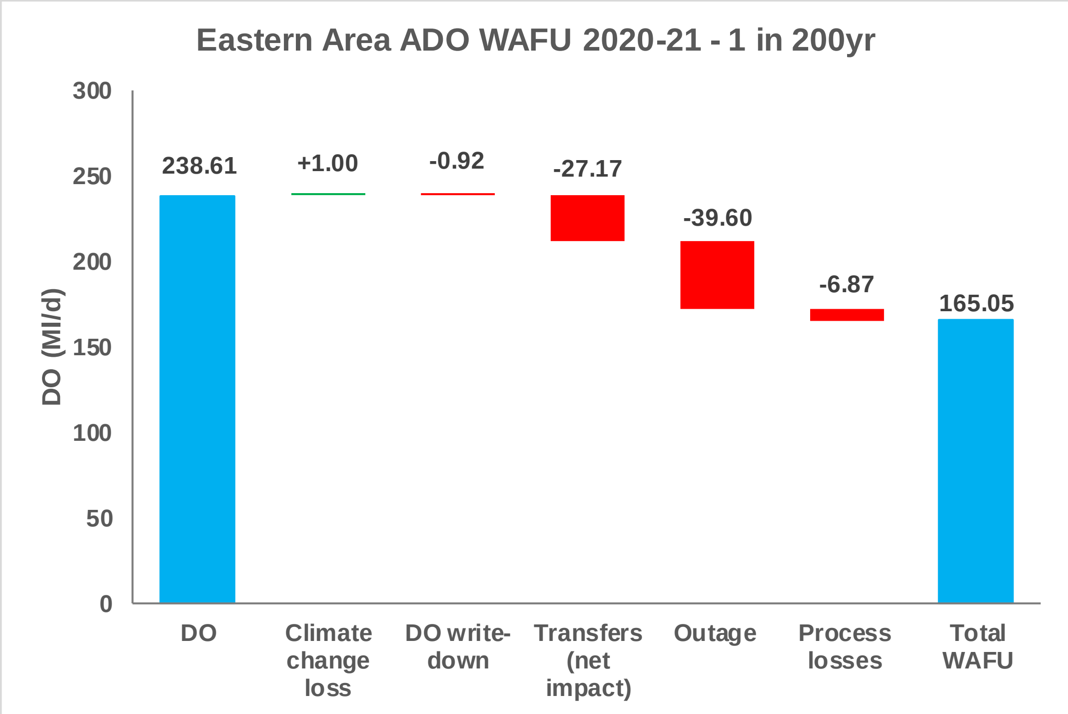


Figure 18 WAFU in the Eastern area at the start of the planning period for a 1 in 200 year drought at PDO

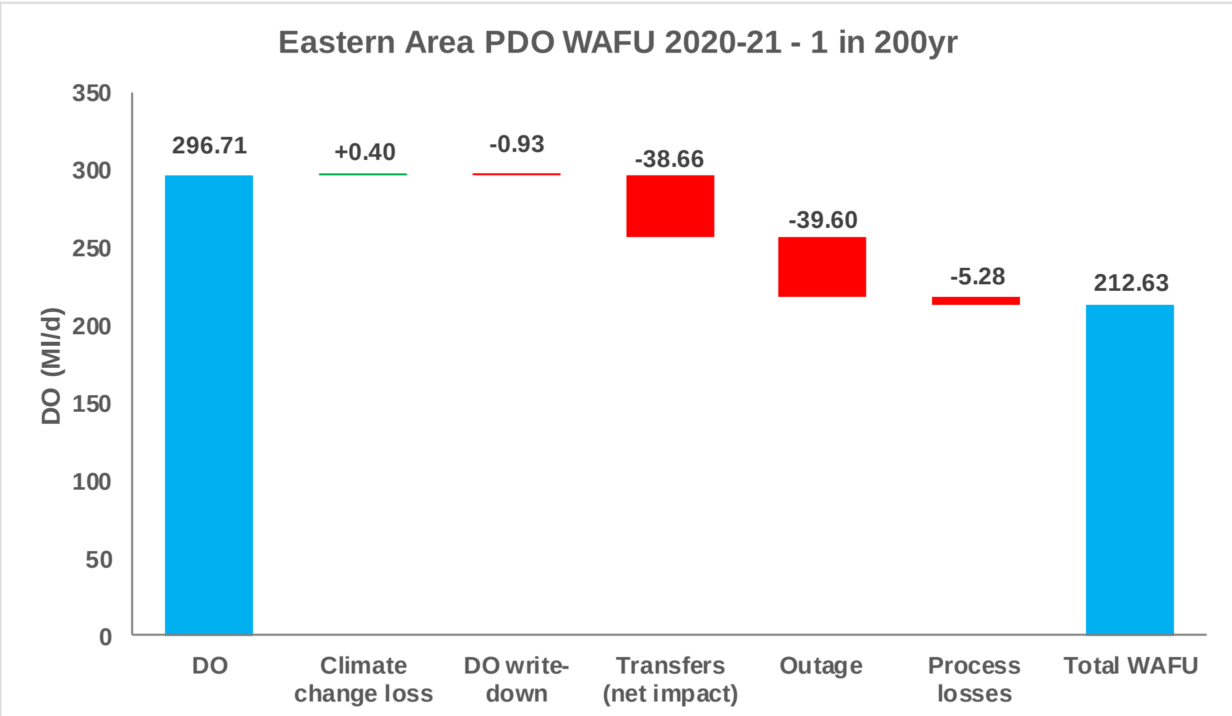


Figure 19 WAFU in the Eastern area at the end of the planning period for a 1 in 200 year drought at ADO

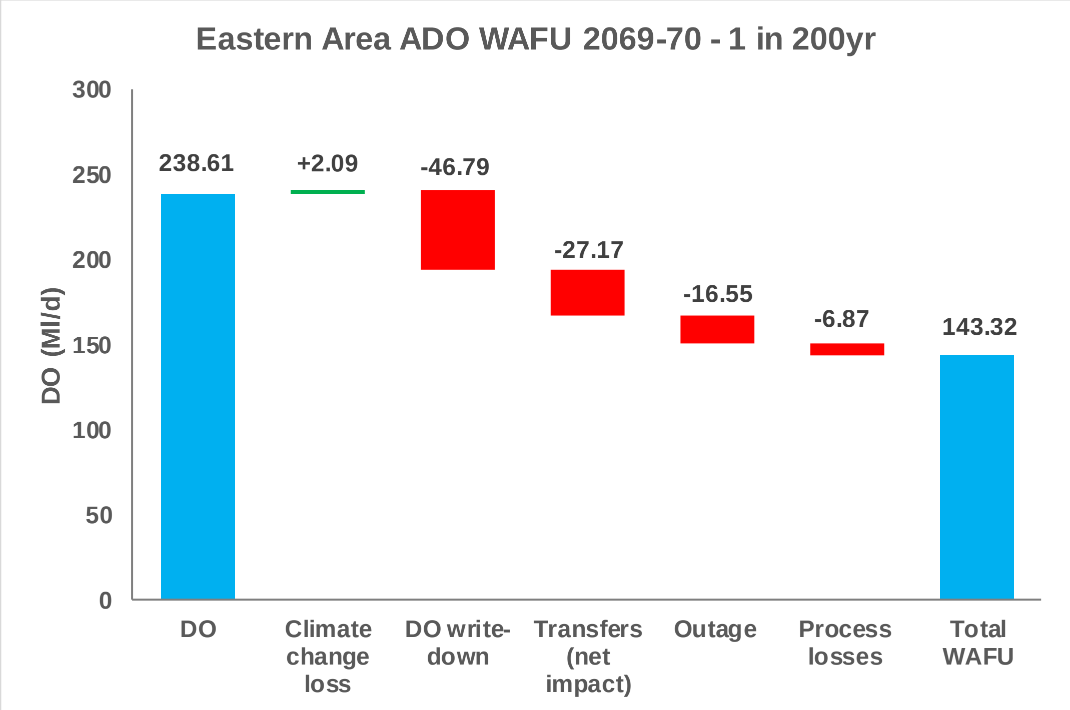
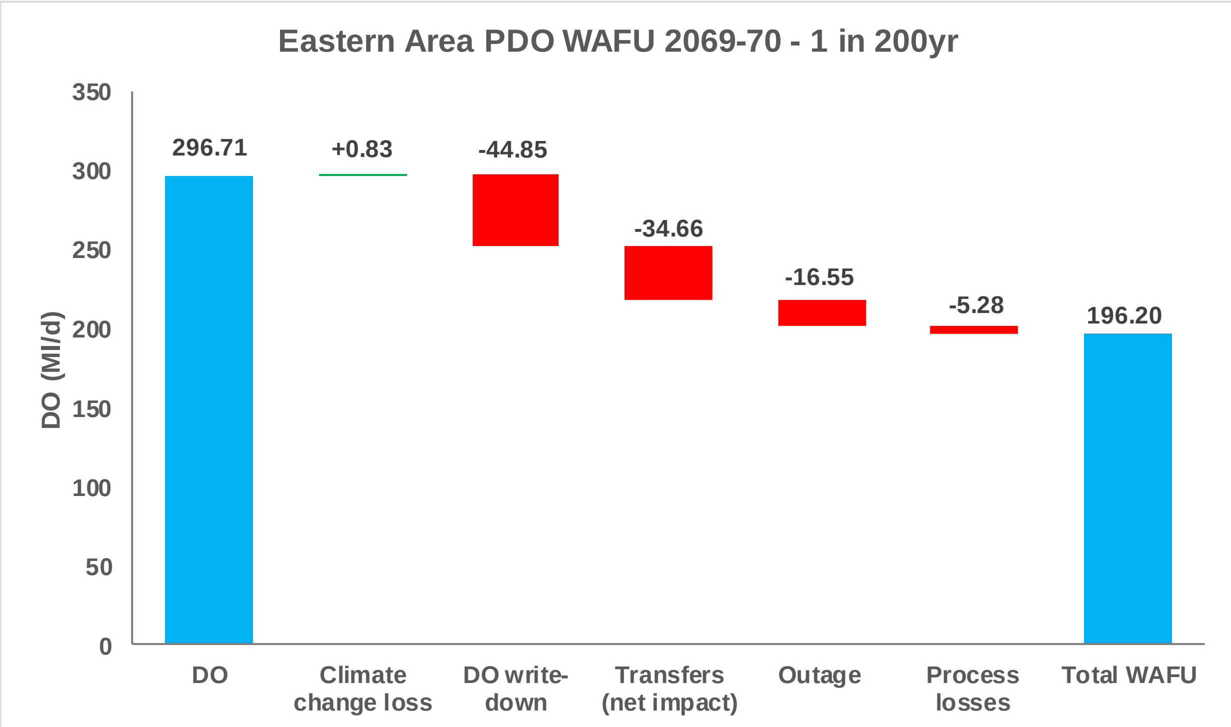


Figure 20 WAFU in the Eastern area at the end of the planning period for a 1 in 200 year drought at PDO



3.3 Western area

Figure 21 and Figure 22 show the WAFU available at the start of the planning period (2020-21) in the Western area at MDO and PDO for Scenario A. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage, process losses and sustainability reductions equates to a reduction in WAFU compared to DO of 180.7Ml/d at MDO and 129.4Ml/d at PDO in 2020-21.

Figure 23 and Figure 24 show the WAFU available at the end of the planning period (2069-70) in the Western area at MDO and PDO for Scenario A. The net impact of climate change, DO write-downs due to nitrate and pesticide issues, bulk transfers, outage, process losses and sustainability reductions equates to a reduction in WAFU compared to DO of 221.6Ml/d at MDO and 212.5Ml/d at PDO in 2069-70.

Figure 21 WAFU in the Western area at the start of the planning period for a 1 in 200 year drought at MDO – Scenario A (implementation of Itchen and Lower Test sustainability reductions in AMP6)

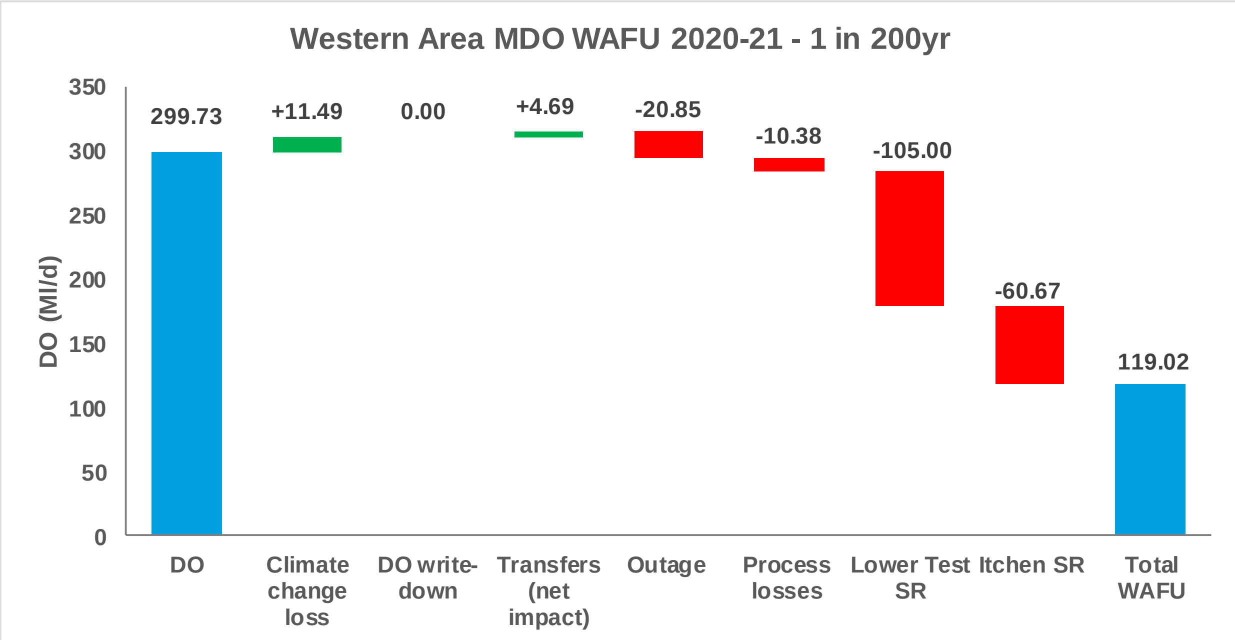


Figure 22 WAFU in the Western area at the start of the planning period for a 1 in 200 year drought at PDO – Scenario A (implementation of Itchen and Lower Test sustainability reductions in AMP6)

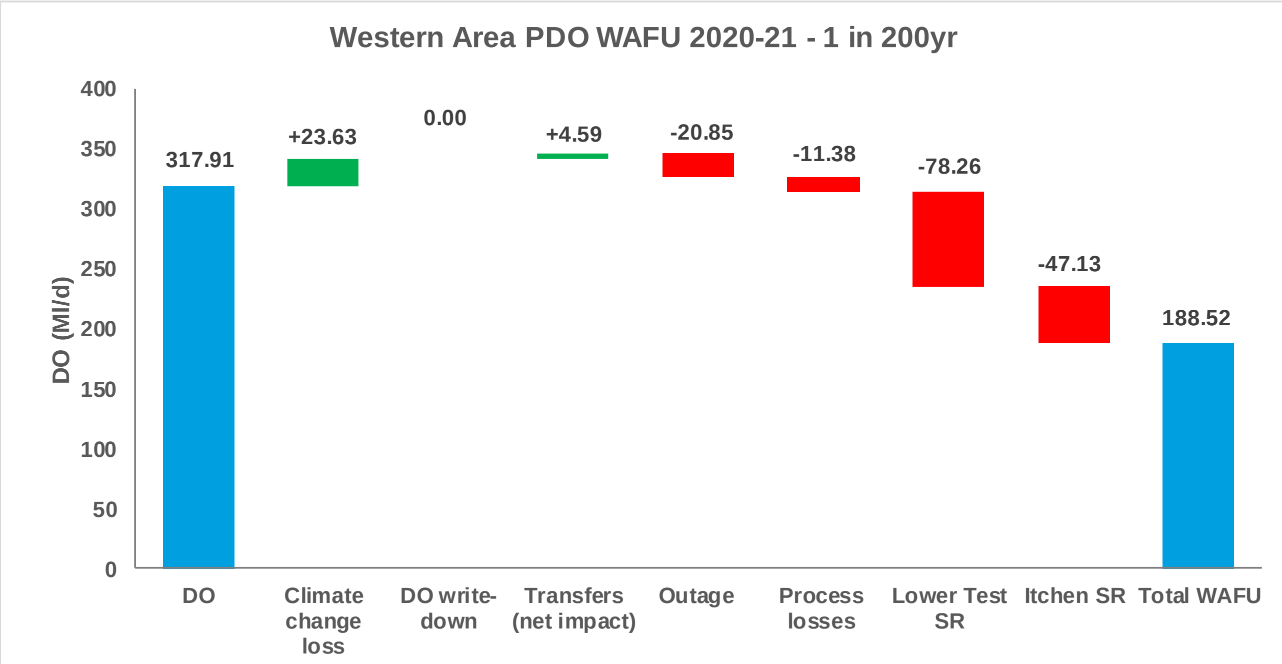


Figure 23 WAFU in the Western area at the end of the planning period for a 1 in 200 year drought at MDO – Scenario A (implementation of Itchen and Lower Test sustainability reductions in AMP6)

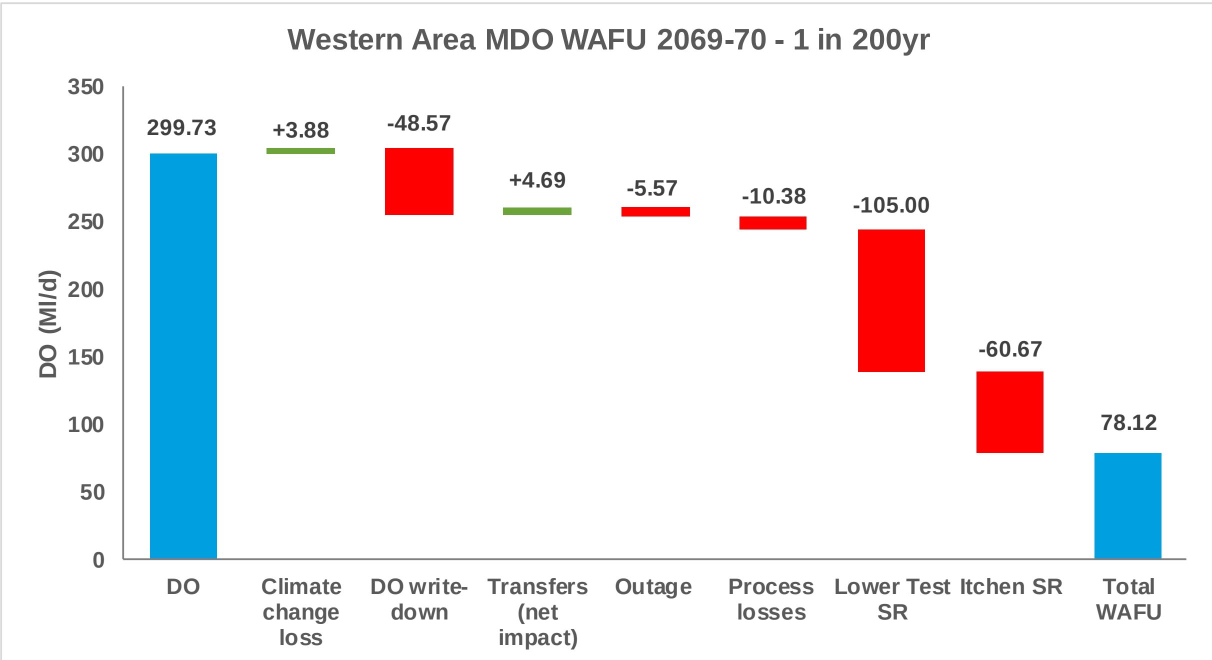
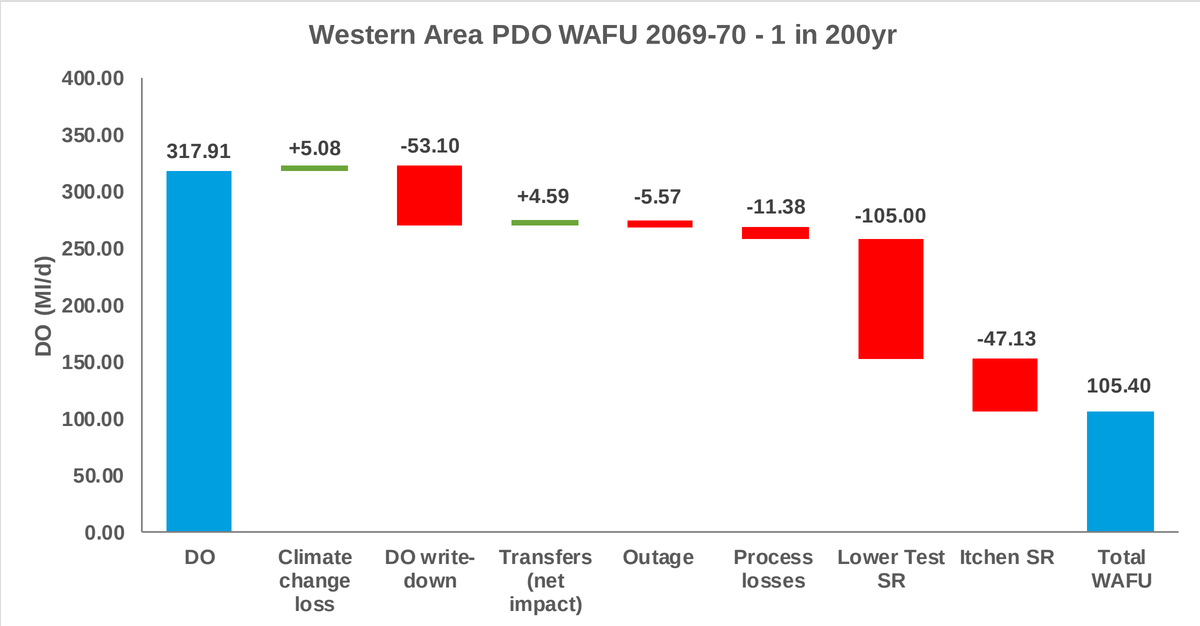


Figure 24 WAFU in the Western area at the end of the planning period for a 1 in 200 year drought at PDO – Scenario A (implementation of Itchen and Lower Test sustainability reductions in AMP6)



4. Headroom and uncertainty

4.1 Introduction

A ‘problem characterisation’ assessment was undertaken by the company at the start of the development of the Water Resource Management Plan (WRMP), the method for which is set out in in recent UKWIR (2016a, 2016b) guidance. This highlighted a number of complexity factors and concerns in each of the company’s supply areas and indicated that the plan would benefit from using a more complex 'extended' decision-making approach (see Annex 1). As a result of the assessment, the company has chosen to develop a ‘fully risk based’ plan that uses a ‘real options’ analysis method to recognise risk and uncertainty, and to make appropriate 'no-regret' investments to meet a plausible range of uncertain future SDBs.

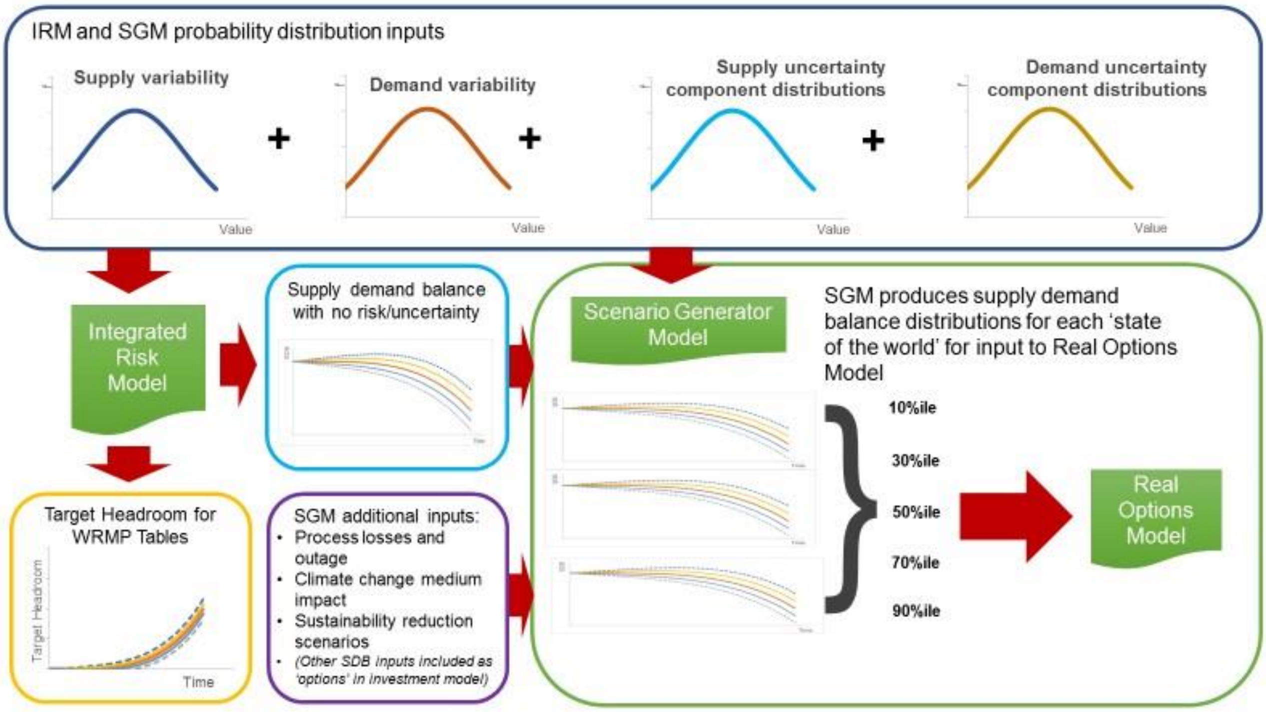
A key input to this risk-based real options approach is the development of a series of baseline SDB profiles that reflect the principal uncertainties faced by the company. The purpose of this section is to describe the approach used to develop these SDB profiles, which are shown in the final section of this Annex. In this section we also describe the development of an estimate of ‘target headroom’ in a format that is compatible with the existing UKWIR best practice approach, and uses the same general risk and uncertainty categories as the UKWIR methodology.

The modelling of risk and uncertainty for WRMP19 is comprised of two parts:

1. Use of Southern Water’s Monte Carlo ‘integrated risk model’ (IRM) that was developed for WRMP14 to develop an estimate of (i) target headroom, which is used for the WRMP tables only, and; (ii) to generate a SDB profile that takes into account the variability of supply and demand that can occur in a given year;
2. The full modelling of future uncertainty in the SDB at different levels of drought severity within a ‘scenario generator model’ (SGM). The SDB profiles that are generated by this model are used as inputs to the real options investment model, described in Annex 8. The SDB profiles are shown in the next section of this Annex. Figure 25 below provides an overview of the headroom and uncertainty modelling process.

Southern Water

Figure 25 - Overview of the IRM and SGM



4.2 Definitions

Several key terms are used within this technical note, and are defined as follows:

IRM

For WRMP14 Southern Water developed a Monte Carlo-based **integrated risk model** (IRM) to generate an estimate of target headroom that formed a key input to the decision-making model.

The IRM provides an estimate of target headroom in a format that is compatible with the existing UKWIR best practice approach, and uses the same general risk and uncertainty categories as the UKWIR methodology. Where possible it accounts for the 'natural' variability in both supply and demand, and integrates this with the risks and uncertainties presented by the UKWIR headroom methodology, to provide an overall integrated risk profile of the SDB that could be encountered in any given year of the WRMP planning period.

Level of Service

The planned average frequency of drought-driven customer demand restrictions. For example, a water company may plan to offer a level of service of one temporary use restriction (eg: a hosepipe ban) in 10 years on average.

Monte Carlo modelling

A mathematical technique used to quantify risk by simulating a range of possible outcomes and the probabilities of their occurrence.

Real options model

A modelling technique that allows the examination of the probability weighted implications of different possible futures, which can help to identify a 'least regrets' option portfolio in the near term.

SGM
For WRMP19 Southern Water has developed a Monte Carlo based **scenario generator model** (SGM), which generates the **full range of SDB profiles that could occur at different drought severities**.

Target headroom
'Target headroom' refers to a planning margin that allows for uncertainty in the supply and demand forecasts, and is defined as the threshold of minimum acceptable headroom (ie: a surplus of supply over demand) which, if breached, would represent an increased risk to the company that it would not able to meet its desired Target Levels of Service. The 2016 Water Resource Planning Guidelines do not prescribe what level of risk is acceptable for planning purposes. It is left to each company to determine the appropriate level of risk that is used in its WRMP.

Available headroom is defined as the difference between WAFU and demand. Available headroom tends to reduce over time, particularly as a result of increasing demand.

Uncertainty
There are two main types of uncertainty that are modelled within the IRM and SGM:

- The uncertainties associated with forecasts of longer-term influences on supply and demand such as climate change and changes in demographics
- Other uncertainties, such as those associated with inaccuracies in measurements and modelling outputs

These two types of uncertainty are sometimes called 'epistemic' uncertainties. They relate to a lack of knowledge about the system itself, and include uncertainties such as those relating to source yields and the effects of metering on demand.

Variability
In this context 'variability' refers to the natural, quantifiable annual variability in both DO and demand, which mainly relates to random weather fluctuations between years. This is sometimes called 'aleatory' variability.

4.3 Integrated Risk Model (IRM)

4.3.1 Model overview

A key component of Southern Water's decision-making approach that was applied for WRMP14 was the treatment of risk and uncertainty. The standard UKWIR target headroom uncertainty methodology only covers the elements that relate to epistemic uncertainty described above, and there is no integration with the risks posed by 'natural' inter-annual variability. This means an arbitrary 'glide path' of risk (eg: the 95th percentile dropping to 80th percentile over the course of the Plan) has to be taken from the Monte Carlo outputs that are generated. The natural variability in DO and demand is not included as a variable risk element, and is instead expressed separately and deterministically, taking a single value for each year that is equal to a stated return period. This means that the variability and uncertainty are not integrated in a way that is consistent with Levels of Service.

For WRMP14 Southern Water therefore developed an integrated Monte Carlo-based risk model (the IRM) to produce an estimate of target headroom that formed a key input to the decision-making model. The model was developed in Excel using the Monte Carlo platform @RISK. The IRM provides an estimate of target headroom in a format that is compatible with the existing UKWIR best practice approach, and uses the same general risk and uncertainty categories as the UKWIR methodology.

Where possible it accounts for the 'natural' inter-year variability in both supply and demand, and integrates this with the risks and uncertainties presented by the UKWIR headroom methodology, to provide an overall integrated risk profile of the SDB that could be encountered in any given year of the WRMP planning period. Although this approach is well-established in other fields, it had not previously been used within the water industry.

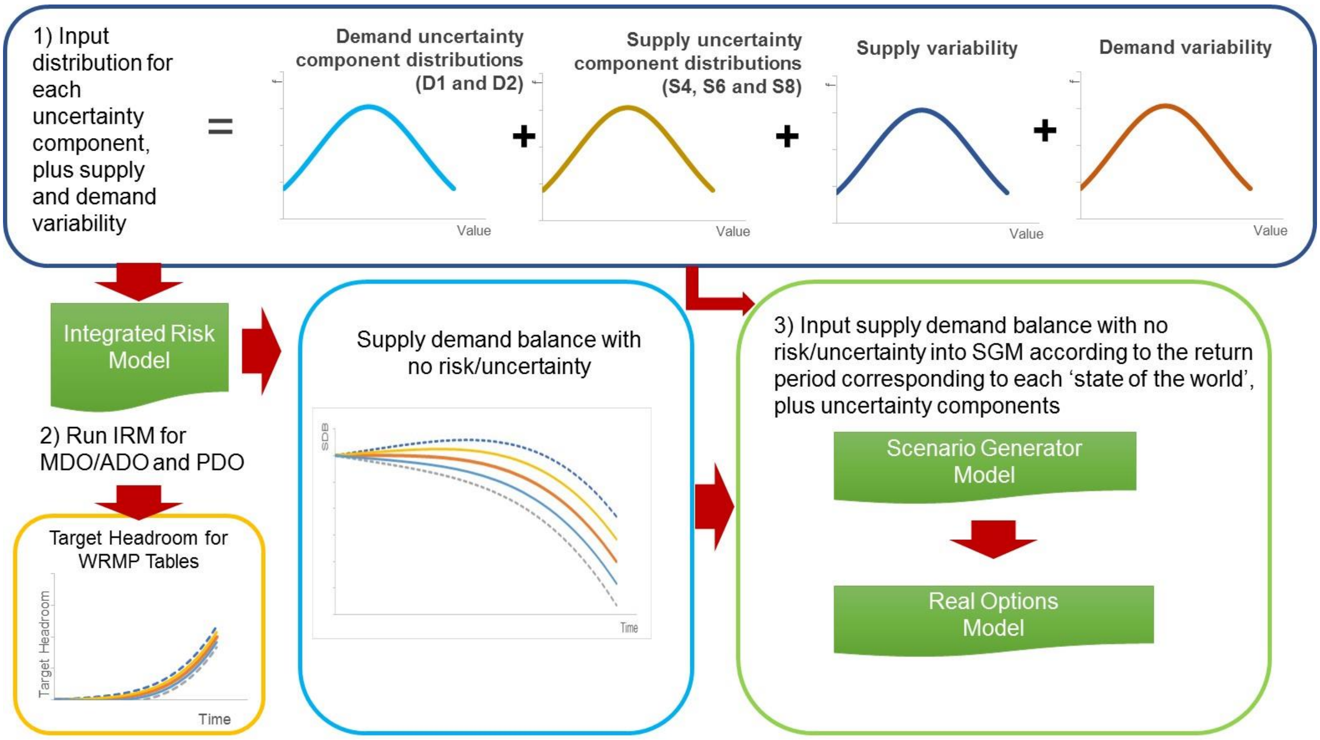
The IRM provides two key advantages:

1. It allows the chosen target headroom value to reflect the company's chosen Level of Service, without arbitrary assumptions (eg if the 1 in 200 year drought event is being selected, target headroom is taken as the expected impact that uncertainty has on an event with a 0.5% probability of occurring in any given year); and
2. As the integration of risk always reduces the impact of individual risk components, it allows Southern Water to include a realistic representation of uncertainties in supply and demand components, without resulting in unrealistic or unacceptable levels of target headroom.

For WRMP19, Southern Water is no longer using target headroom as a separate input to the SDB. However, there remains a need to report target headroom within the WRMP tables. The IRM developed for use in WRMP14 has therefore been used for this first step in the risk modelling process.

As summarised below in Figure 26, the IRM incorporates all risks and uncertainties in a Monte Carlo model, including uncertainties defined by the UKWIR (2002) headroom methodology. Stochastic rainfall models are used to generate DOs at specified return periods, while demand variability is assessed through examination of dry year factors.

Figure 26 - Overview of the IRM Modelling Process



The model generates an estimate of WRZ-level target headroom across the planning period (2016-17 to 2069-70) at four ‘states of the world’:

- ‘Severe drought’: 1 in 200 year drought at MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas)
- ‘Extreme drought’: 1 in 500 year drought MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas)

4.3.2 Timesteps

The IRM includes five year timesteps from 2019-20 to 2069-70, in addition to the 2016-17 base year. This was considered to provide an appropriate balance between model run time and the granularity required for input to the decision-making model. As annual supply-demand values without uncertainty were required for the SGM for the first 10 years of the model, the values from the IRM were interpolated over the five year timesteps up to 2029.

4.3.3 Inputs and model structure

The IRM contains several key elements:

- Supply and demand probability distributions to reflect natural annual variability
- Supply and demand-side uncertainty components
- Correlations between key components

These are covered below.

Supply variability

For the supply-side, probability distributions for DO were only applied to those WRZs where an accurate representation of supply variability across the full range of potential droughts (including extreme events) could be created and entered as a custom distribution into the @Risk model. The custom distribution was mathematically calculated to ensure that all probabilities on a cumulative density function (CDF) directly reconciled with the outputs of the stochastic water resource modelling. Target headroom values were calculated for a 1 in 200 year and 1 in 500 year return period.

For those WRZs where either it was not mathematically possible to create a bespoke probability curve for supply variability, or where the DO was primarily constrained by treatment capacity, licence conditions or infrastructure capacity, it was not appropriate to apply a supply-side probability distribution for DO to the model. In that case supply was set at a single (deterministic) value, and the risk level was set at 1 in 10 years according to the key Level of Service constraint that dictates the nature of the drought event, as this would be effectively constrained by demand and not supply in these cases. The WRZs that fall into each category are shown in Table 3.

Southern Water

Table 2 Type of IRM used for each WRZ

Category for IRM modelling	WRZs included in that category	Notes
Full supply variability	• Sussex Hastings ADO • Kent Thanet WRZ ADO, PDO • Kent Medway East WRZ ADO, PDO • Kent Medway West WRZ ADO • Sussex Brighton WRZ MDO, PDO • Sussex North WRZ MDO, PDO • Sussex Worthing WRZ MDO, PDO • Hampshire Southampton East WRZ MDO, PDO • Hampshire Southampton West WRZ MDO, PDO (with Lower Test sustainability reduction)	Variable DO either owing to sensitivity of the groundwater sources to drought (Kent Thanet WRZ, Sussex Brighton WRZ, Sussex Worthing WRZ, Kent Medway East WRZ), hands-off licence conditions that affect DO (Hampshire Southampton East WRZ, Sussex North WRZ, Sussex Hastings, Kent Medway West WRZ), or both.
No supply variability	• Sussex Hastings PDO • Kent Medway West WRZ PDO • Isle of Wight WRZ MDO, PDO • Hampshire Winchester WRZ MDO, PDO • Hampshire Southampton West WRZ MDO, PDO (without Lower Test sustainability reduction)* • Hampshire Rural WRZ MDO, PDO • Hampshire Kingsclere WRZ MDO, PDO • Hampshire Andover WRZ MDO, PDO	**Sussex Hastings** – At PDO all sources are licence or infrastructure constrained. **Kent Medway West WRZ** – Groundwater sources are predominantly licence or infrastructure constrained (only the River Medway Scheme shows large variability). **Isle of Wight WRZ** – All sources are predominantly licence constrained, except for Newport (which has variable yield from one main). **Hampshire Winchester WRZ** – All sources are licence/Infrastructure constrained. **Hampshire Southampton West WRZ** – All sources (ie just Test Surface Water) licence/infrastructure constrained (prior to implementation of the Lower Test sustainability reduction). **Hampshire Rural WRZ** – All sources licence/infrastructure constrained **Hampshire Kingsclere WRZ** – All sources licence constrained except for minor reduction at Newbury under the most severe drought. **Hampshire Andover WRZ** - All sources except Overton are licence/infrastructure constrained.

*****Modelled using a discrete distribution with a DO of 105Ml/d at all drought severities except for the 1 in 500 for MDO, where the DO reduces to 90.4Ml/d.

Demand variability

For the demand-side, a symmetrical Beta distribution was applied to avoid long 'tails', as analysis of historical demand data suggests that there is a realistic upper and lower limit on demand that tends to occur regardless of drought severity. The input parameters for this Beta distribution were calculated to ensure that the mean reflected the 'normal' year inputs that were used for the normal year demand forecast, and the 90%ile was equal to the 'dry year' demand inputs that were used for the dry year demand forecast. Annex 2 explains the derivation of the normal year and dry year demand forecasts across the planning period.

Supply-side uncertainties
Table 3 below lists all of the supply side headroom components contained within the UKWIR (2002) methodology, along with the reasons for inclusion/exclusion within the WRMP19 version of the IRM.

Table 3 Supply-side headroom components from the UKWIR (2002) methodology

Supply-side component	Explanation	Included?	Justification
S1: Vulnerable surface water licences	Arises from concerns over the sustainability of surface water abstractions at the licensed rate and the likelihood that the licence will be revoked, reduced or otherwise modified.	No	Included within the SGM.
S2: Vulnerable groundwater licences	Arises from concerns over the sustainability of groundwater abstractions at the licensed rate and the likelihood that the licence will be revoked, reduced or otherwise modified.	No	Included within the SGM.
S3: Time-limited licences	Relates to the uncertainty over whether the Environment Agency will renew, revoke or modify a time-limited licence.	No	Assessment of potential sustainability reductions for inclusion in the SGM is based on compliance with the Environmental Flow Indicator (EFI).
S4: Bulk imports	Although the reliability of bulk imports is subject to similar uncertainties to a company's own resources, the receiving company will have limited access to data to assess these uncertainties. Therefore included as a separate component.	Yes	Southern Water receives two large bulk imports from Portsmouth Water.
S5: Gradual pollution of sources causing a reduction in abstraction	The impact of gradual pollution on a source may be significant, even leading to abandonment of a source in some cases	No	Impacts from pollution (eg nitrates or turbidity) have been allowed for as discrete values in the investment model.
S6: Accuracy of supply-side data / overall source yield uncertainty	Data inaccuracy may render estimates of DO unreliable.	Yes	Relevant for all sources. Models and approaches used to derive DOs may lead to inaccuracies. Where the fully integrated model is applied and where sufficient data are available, then component S6 has a variable range of uncertainty, whereby uncertainty tends to increase as drought severity increases.

Supply-side component	Explanation	Included?	Justification
S8: Uncertainty of impact of climate change on source yields	The impacts of climate change may alter source DOs. Although such impacts are included explicitly within the supply-demand balance, uncertainty in the estimates needs to be included in the headroom analysis.	Yes	Relevant for all sources.
S9: Uncertain output from new resource developments	This component is typically included for the final planning scenario. It relates to the uncertainty associated with the outputs of new source developments required to maintain service levels.	No	Not included. Analysis previously showed that the level of uncertainty for new options was generally not significantly greater than existing resources, so the net effect on target headroom as a percentage was negligible.

Supply-side uncertainty distributions

An overview of the distributions that were used for the uncertainty components is provided below (Table 4), along with the approach used to elicit values in each of the probability distributions.

Table 4 Supply-side headroom uncertainty components and probability distributions used in the model

Supply-side component	Distribution used	Explanation
S4: Bulk imports	Discrete	A discrete distribution is used to illustrate that in any given year there is X% chance that a bulk import will be reliable (a non-event) and a (100-X)% chance that it will not (an event). Only if an event occurs will there be a loss in DO of the specified proportion of import DO for the specified number of days. This distribution is consistent with that suggested within the UKWIR (2002) methodology.
S6: Accuracy of supply-side data	Normal	A normal distribution is used for component S6, as this is the only statistically valid approach. The Central Limit Theorem shows that all distributions that are made up from multiple, uncertain components will always tend to a normal distribution.
S8: Uncertainty of impact of climate change on source yields	Triangular	A triangular distribution is used for component S8, defined by the changes in source yield that are derived from simulating the ‘wet’, ‘medium’, and ‘dry’ climate change scenarios. This type of distribution is the most appropriate due to the uncertainty associated with the climate change analyses, and is consistent with the UKWIR (2002) methodology.

Uncertainty of bulk imports (S4)

This was based on a simple assessment of potential bulk supply outage risk, and the impact this would have during the MDO/ADO and PDO periods. A summary of the assumptions used is as follows:

- **Sussex North WRZ** – an import of 15.0Ml/d from Pulborough was assumed from Portsmouth Water
- **Hampshire Southampton East WRZ** – an import of 15.0Ml/d was assumed from Portsmouth Water to the Moor Hill reservoir

- At MDO, these were assumed to have a 10% probability of loss in DO, and 10 days of DO lost during a year. At PDO, the probability of loss in DO was reduced to 5%, with 7 days of DO lost over the PDO period. These estimates were defined based on operational experience

Accuracy of supply-side data (S6)
The IRM was developed to enable the dependency or interrelation between variability in supply or demand and uncertainty to be represented within the SDB. For example, there is a higher level of confidence in an estimate of source yield under conditions where there is actual operational experience than for more severe drought conditions.

A detailed analysis was carried out for WRMP14 to estimate the uncertainty associated with WRZ-level DO (S6) under different drought conditions. The model applies the level of uncertainty corresponding to the DO level selected in each iteration of the Monte Carlo simulation. The results of this detailed analysis from WRMP14 were used within the WRMP19 version of the model to represent the level of uncertainty associated with different return periods.

This dependent relationship is also used for component D2, discussed below. The dependent relationships between supply variability and climate change impacts are fully represented in the SGM, rather than the IRM.

Uncertainty of impact of climate change on source yields (S8)
The 'wet' climate change scenario and 'dry' climate change scenario losses in supply compared to the medium estimate at the 1 in 200 year return period were used to model the uncertainty of the impact of climate change on supply within the IRM. A triangular distribution was used for this component S8, with the difference between the 'dry' and medium estimate as the maximum impact, zero as the expected value and the difference between the 'wet' and medium estimate as the minimum impact.

The derivation of the wet, dry and medium climate change scenarios for the 2080s is covered in Annex 3. The medium scenario is considered to represent the most likely impact on DO, whilst the dry and wet scenarios represent the 90th and 10th percentiles of the distribution of UKCP09 scenario impacts respectively. Charlton and Watts (2017) describes the approach used to scale back the impacts to each year of the planning period using the scaling factor below:

$$Scale\ factor = \frac{Year - 1975}{2085 - 1975}$$

Development of these three scenarios highlighted an issue with using highly skewed values in a triangular distribution to represent the climate change impact uncertainty. For this distribution, the most likely change was assumed to be zero, as the most likely scenario is represented by the medium impact. In many cases the magnitudes of the 'wet' or 'dry' scenarios were significantly different from one another, resulting in an asymmetrical distribution. It was noted that a non-symmetrical triangular distribution results in a non-zero mean, even if the 'most likely' value is set at zero (this can be shown through simple geometry). As the mean is not zero, then this skew has a direct impact on headroom, equal to half the difference between the minimum and maximum values. The impact on headroom from this effect can be large, even before the uncertainty range of the distribution is taken into account. Whilst this represents something of a conceptual flaw in the UKWIR methodology, it was decided that the triangular distribution should be kept to ensure compatibility with the UKWIR methodology.

Demand-side uncertainties

Table 5 lists all of the demand-side headroom components contained within the UKWIR 2002 methodology, along with the reasons for inclusion/exclusion within the WRMP19 IRM.

Table 5 Demand-side headroom components from the UKWIR (2002) methodology

Supply-side component	Explanation	Included?	Justification
D1: Accuracy of sub-component data	There is a risk that the consumption data on which demand forecasts are based are of poor quality, leading to errors in demand prediction. The most important source of data in this regard is the distribution input flow meter measurements of variable accuracy that are summed to calculate the distribution input.	Yes	Relevant for all WRZs.
D2: Demand forecast variation	Arises from the risk that actual demand will depart from the dry year demand forecast used for the supply-demand balance due to uncertainties associated with growth in the household and non-household sectors and water efficiency behaviour.	Yes	Relevant for all WRZs.
D3: Uncertainty of impact of climate change on demand	Arises from uncertainties regarding the estimates of climate change impacts on demand.	No	Although this was previously included separately for WRMP14, this has now been combined within component D2.
D4: Uncertain outcome from demand management measures	The size of reductions in demand that planned demand management measures may achieve is generally uncertain, and the date by which such demand reductions are realised even more so.	No	Although this was previously included separately for WRMP14, this has now been combined within component D2.

Demand-side uncertainty distributions

An overview of the distributions that were used for the uncertainty components is provided in Table 6 below, along with the approach used to elicit values in each of the headroom distributions.

Table 6 Demand-side headroom uncertainty components and probability distributions used in the model

Supply-side component	Distribution used	Explanation
D1: Accuracy of sub-component data	Normal	A normal distribution was considered to be the most appropriate for component D1, defined by the typical percentage uncertainty associated with flow meter readings and a mean of zero, as there is no evidence that flow meter errors are biased positively or negatively. This probability distribution is applied throughout the planning period as the accuracy range is not expected to change on this timescale, and is consistent with that suggested within the UKWIR (2002) methodology.
D2: Demand forecast variation	Triangular	A triangular distribution is used for component D2, defined by the maximum decrease, most likely change and maximum increase in the demand forecast. The most likely change is zero, as this is represented by the actual demand forecast. The maximum decrease in demand represents the difference between the base case and the minimum demand forecasts during the planning period. The maximum increase in demand represents the difference between the base case and the maximum demand forecasts during the planning period. This follows the approach recommended within the UKWIR (2002) methodology.
D3: Uncertainty of impact of climate change on demand	N/A	Combined with D2: Demand forecast variation
D4: Uncertain outcome from demand management measures	N/A	Combined with D2: Demand forecast variation

Accuracy of sub-component data (D1)

A percentage uncertainty of ±3% (around a mean of zero) was used to represent the accuracy of sub-component demand data, as this is the typical uncertainty of a flow meter reading.

Demand forecast variation (D2)

The demand in any given year over the planning period may vary from a baseline forecast as a result of uncertainties associated with:

- Population growth
- Demand from the non-household sector
- The impact of climate change on demand
- Customer behaviour in terms of water efficiency

The baseline **household growth scenario** is based on the Experian 7.1 forecast (Experian, 2017); the low household growth scenario is based on the UKWIR lower confidence interval methodology, and the high household growth scenario is based on the UKWIR higher confidence interval methodology (UKWIR, 2016c).

The low **non-household growth scenario** is based on half the rate of the baseline growth rate and high household growth scenario is based on double the rate of the baseline growth rate.

The low **climate change impact scenario** is based on the South East Climate Projections P10 (UKWIR, 2013); the medium climate change impact scenario is based on the South East Climate Projections P50 and the high climate change impact scenario is based on the South East Climate Projections P90.

The **low water efficiency scenario** was based on an increase in shower duration by 1 minute and a doubling of the assumed garden watering volume by 2030, and the **high water efficiency scenario** was based on a reduction in shower duration by 1 minute and a halving of the assumed garden watering volume by 2030.

The uncertainty in the demand forecast was modelled using a triangular distribution with the percentage differences between the minimum and baseline forecast, and between the maximum and baseline forecast in each year of the model (see Table 7 and Table 8 below).

For the draft WRMP, the maximum and minimum forecasts included customer behaviour in terms of low and high water efficiency assumptions respectively (see Table 7). However, for the revised draft and final WRMP, baseline water efficiency assumptions were used for the maximum and minimum forecasts (see Table 8). This is to avoid the potential for double counting the demand savings from the Target 100 option (see Annex 6, and Annexes 9 to 11 for further information about Target 100). This narrows the demand forecast uncertainty distributions from an average of +34% and -21% in the draft plan compared to the baseline demand forecast to +9% and -10% for the revised draft and final plan.

Table 7 Demand forecast assumptions used in uncertainty modelling – draft WRMP

Demand forecast scenario	Assumptions used
Baseline forecast	• Baseline household population growth; • Medium climate change impact; • Baseline water efficiency; and • Baseline non-household growth.
Maximum forecast	• High household population growth; • High climate change impact; • Low water efficiency; and • High non-household growth.
Minimum forecast	• Low household population growth; • Low climate change impact; • High water efficiency; and • Low non-household growth.

Table 8 Demand forecast assumptions used in uncertainty modelling – revised draft and final WRMP

Demand forecast scenario	Assumptions used
Baseline forecast	• Baseline household population growth; • Medium climate change impact; • Baseline water efficiency; and • Baseline non-household growth.
Maximum forecast	• High household population growth; • High climate change impact; • Baseline water efficiency; and • High non-household growth.
Minimum forecast	• Low household population growth; • Low climate change impact; • Baseline water efficiency; and • Low non-household growth.

These scenarios were developed for the Normal Year Annual Average (NYAA) forecast. As dry year and peak factors were subsequently applied to the baseline forecast and scenarios to generate Dry Year Annual Average (DYAA), Dry Year Critical Period (DYCP) and Dry Year Minimum Deployable Output (DYMDO) baseline forecast and scenarios, there is additional uncertainty associated with these factors. This uncertainty was estimated to be approximately plus or minus half of the DYMDO/DYAA uplift factor, so this percentage uncertainty was added to the demand forecast uncertainties for the DYAA, DYCP and DYMDO scenarios.

As was the case with the uncertainty of the impact of climate change on supply, development of these scenarios highlighted an issue with using highly skewed values in a triangular distribution to represent the demand forecast variation. For this distribution, the most likely change was assumed to be zero, as the most likely scenario is represented by the baseline forecast. In this case the maximum increase was higher than the maximum decrease in demand from the 'most likely' zero value. As explained above, this skew has a direct impact on headroom, equal to half the difference between the minimum and maximum values. However, it was decided that the triangular distribution should be kept to ensure compatibility with the UKWIR methodology.

The assumptions for each of these components are discussed in Annex 2.

Correlations

In order to ensure that the output 'SDB profiles without uncertainty' are equal to the difference between the input supply and demand values at each return period modelled, a coefficient of -0.6 was used for the correlation between supply and demand variability for those WRZs that used the fully integrated model. This correlation coefficient was calculated so that it would fulfil the central underlying assumption of WRMPs that has been used to date: namely that the worst historic supply side drought will also drive levels of demand that are equal to approximately a 1 in 10 year demand level – i.e. that DYAA demand occurs at the same time as the worst historic event. This ensures that the deterministic SDB and the stochastically generated SDB are almost identical for the P=0.01 (i.e. 1 in 100 year) level of occurrence. This coefficient means that the SDB for the 1 in 200 year event is also similar for the stochastic and deterministic balances.

The calculation was undertaken using iterative Monte-Carlo runs to generate the appropriate SDB from the baseline data.

For those WRZs that only included variability in demand, there was no need for any correlation between supply and demand, as the supply input was a single deterministic value.

4.3.4 Outputs

Using the inputs described above, the IRM calculates three sets of SDB profiles at the relevant return period (in this case, 1 in 200 year and 1 in 500 year drought):

1. A simple additive SDB without probabilities (ie supply minus demand).
2. A probabilistic SDB that includes both 'aleatory' uncertainty in supply and demand (ie the natural, quantifiable annual variability in both DO and demand) and 'epistemic' uncertainty (ie uncertainty components S4, S6, S8, D1 and D2).
3. A probabilistic SDB with no risk or uncertainty (ie with 'aleatory' variability only and without inclusion of any of the uncertainty components).

The target headroom allowance is calculated by subtracting SDB profile (2) from (1). This represents the effect that uncertainty in supply-demand modelling has on the SDB at the level of risk that defines the Level of Service design event. **This is used to complete the WRMP tables only and is not used in the SGM.**

SDB profile (3) is used as an input to the SGM.

The results of the modelling in terms of target headroom for each WRZ are provided in Table 9 below. These are reported within the WRMP tables as absolute values. The target headroom results generally show a steady increase through the planning period, driven by the increasing uncertainty in the demand forecast and impact of climate change on supply through time.

By the end of the planning period, target headroom ranges from 0.4% to 12.3% of demand for the main scenarios. The wide range of target headroom results reflects the fact that with the integrated risk approach used for both WRMP14 and WRMP19, there is no requirement to select an arbitrary ‘glidepath’ of risk (e.g. 95th percentile dropping to 80th percentile over the course of the Plan). The target headroom values generated therefore better reflect the individual supply and demand risk characteristics of each WRZ. For example, in the Isle of Wight WRZ all sources are predominantly licence constrained, resulting in a supply profile which does not change significantly by return period and a low degree of uncertainty due to the impact of climate change on supply. This corresponds to a relatively low target headroom uncertainty. By contrast, in Sussex North WRZ there is a change in predicted yield by drought return period, and a relatively large degree of uncertainty regarding the impacts of climate change on supply at MDO in particular, resulting in a relatively high target headroom uncertainty.

Table 9 Target headroom uncertainties (%) for a 1 in 200 yr event (severe drought) [2016-2069]

		2016	2019	2024	2029	2034	2039	2044	2049	2054	2059	2064	2069
Sussex Hastings*	DYAA	4.2%	4.1%	3.8%	4.0%	3.7%	3.1%	3.7%	3.0%	2.1%	2.3%	1.4%	1.3%
	DYPDO	5.4%	5.6%	5.7%	5.8%	5.8%	5.9%	5.9%	6.0%	6.0%	6.0%	6.1%	6.2%
Kent Thanet	DYAA	4.8%	5.0%	4.9%	5.3%	6.0%	6.1%	6.5%	6.8%	7.2%	7.5%	8.0%	8.4%
	DYPDO	4.4%	4.8%	5.0%	5.5%	6.2%	6.6%	6.9%	7.4%	7.8%	8.4%	8.9%	9.6%
Kent Medway West	DYAA	2.9%	2.0%	2.4%	2.3%	2.3%	1.8%	1.6%	1.5%	1.2%	0.3%	1.4%	1.1%
	DYPDO	6.8%	8.5%	8.4%	8.3%	8.1%	8.0%	7.8%	7.4%	7.2%	7.0%	6.9%	6.7%
Kent Medway East	DYAA	8.3%	8.6%	8.5%	8.6%	8.7%	8.7%	8.9%	8.8%	9.2%	9.2%	9.5%	9.7%
	DYPDO	7.9%	8.2%	8.3%	8.5%	8.8%	8.8%	9.3%	9.4%	9.7%	9.7%	10.5%	10.4%
Sussex Brighton	DYMDO	6.0%	5.9%	6.3%	6.4%	6.5%	7.0%	6.9%	7.2%	7.4%	8.0%	7.9%	8.3%
	DYPDO	5.2%	5.4%	5.6%	5.9%	6.0%	6.4%	6.7%	7.1%	7.2%	7.4%	7.8%	8.0%
Sussex Worthing	DYMDO	7.5%	7.4%	8.1%	7.9%	8.6%	8.8%	8.9%	9.2%	9.5%	10.1%	10.2%	10.1%
	DYPDO	7.5%	8.2%	8.1%	8.7%	9.3%	9.6%	9.9%	10.3%	10.4%	10.9%	10.7%	11.3%
Sussex North	DYMDO	5.7%	6.1%	6.8%	6.6%	6.8%	7.9%	7.9%	7.9%	8.0%	9.4%	9.0%	8.7%
	DYPDO	6.2%	6.0%	5.6%	5.9%	6.3%	6.0%	6.1%	6.5%	6.0%	6.0%	5.8%	6.7%
Isle of Wight	DYMDO	1.5%	1.4%	1.5%	1.6%	1.6%	2.0%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%
	DYPDO	1.6%	4.3%	1.6%	1.7%	1.7%	2.2%	1.8%	1.8%	1.7%	1.8%	1.8%	1.8%
Hampshire Winchester	DYMDO	4.2%	4.3%	4.3%	4.3%	4.5%	4.7%	4.9%	4.5%	4.5%	4.5%	4.5%	4.5%
	DYPDO	2.9%	3.1%	3.1%	3.1%	3.3%	3.5%	3.7%	3.3%	3.3%	3.3%	3.3%	3.3%
Hampshire Southampton West A*	DYMDO	9.4%	9.9%	11.4%	9.2%	9.2%	9.6%	10.0%	10.4%	10.9%	11.2%	11.7%	12.3%
	DYPDO	21.6%	22.5%	27.0%	0.7%	0.4%	0.6%	0.2%	1.3%	0.7%	0.3%	0.4%	0.4%
Hampshire Southampton East A	DYMDO	10.3%	10.9%	11.6%	13.2%	14.0%	14.8%	15.3%	16.3%	17.4%	18.3%	19.6%	20.4%
	DYPDO	8.1%	7.7%	9.7%	9.7%	10.2%	12.4%	12.7%	13.6%	14.4%	15.0%	17.3%	16.7%
Hampshire Rural	DYMDO	5.3%	7.3%	7.3%	7.4%	7.2%	7.2%	7.1%	6.8%	6.7%	6.4%	6.4%	6.3%
	DYPDO	3.0%	4.9%	5.0%	5.0%	4.8%	5.0%	4.9%	4.5%	4.4%	4.3%	4.3%	4.2%
Hampshire Kingsclere	DYMDO	3.3%	3.4%	3.6%	3.8%	3.9%	4.5%	4.3%	4.5%	4.6%	4.8%	5.0%	5.0%
	DYPDO	2.5%	2.7%	2.8%	2.9%	3.1%	3.6%	3.4%	3.4%	3.5%	3.7%	3.7%	3.9%
	DYMDO	4.4%	4.4%	4.5%	4.5%	4.6%	4.6%	4.8%	4.7%	4.7%	4.7%	4.7%	4.8%

Hampshire Andover	DYPDO	3.7%	3.6%	3.6%	3.6%	3.6%	3.5%	3.6%	3.4%	3.4%	3.3%	3.3%	3.3%

* The 1 in 500 year scenario (extreme drought) is shown for Hampshire Southampton West WRZ Scenario A at MDO and Sussex Hastings at ADO, as due to the distributions of DO for these WRZs, the headroom values were negative in some years at the 1 in 200 year drought return period.

The SDBs **minus any risk and uncertainty**, which are used as inputs to the SGM, are shown in Figure 27 to Figure 32 as 'plume plots'. These include supply (DO) and demand variability only. As the IRM runs multiple (100,000) iterations, it produces a range of results, the distributions of which are shown in these 'plume plots'. The percentile bands show the likelihood that the SDB will be equal to or lower than a certain value. For example, in Figure 27, by 2069-70, 50% of the model iterations produced a SDB below 54Ml/d for the Central area at MDO, and 50% of model iterations produced a SDB greater than 54Ml/d. There is therefore a 50% probability that the SDB will be around 54Ml/d or lower, and a 50% probability that it will be greater than this. Similarly, Figure 27 shows that there is a 10% probability that the SDB will be around 25Ml/d or lower by 2069-70, and 90% probability that it will be greater than this.

Figure 27 Central area total probabilistic SDB at MDO with no risk or uncertainty generated by the IRM

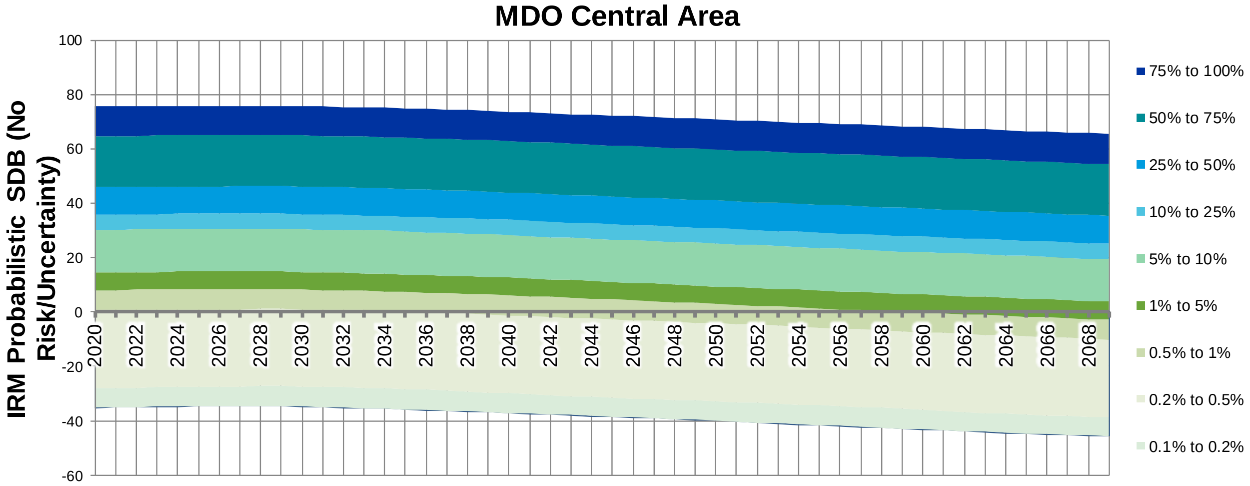


Figure 28 Central area total probabilistic SDB at PDO with no risk or uncertainty generated by the IRM

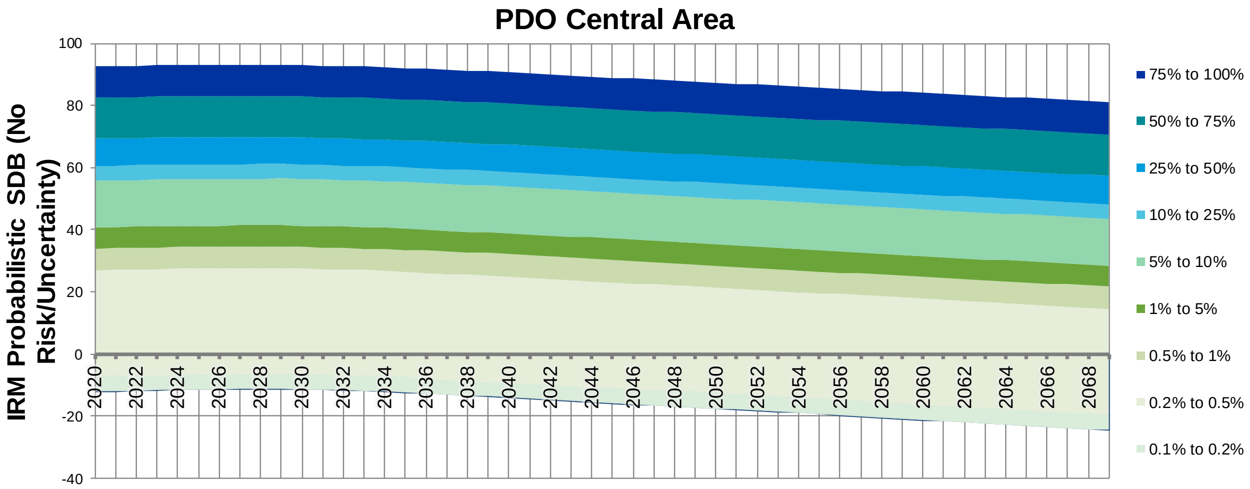


Figure 29 Eastern area total probabilistic SDB at ADO with no risk or uncertainty generated by the IRM

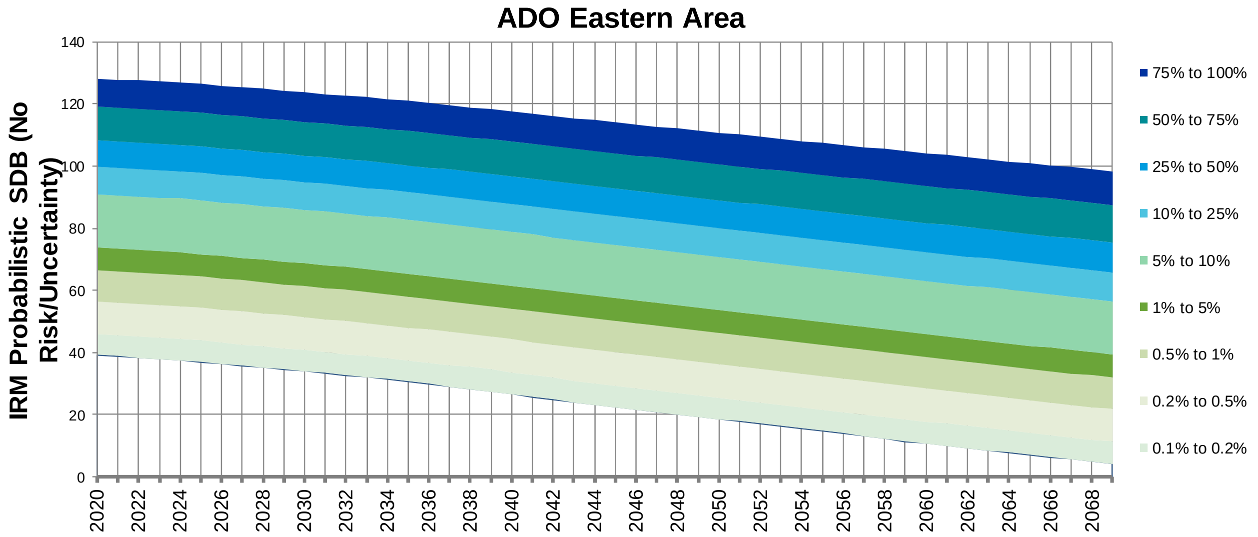


Figure 30 Eastern area total probabilistic SDB at PDO with no risk or uncertainty generated by the IRM

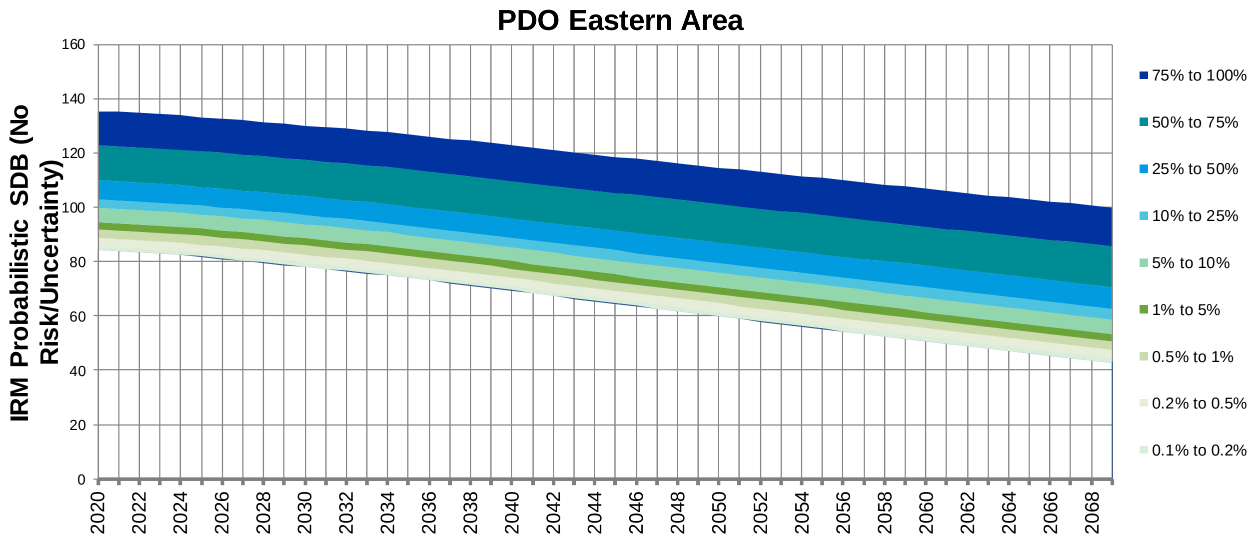


Figure 31 Western area total probabilistic SDB at MDO with no risk or uncertainty generated by the IRM (Scenario A)

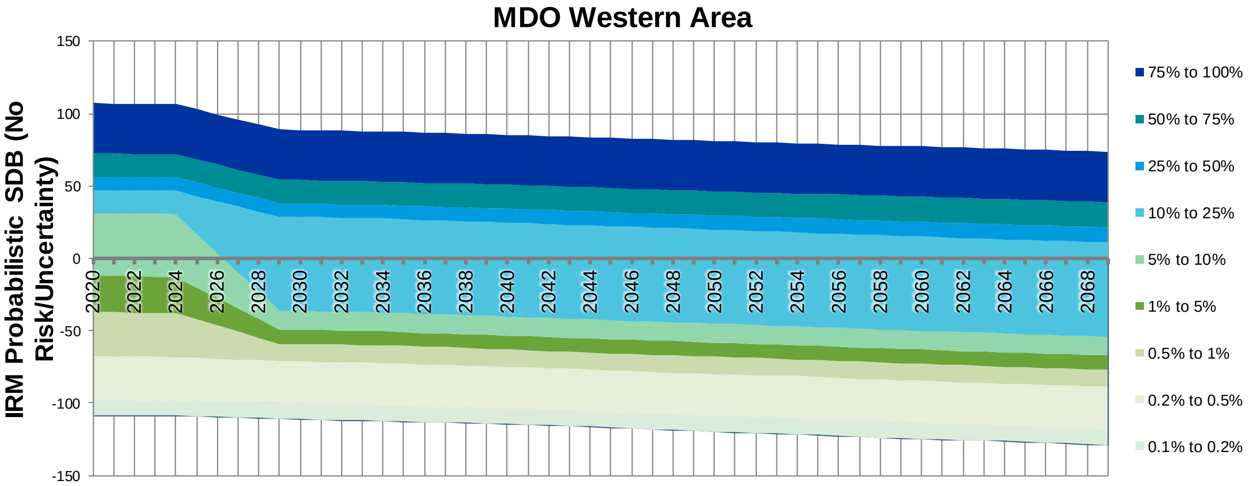
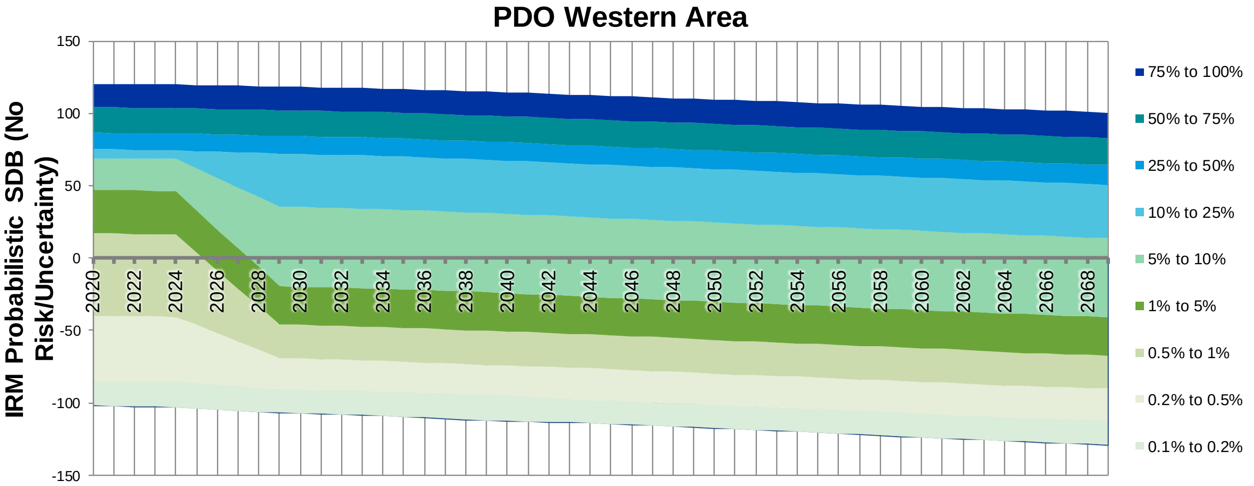


Figure 32 Western area total probabilistic SDB at PDO with no risk or uncertainty generated by the IRM (Scenario A)



4.4 Scenario Generator Model (SGM)

4.4.1 Model overview

The purpose of this model is to provide an estimate of future uncertainty in the SDB and to **generate the overall distribution of SDB forecasts from which the company can select different percentiles to represent a range of possible futures**. This represents an innovation in the company's treatment of risk in the SDB, commensurate with the uncertainties faced by the company at the present time, following the outcome of the problem characterisation assessment (see Annex 1). **These SDBs at different percentiles are used as the input to the real options model**. Figure 33 provides an overview of this approach.

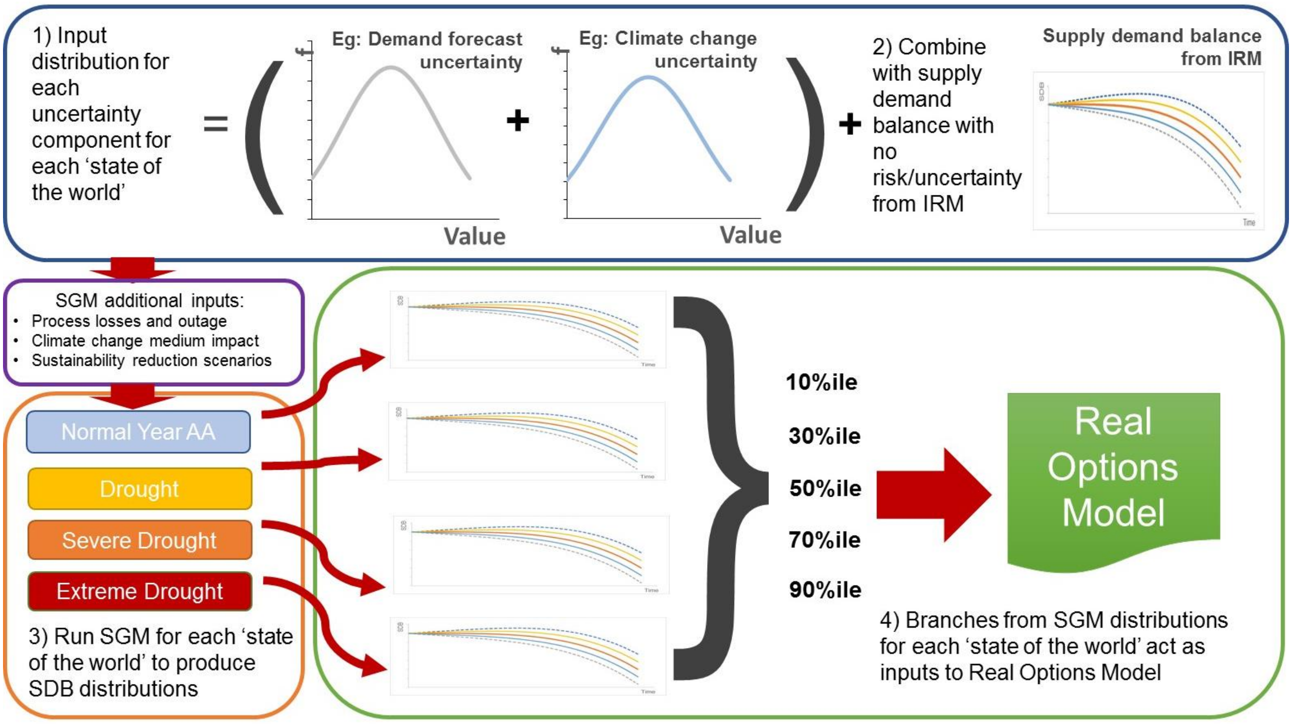
The model uses a Monte Carlo simulation approach and incorporates the supply and demand-side risks and uncertainties included within the IRM, in addition to the future uncertainty of the impact of sustainability reductions. The model was developed in Excel using the Monte Carlo platform @RISK. There is no double counting of uncertainty with the IRM because the only output used from the IRM is the SDB with no uncertainty. The estimate of target headroom generated from the IRM is used for regulatory reporting only, and not as an input to the decision-making model.

The SGM produces an estimate of the WRZ-level SDB at seven 'states of the world' across the planning period (2016-17 to 2069-70). These are as follows:

- Normal year annual average
- 'Drought': 1 in 20 year drought at MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas)
- 'Severe drought': 1 in 200 year drought at MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas)
- 'Extreme drought': 1 in 500 year drought MDO (Central and Western areas) or ADO (Eastern area) and PDO (all areas)

These 'states of the world' are further discussed in Annex 8.

Figure 33 – Schematic showing how the SGM uses uncertainty input distributions and the results of the IRM to produce various scenarios for investment modelling



4.4.2 Timesteps

The SGM includes annual timesteps up to 2029-30 in order to capture the impact of the introduction of a number of potential sustainability reductions in 2027-28 on the SDB. Following this, it uses five year timesteps from 2029-30 to 2069-70.

4.4.3 Inputs and model structure

The inputs to the SGM are summarised in Table 10 below:

Table 10 Summary of inputs to the SGM

Input	Description
Supply-demand balance with no uncertainty	Estimate of the supply-demand balance at each state of the world for each WRZ without any allowance for uncertainty components S4, S6, S8, D1 and D2. This value is added to the supply-demand balance. Output from the IRM.
DO	DO at each state of the world for each WRZ. The methodology used to produce an estimate of the DO is described in Annex 3. This input is used for the supply-side uncertainty distributions only, as supply and demand at the relevant state of the world are already included in the supply-demand balance with no risk and uncertainty.
Demand forecast	The demand forecast at each state of the world for each WRZ. The NYAA forecast was used for the NYAA state of the world; for all other states the DYMDO, DYAA or DYCP demand forecasts were used as appropriate. This input is used for the demand-side uncertainty distributions only, as supply and demand at the relevant state of the world are already included in the supply-demand balance with no risk and uncertainty. Annex 2 provides a summary of how these forecasts were developed.
Outage	A deterministic allowance for outage was included in the model. For the draft WRMP the same MDO/ADO or PDO value was used for all drought return periods. For the revised draft WRMP, different outage forecasts were developed for the normal year and 1 in 20 year droughts, and for the 1 in 200 year droughts upwards, to reflect the assumption that outage is likely to be slightly lower under more severe droughts. The two sets of values diverge from 2024 onwards, and for the revised draft and final plan there is assumed to be no difference between MDO/ADO and PDO conditions for outage. The outage value is subtracted from the supply-demand balance. Annex 3 provides a summary of how the outage estimates were developed.
Process losses	A deterministic allowance for process losses was included in the model. The same MDO/ADO or PDO value was used for drought all return periods, in the absence of data showing how process losses would vary during different drought conditions. This value is subtracted from the supply-demand balance. Annex 3 provides a summary of how the process loss estimates were developed.
Sustainability reductions	As this is a key area of uncertainty for the company, the impact of future sustainability reductions at a WRZ level was modelled using a discrete uncertainty distribution. Different values were used for each state of the world where appropriate. The calculated value is subtracted from the supply-demand balance. Further explanation of the assumptions used is provided below.
Baseline DO loss due to climate change	The medium climate change impact in each year of the planning period is included as a deterministic allowance which varies according to the state of the world. This value is subtracted from the supply-demand balance. For some WRZs the medium climate change impact estimate was a gain in DO for some states of the world, which was represented as a negative value. Annex 3 provides an explanation of how the estimates of climate change impacts were developed.

Input	Description
S4: Bulk imports	The same input values and distribution were used as for the IRM, although the values are reduced for the extreme drought scenario as the full volume might not be available. This value is subtracted from the supply-demand balance.
S6: Accuracy of supply-side data	The same input values and distribution were used as for the IRM. Where previous analysis showed that the level of uncertainty associated with the DO estimate varied with drought severity, different values were used for each state of the world in accordance with the IRM. This value is added to the supply-demand balance.
S8: Uncertainty of impact of climate change on source yields	As with the IRM, a triangular distribution was used to model the uncertainty in the estimate of the baseline DO loss (or gain) due to climate change. An estimate of the 'dry' climate change scenario and 'wet' climate change scenario DO loss was used to calculate impacts for each year of the planning period. Whereas the IRM used the 1 in 200 year uncertainty values, within the SGM the level of uncertainty adopted differed between states of the world in many cases, based on the outputs of the climate change modelling. This ensured that the range of supply-demand balances at each state of the world was fully represented. Annex 3 provides an explanation of how the estimates of climate change impacts were developed. This value is added to the supply-demand balance as the dry scenario is represented by negative values and the wet scenario by positive values.
D1: Accuracy of sub-component data	As with the IRM, a percentage uncertainty of ± 3% (around a mean of zero) was used to represent the accuracy of sub-component demand data, as this is the typical uncertainty of a flow meter reading. The same percentage uncertainty was used for all states of the world, as there is no evidence that this value is dependent on drought severity. This value is subtracted from the supply-demand balance.
D2: Demand forecast variation	The same input values and distribution were used as for the IRM. The NYAA uncertainty estimates were used for the NYAA state of the world; for all other states the DYMDO, DYAA or DYCP demand forecast uncertainty estimates were used. This value is subtracted from the supply-demand balance as the minimum scenario is represented by negative values and the maximum scenario by positive values.

4.4.4 Sustainability reductions

We have used a real options modelling approach to examine the impact of the future uncertainties, based on a sampling of the SDB probability distributions. One of the main sources of uncertainty in the SDB is in relation to the magnitude and timing of future potential sustainability reductions.

The EA requested that companies consider three sustainability scenarios. We refer to these as 'cases' to distinguish them from the four alternative sustainability scenarios we considered for our Western area in the draft WRMP. The EA criteria for these three cases, and the approach we have taken to our assessment, are summarised later in this section and explained in more detail in Annex 3.

Three cases for inclusion of unconfirmed sustainability reduction have been developed for each WRZ (Lower, Middle and Upper). These are represented in the SGM using discrete distributions, with an assumption regarding the likelihood of each case.

Table 11 and Table 12 below provide an overview of the approach and values used for the three sustainability reduction cases. For the Central and Eastern areas, a **25%** likelihood was assigned to each of the Lower and Middle scenarios, and **50%** to the Upper scenario.

For the Western area for the draft WRMP, different versions of the SGM were created for each WRZ and for each case (Lower, Middle and Upper), each with a likelihood of **100%.** This enabled the real options model branches for the Western area to be based on specific sustainability reductions rather than sampling from the overall SDB distribution.

However, for the revised draft and final WRMP, to reflect representations received in the consultation and for consistency with the Eastern and Central areas, the approach was changed to be the same as that used for the Central and Eastern areas (ie combined SDBs with **25%** likelihood assigned to each of the Lower and Middle cases, and **50%** to the Upper case). The branches within the investment model for the Western area are therefore based on the same approach as for the Central and Eastern areas for the revised draft and final plan (see section 4.4.6 below).

A summary of the approach used to derive the Lower, Middle and Upper sustainability reduction values is provided below, and is also described in detail in Annex 3.

The Water Industry National Environment Programme (WINEP)
The EA issued a programme for three formal PR19 WINEP releases between March 2017 and March 2018:

- WINEP 1: Released on 31 March 2017
- WINEP 2: 29 September 2017
- WINEP 3: 30 March 2018

In the lead up to WINEP 1, the EA worked with water companies to understand the need for sustainability investigations and reductions through review of EA data. This 'sustainable catchments' plan was initiated at a national workshop in September 2016 and an associated release of guidance with a spreadsheet of data for each company. Further clarifications and guidance were issued through to January 2017.

Sustainable catchments – Southern Water's review
Having reviewed the EA guidance and spreadsheet, we provided our proposed approach to EA national co-ordinators and Area staff for comment. No major comments were received so we progressed our assessment and met with Area teams in November and December 2016 to discuss

initial results. Taking account of additional guidance and discussions with national specialists in January 2017, further meetings were held with Area teams in February 2017. The outcomes from this process informed WINEP 1 which was issued in March 2017. Every Southern Water source is split into points (eg representing boreholes), each with a type of measure and level of confidence. These are classified according to EA Guidance into:

- Green [Certain] – water company action is needed, with clarity on required measure
- Amber [Indicative] – water company action is needed, but suggested measure awaiting decision on affordability
- Red [Unconfirmed] – water company action is needed, but measure not yet clear

The vast majority of abstraction points are assigned to 'investigation and options appraisal' in the 'certain' category, yet this does not mean a certain sustainability reduction.

Incorporating confirmed and unconfirmed sustainability changes into WRMP19

In its guidance issued in June 2017, the EA provided further information about how water companies should assess sustainability reductions in their plans. The guidance requested that companies consider three sustainability scenarios, which we have called 'cases'. The three cases are:

- A Lower case that includes only green sustainability changes; assumed to have a 25% probability
- A Middle case that includes green and amber sustainability changes and a pragmatic estimate of the red sustainability changes; assumed to have a 25% probability
- An Upper case that includes green, amber and red sustainability changes and a pragmatic estimate of any further sustainability changes that may be required following investigations and options appraisals, or driven by future legislation or requirements assumed to have a 50% probability

The probability assumed for the three different sustainability reduction cases reflects our experiences of the sustainability reductions process over the last few AMP cycles. For example, we were unable to include a sustainability reduction for the Test in our draft WRMP14 (published in May 2013), yet by the time of the next draft plan for WRMP19, we faced the prospect of a licence change leading to the full loss of DO of this source, which then materialised when the licences were changed in March 2019. This had a significant impact on the SDB for the Hampshire Southampton WRZs within a short five year timeline. We believe our approach is therefore a reasonable and pragmatic attempt to account for the uncertainty around potentially very significant impacts of sustainability reductions on our SDB.

The timing of most of the sustainability reductions is another critical factor. The unconfirmed sustainability reductions are assumed to occur in 2027 (in line with the WFD timeline). This does not allow much time to plan for and develop new resources to address the deficits that would result. Through our real options modelling, we can assess how these and other uncertainties related to growth and climate change, may affect the plan, and select a preferred plan that can address whichever "future" we actually end up with.

Regarding further sustainability changes for inclusion in the 'Upper case', the guidance noted that these may be required to:

- Prevent deterioration of water body status (where investigations are proposed for AMP7);
- Meet WFD environmental objectives for 2027;
- Meet protected area revised Common Standards Monitoring Guidance requirements for flow; and
- Implement requirements of the Salmon 5 point approach.

For the draft WRMP we considered, in combination: the June 2017 guidance; the WINEP 1 spreadsheet; and the additional discussions on Western area sustainability reductions. Based on these, we set out our proposed approach for assessing sustainability reduction scenarios and discussed these with the EA in several pre-consultation meetings between May and October 2017.

As indicated in Annex 3, WINEP 1 did not have any green or amber sustainability changes and had just four licences listed as red sustainability changes. In addition to the generic guidance, we met with the EA to discuss specific sustainability reduction scenarios for the Western area in light of the Section 52 notices received.

A challenge we faced was how to estimate potential DO reductions, particularly for the 'Upper case' which was to include 'a pragmatic estimate of any further sustainability changes that may be required following investigations and options appraisals, or driven by future legislation or requirements'.

The approach we took for the sustainability reduction scenario assessment, based on our proposed method and feedback from the EA, is summarised in Annex 3. For the revised draft WMRP we reviewed the changes from WINEP 1 to WINEP 3. In WINEP 3 further details were specified for investigations on the River Test and River Itchen. In addition, there were changes in the level of certainty assigned to some investigations or completion dates. However, there were no new sustainability reductions identified from our review, so no need to change the assumptions for the revised draft or final WRMP from those we had applied to the draft WRMP. These are summarised below in Table 11.

Table 12 below summarises the WRZ-level sustainability reductions for each WRZ and area under the above three cases. There have been some minor reductions to some of the calculated sustainability reduction values between the draft and revised draft WRMP; these are driven by changes to DO for several sources and a correction to the formula used to calculate the sustainability reduction at Fawkham (Kent Medway West WRZ).

For the revised draft plan, following the outcome of the Western Public Inquiry in March 2018 an additional sustainability reduction on the Itchen from 2024 was included in the Lower case (and thereby also in the Middle and Upper cases) as part of the DO figures. At the end of the Inquiry the EA referred to in their closing statements, the prospect of further review of the proposed hands off flow conditions on the River Itchen licences at the point of intended renewal in 2024. Whilst these revisions still have to be investigated during the next AMP (2020-2025) the last independent review of the hands off flow conditions proposed a flow condition of 224Ml/d, which is higher than the current proposed conditions of 198Ml/d. Therefore in order to have long-term regard to an anticipated further reduction in abstraction we used this estimate of 224Ml/d as the potential new hands off flow condition on the river Itchen licence in order to assess the likely impact on the supply forecast post 2024. This ensured that the solutions we are developing for the Western supply area are capable of accommodating this additional change to the licence over and above those which have been proposed and agreed during the Inquiry.

For the final WRMP, as instructed by Defra in its letter dated 19 March 2019, we have revised this assumption, and have instead included the uncertainty associated with this further sustainability reduction through including it in the Middle and Upper cases only. This is consistent with the consideration of other uncertain and unconfirmed sustainability reduction in our plan, across all supply areas. The impacts of this change in assumption on the preferred plan are described in Annex 9.

Table 11 Overview of approach used to incorporate sustainability reduction uncertainty

Sustainability reduction case	EA Guidance	Southern Water WINEP1 and changes in WINEP3	Southern Water's approach
Lower case	Only Green sustainability changes	None WINEP3: No changes from WINEP1	Itchen and Lower Test
Middle case	Green and Amber sustainability changes plus pragmatic estimate of Red sustainability changes	No Green or Amber. Red: Lower Test, Pillhill Brook and Lukely Brook WINEP3: No changes from WINEP1	Above plus: • Andover to recover to EFI*. • Newport and Lukely Brook to recover to EFI. • Alresford and Winchester recover to EFI. • An additional sustainability reduction on the Itchen in 2024**.
Upper case	Above plus a pragmatic estimate of sustainability reductions following Investigation / Options Appraisal or 'future legislation or requirements'	Southern Water has 103 abstractions on its 'DO list' (including some with zero DO) Only 13 are not listed in WINEP with Green or Red Investigation / OA WINEP3: For some investigations - a change to green 'certainty' or completion date - but no changes made to assumptions relative to the draft WRMP	It is assumed that: 1. Abstraction rates may be capped at Recent Actual (RA)*** rates for licences impacting on EFI non-compliant WFD river water bodies 2. Further reductions may be required to lower than RA rates to provide Southern Water-proportionate reductions to return to EFI Licences in North Kent Marshes investigations mostly impact on 'marginal' water bodies which do not have EFIs. We have therefore assumed an indicative 10% reduction across the relevant WRZs. The additional Itchen sustainability reduction is included under the Upper as well as the Middle case for Hampshire Southampton East WRZ.

* Environmental Flow Indicators (EFIs) demonstrate where abstraction pressure may start to cause an undesirable effect on river habitats and species. The EA have indicated that they will be applied as a default basis for licensing unless there is agreed location information that defines a more local flow constraint to support Good Ecological Status and objectives given in the River Basin Management Plan.
** Included under all three cases for the revised draft WRMP, but only under the Middle and Upper case for the final WRMP, as instructed by Defra in its letter dated 19 March 2019.
*** Recent Actual (RA) abstraction rates are the average abstraction seen in the six year period 2007-2013.

Table 12 Summary of sustainability reductions by WRZ and area (1 in 200 year return period)

WRZ	Lower case	Middle case	Upper case
Hampshire Andover	None	Andover to recover to EFI 1:200 year MDO: 11.5Ml/d 1:200 year PDO: 15.4Ml/d	As Middle
Hampshire Kingsclere	None	None	1:200 year MDO: 2.9Ml/d 1:200 year PDO: 2.9Ml/d
Hampshire Rural	None	None	1:200 year MDO: 0.3Ml/d 1:200 year PDO: 0.3Ml/d
Hampshire Southampton East	Itchen, Twyford. Included in baseline DO figures. Varies by return period. 1:200 year MDO: 60.7Ml/d 1:200 year PDO: 47.1Ml/d	Itchen (including additional sustainability reduction in 2024), Twyford. Included in baseline DO figures, except for the additional sustainability reduction in 2024. Varies by return period. From 2017-18: 1:200 year MDO: 60.7Ml/d 1:200 year PDO: 47.1Ml/d 2024-25 onwards*: 1:200 year MDO: 86.7Ml/d 1:200 year PDO: 73.1Ml/d	As Middle
Hampshire Southampton West	Lower Test. Included in baseline DO figures. Varies by return period. From 2017-18: 1:200 year MDO: 105.0Ml/d 1:200 year PDO: 78.3Ml/d From 2027-28: 1:200 year MDO: 105.0Ml/d 1:200 year PDO: 105.0Ml/d	As Lower	As Lower
Hampshire Winchester	None	Winchester and Alresford limited to Recent Actual abstraction 1:200 year MDO: 11.2Ml/d 1:200 year PDO: 12.3Ml/d	As Middle

WRZ	Lower case	Middle case	Upper case
Isle of Wight	None	Newport and Lukely Brook to recover to EFI Varies by return period 1:200 year MDO: 7.7Ml/d 1:200 year PDO: 10.6Ml/d	Varies by return period 1:200 year MDO: 10.5Ml/d 1:200 year PDO: 17.5Ml/d
Western area total	Itchen, Twyford, Lower Test. Included in baseline DO figures. Varies by return period. 2017-18 to 2026-27: 1:200 year MDO: 165.7Ml/d 1:200 year PDO: 125.4Ml/d 2027-28 onwards: 1:200 year MDO: 165.7Ml/d 1:200 year PDO: 152.1Ml/d	As Lower, plus additional Itchen sustainability reduction, Andover, Newport, Lukely Brook, Winchester and Alresford Varies by return period 2017-18 to 2023-24: 1:200 year MDO: 165.7Ml/d 1:200 year PDO: 125.4Ml/d 2024-25 to 2026-27: 1:200 year MDO: 191.7Ml/d* 1:200 year PDO: 151.4Ml/d* 2028-29 onwards: 1:200 year MDO: 222.0Ml/d* 1:200 year PDO: 216.4Ml/d*	Varies by return period 2017-18 to 2023-24: 1:200 year MDO: 165.7Ml/d 1:200 year PDO: 125.4Ml/d 2024-25 to 2026-27: 1:200 year MDO: 191.7Ml/d* 1:200 year PDO: 151.4Ml/d* 2028-29 onwards: 1:200 year MDO: 228.0Ml/d* 1:200 year PDO: 226.5Ml/d*
Sussex Brighton	None	None	Varies by return period 1:200 year MDO: 23.3Ml/d 1:200 year PDO: 27.6Ml/d
Sussex Worthing	None	None	Varies by return period 1:200 year MDO: 20.0Ml/d 1:200 year PDO: 27.4Ml/d
Sussex North	None	None	Varies by return period 1:200 year MDO: 9.1Ml/d 1:200 year PDO: 17.1Ml/d
Central area total	None	None	Varies by return period 1:200 year MDO: 52.4Ml/d 1:200 year PDO: 72.1Ml/d

WRZ	Lower case	Middle case	Upper case
Kent Medway East	None	None	Varies by return period 1:200 year MDO: 8.4Ml/d 1:200 year PDO: 9.7Ml/d
Kent Medway West	None	None	Varies by return period 1:200 year MDO: 5.0Ml/d 1:200 year PDO: 5.8Ml/d
Kent Thanet	None	None	Varies by return period 1:200 year MDO: 8.4Ml/d 1:200 year PDO: 11.4Ml/d
Sussex Hastings	None	None	None
Eastern area total	None	None	Varies by return period 1:200 year MDO: 21.8Ml/d 1:200 year PDO: 26.9Ml/d

*Includes additional sustainability reduction on the Itchen from 2024

4.4.5 Dependencies

The real options modelling approach used recognises that there are a range of different futures that we need to take into account for the WRMP. The different futures reflected in the SGM include uncertainties relating to supply, demand, climate change impacts and future sustainability reductions. There are potential dependencies between some of these components; for example, a high climate change impact future may lead to more sustainability reductions being implemented. It has been possible to quantify some of these dependencies, whereas others are more challenging to quantify at present, particularly those that relate to future policy decisions rather than physical or meteorological phenomena. In future plans it may be possible to quantify some of these dependencies.

The following dependencies have been included in the overall IRM and SGM modelling approach:

- The dependency between supply and demand variability has been included in the modelling using a negative correlation coefficient of -0.6 in the IRM (see section 4.3.3). The resulting SDBs at different return periods are used as inputs to the SGM
- The dependency between drought severity and yield uncertainty has been built into the IRM and SGM modelling through the use of different distributions for each drought return period, where suitable data were available
- The dependency between drought severity, medium climate change impact on supply and the uncertainty of the impact of climate change on supply has been built into the SGM modelling through the use of different medium values and distributions for each drought return period
- The dependency between drought severity and the magnitude of potential sustainability reductions has been built into the SGM modelling, with the uncertainty distribution used being dependent on drought return period

4.4.6 Outputs

The outputs from the SGM are the WRZ-level SDBs for each state of the world from the 0th to 100th percentile, at percentile intervals of 5%. These SDBs represent the range of potential futures for different drought conditions that the company must take into consideration.

The SDB used prior to 2027 is based on the 50th percentile. Beyond this there is a greater degree of uncertainty in the SDB and therefore the 10th, 30th, 50th, 70th and 90th percentiles are used as inputs to the real options model. This ensures that a realistic range of plausible future deficits can be planned for. Annex 8 provides further detail on how the branches have been applied in the real options model. The results are summarised in the 'SDB' section below, along with the differences between the draft and revised draft figures.

4.4.7 Relative contribution of different sources of uncertainty

In addition to the annual variability of supply and demand, there are a number of sources of uncertainty that contribute to the overall SDB, as described above. These include:

- S4 – Uncertainty in the availability of bulk supplies
- S6 – Uncertainty over the accuracy of the supply side data
- S8 – Supply-side climate change uncertainty
- D1 – Uncertainty over the accuracy of the sub-component demand data
- D2 – Demand forecast uncertainty
- Uncertainty over the impact of sustainability reductions

In order to understand the relative contribution of different sources of uncertainty, a sensitivity analysis was undertaken of the SDB results from the SGM. This was done primarily by looking at either the 10th or 90th percentile value of each individual source of uncertainty listed above, and comparing their relative magnitude. The choice of the percentile for each component was designed to show a 'pessimistic' SDB scenario, with a negative impact on the SDB. This is summarised in Table 13.

Table 13 The percentiles analysed for each source of uncertainty

Source of uncertainty	Percentile selected	Justification
S4	90th	This uncertainty component has a minimum of zero, so the 90th percentile represents a negative impact on the SDB (ie a loss of supply). However, as this impact is set to occur at the 95th percentile and above, the impact at the 90th percentile is zero.
S6	10th	This component is represented by a normal distribution with a mean of zero. The 10th percentile represents a low supply value and therefore a negative impact on the SDB.
S8	10th	This component is represented by a triangular distribution, with the minimum value representing the dry climate change scenario, and the maximum value representing the wet climate change scenario. The 10th percentile therefore represents a negative impact on the SDB.
D1	90th	This component is represented by a normal distribution with a mean of zero. The 90th percentile represents high DI value and therefore a negative impact on the SDB.
D2	90th	This component is represented by a triangular distribution, with the minimum value representing the minimum demand forecast, and the maximum value representing the maximum demand forecast. The 90th percentile therefore represents a high demand forecast and subsequently a negative impact on the SDB.
Sustainability Reductions	90th	This uncertainty component has a minimum of zero, so the 90th percentile represents a negative impact on the SDB (ie a loss of supply).

The results can be seen in Figure 34 to Figure 37, which show the relative impact on the SDB of each modelled component of uncertainty at the selected percentiles in 2020-21 and 2069-70 at the 1 in 200 year drought level.

At the start of the planning period (2020-21), S8 (uncertainty of climate change impact on supply) dominates the relative impact on the SDB for the Western area at MDO and PDO, whereas S6 (accuracy of supply-side data) is dominant in the Eastern and Central areas at the selected percentiles at ADO/MDO and PDO.

By the end of the planning period the potential implementation of additional sustainability reductions represents the greatest source of uncertainty for all areas at ADO/MDO and PDO. This differs from the draft plan, for which D2 (demand forecast uncertainty) was a more dominant influence, particularly in the Western area at MDO at the start of the planning period and for the Western and Eastern areas at the end of the planning period at ADO/MDO. This reduction in relative importance relates to the change in demand forecast scenarios used for the demand forecast uncertainty distribution for the revised draft and final plan, which is described in section 4.3.3 above and shown in Table 7 and Table 8.

Figure 34 Relative impact of each source of uncertainty on the SDB (Ml/d) in 2020-21 for Dry Year MDO/ADO for a 1 in 200 year drought at the selected percentiles [see Table 13]

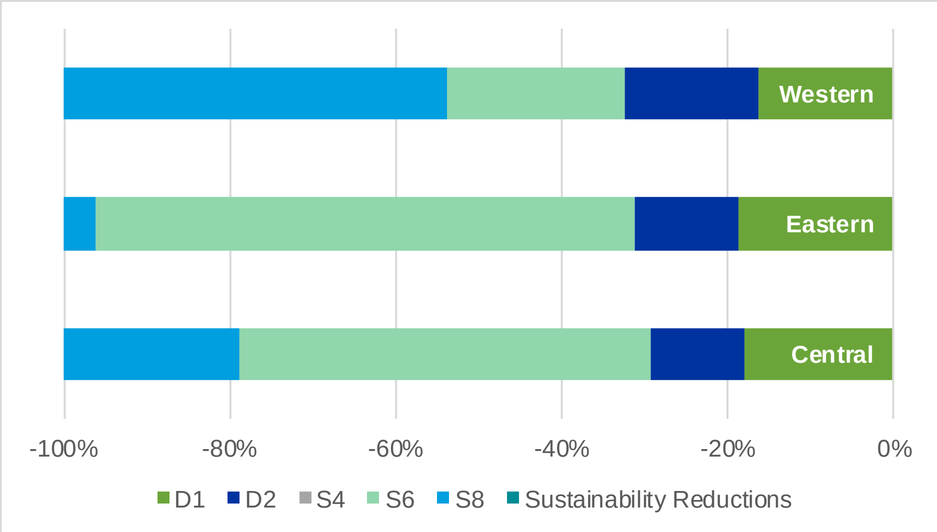


Figure 35 Relative impact of each source of uncertainty on the SDB (Ml/d) in 2069-70 for Dry Year MDO/ADO for a 1 in 200 year drought at the selected percentiles [see Table 13]

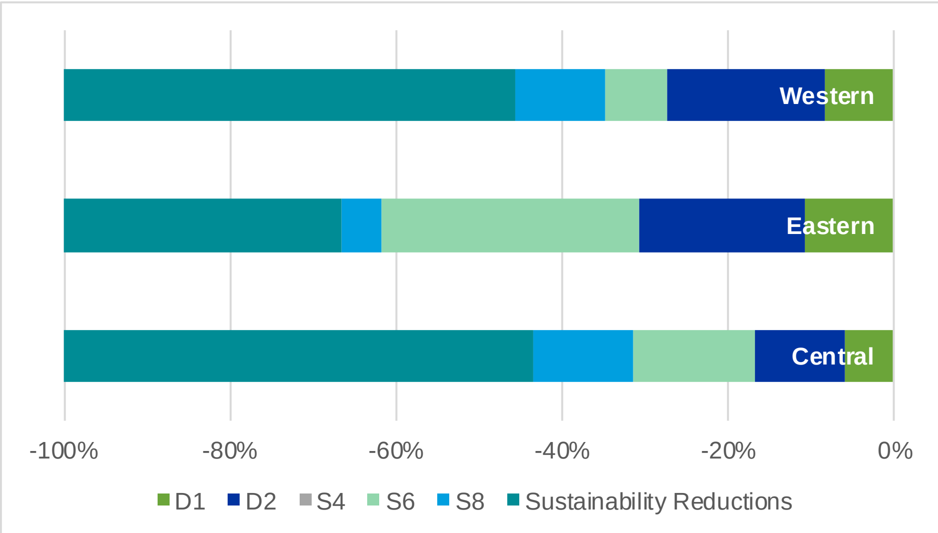


Figure 36 Relative impact of each source of uncertainty on the SDB (Ml/d) in 2020-21 for Dry Year PDO for a 1 in 200 year drought at the selected percentiles [see Table 13]

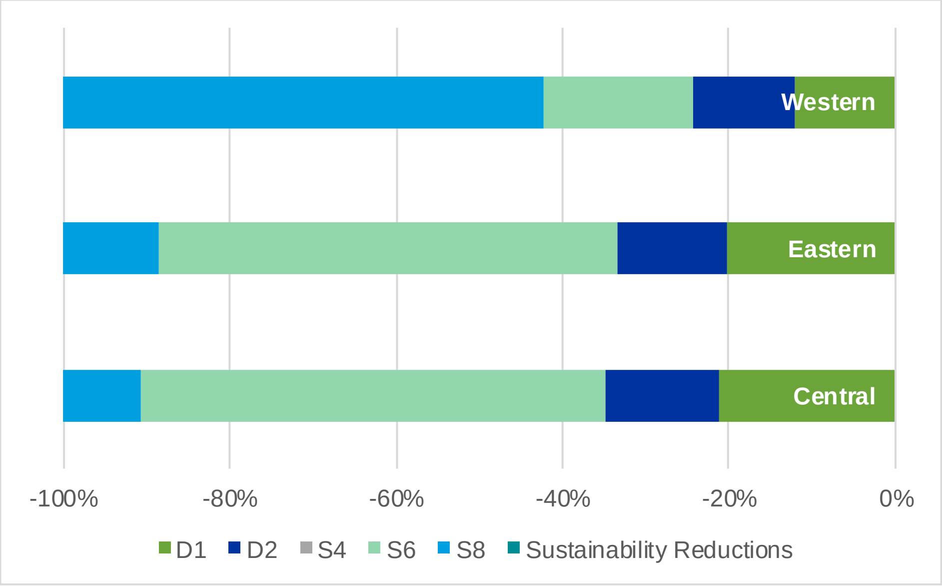
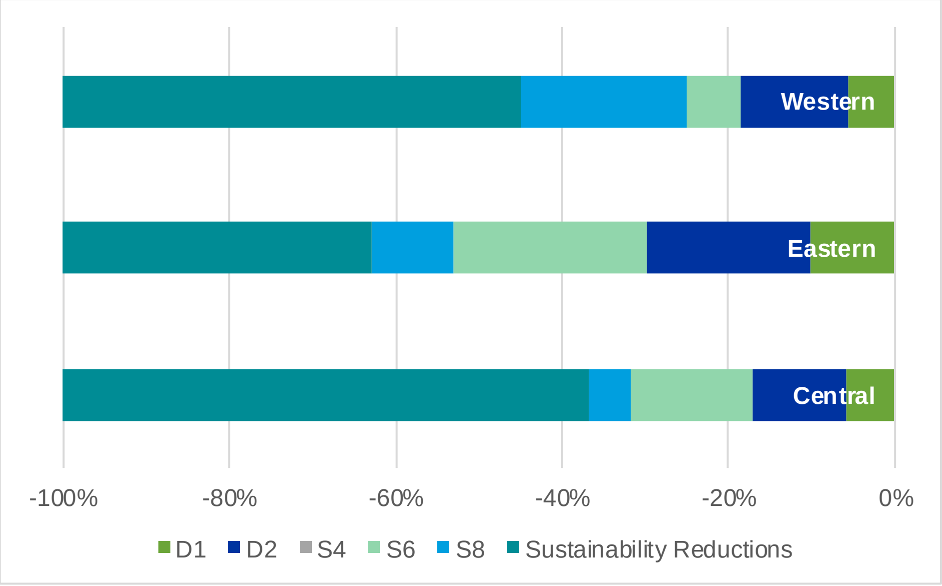


Figure 37 Relative impact of each source of uncertainty on the SDB (Ml/d) in 2069-70 for Dry Year PDO for a 1 in 200 year drought at the selected percentiles [see Table 13]



5. Supply-demand balance

The section presents the overall baseline SDBs that are used as inputs to the real options analysis.

5.1 Central area

5.1.1 Differences between the draft WRMP and final WRMP

Figure 38 and Figure 39 show the change in the 50th percentile SDB at the severe drought level at MDO and PDO respectively between the draft plan and revised draft plan. Both figures show an overall higher SDB for the revised draft plan with the difference steadily increasing throughout the planning period.

At MDO this increase is predominantly driven by the reduced outage forecast in Sussex Brighton WRZ and Sussex North WRZ, a larger baseline DO gain due to climate change for Sussex Brighton WRZ and Sussex Worthing WRZ, a less severe ‘dry’ climate change scenario for Sussex North WRZ and a lower demand forecast for Sussex Worthing WRZ.

At PDO this increase is predominantly driven by a DO correction and lower baseline climate change loss in Sussex North WRZ, a reduction in the outage forecast for all three zones, a larger baseline DO gain due to climate change and lower demand forecast for Sussex Worthing WRZ and a less severe ‘dry’ climate change scenario for Sussex Brighton WRZ.

Further information on the changes in the individual SDB components is provided in Annexes 2 and 3.

There is no change from the revised draft WRMP.

Figure 38 Central area SDBs relative to the draft WRMP - MDO 50th percentile

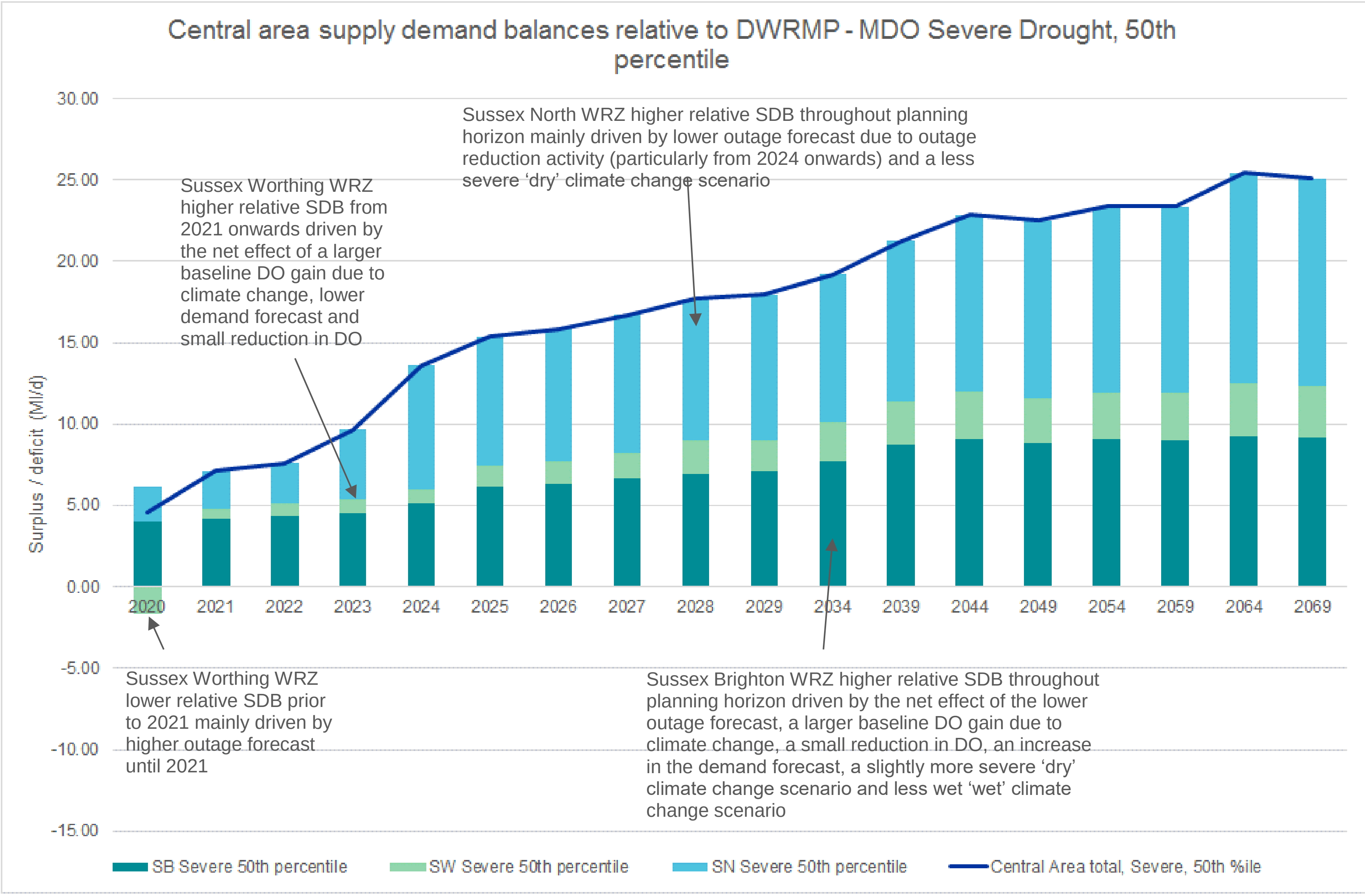
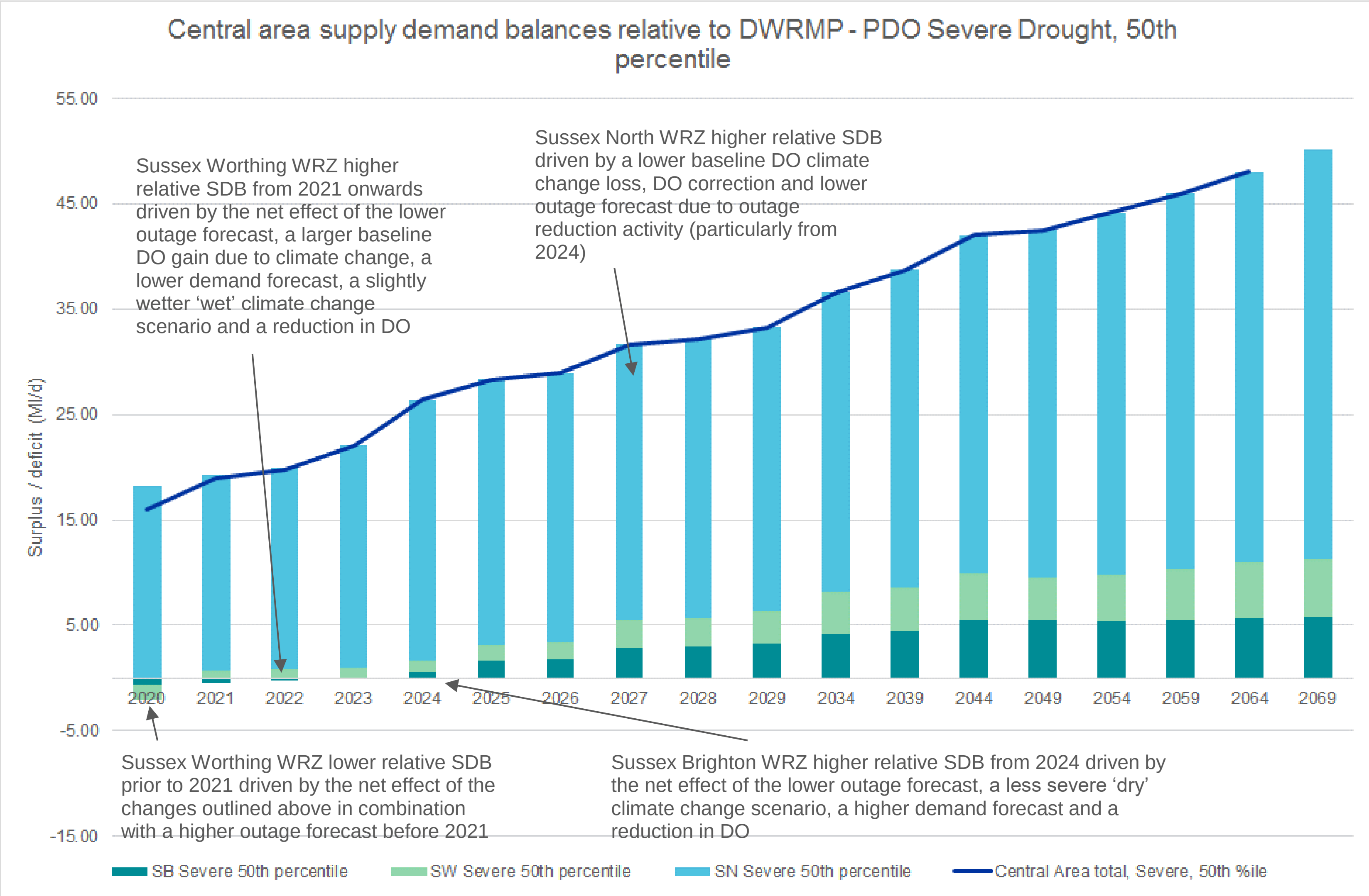


Figure 39 Central area SDBs relative to the draft WRMP - PDO 50th percentile



5.1.2 Summary of results

Figure 40 and Figure 41 show the baseline SDB distribution at MDO and PDO respectively. As with the integrated risk model (IRM) outputs, these are shown as 'plume plots'. As the SGM runs multiple (100,000) iterations, it produces a range of results, the distributions of which are shown in these 'plume plots'. The percentile bands show the likelihood that the SDB will be equal to or lower than a certain value. For example, in Figure 40, by 2069-70, 30% of the model iterations produced an SDB below -66Ml/d (ie a deficit) for the Central area at MDO, and 70% of model iterations produced an SDB greater than this. There is therefore a 30% probability that the SDB will be in deficit by around -66Ml/d or lower, and a 70% probability that it will be higher than this.

It should be noted that except where indicated, these SDBs do not include bulk supplies or DO write-downs due to nitrate and pesticide impacts, as these have been included within the investment model as options. The DO write-downs due to nitrate and pesticide impacts are summarised in Annex 3 and shown in section 3 at area level.

The results show that there is a forecast deficit from 2020-21 onwards below the 90th percentile at MDO, and below the 35th percentile at PDO. At the 50th percentile, there is a deficit of -16.5Ml/d in 2020-21 at MDO and a surplus of 7.7Ml/d at PDO, reducing to -42.2Ml/d at MDO and -32.2Ml/d at PDO by the end of the planning period. The sharp reduction in the SDB in 2027-28 is due to the modelled impact of potential sustainability reductions.

The 50th percentile 1 in 200 year SDB is slightly lower at MDO at the start of the planning period than the equivalent WRMP14 SDB forecast for 2020-21, which was -11.2Ml/d, and slightly higher at PDO, which was -4.5Ml/d. The reduction in the forecast SDB at MDO and slight increase at PDO at the start of the planning period compared to WRMP14 is due to the net impact of a number of individual SDB components. These can be summarised as follows:

- The DO forecast is lower at both MDO and PDO for the revised draft WRMP19 than for WRMP14 by 6.1Ml/d and 12.1Ml/d respectively
- The dry year demand forecast is higher at MDO (by 10.3Ml/d) and lower at PDO (by 10.6Ml/d) for the revised draft WRMP19 compared to WRMP14
- Process losses are higher at MDO and PDO for the revised draft WRMP19 compared to WRMP14 by 1.7Ml/d and 1.0Ml/d respectively
- Outage is higher at MDO and PDO for the revised draft WRMP19 compared to WRMP14 by 6.8Ml/d and 4.0Ml/d respectively
- Medium climate change impacts are lower at MDO (by 2.6Ml/d) and PDO (by 0.8Ml/d) for the revised draft WRMP19 compared to WRMP14

Overall, for MDO the impact of the lower DO and higher demand forecast, process losses and outage forecasts outweigh the lower climate change impact. At PDO, the lower DO, higher process losses and outage slightly exceed the impact of the lower demand forecast and climate change impacts. The reasons for the changes in each component are discussed in Annexes 2 and 3.

In the Central area, the net impact of bulk supplies is positive (+9.6Ml/d) throughout the planning period at MDO and PDO. This is the same value included in the WRMP14 baseline SDB. The WRMP19 baseline SDB distribution including bulk supplies is shown in Figure 42 below. This reduces the deficit such that there is a forecast deficit from 2020-21 onwards below the 70th percentile at MDO. However, at the 50th percentile there is still a deficit at from start of the planning period at MDO, although there is a slight surplus from 2024-25 to 2026-27. There are several Drought Orders and Permits available to address the deficit, although these have not been included in the baseline SDB as they are included within the feasible options set.

Figure 40 Baseline SDB distribution at the 'severe drought' level for Central area MDO

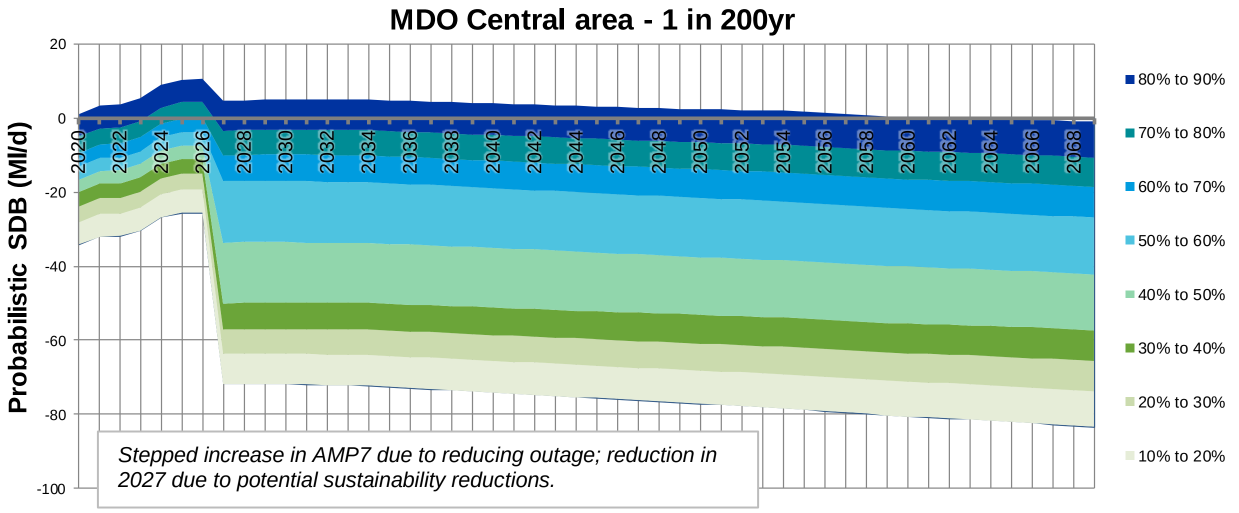


Figure 41 Baseline SDB distribution at the 'severe drought' level for Central area PDO

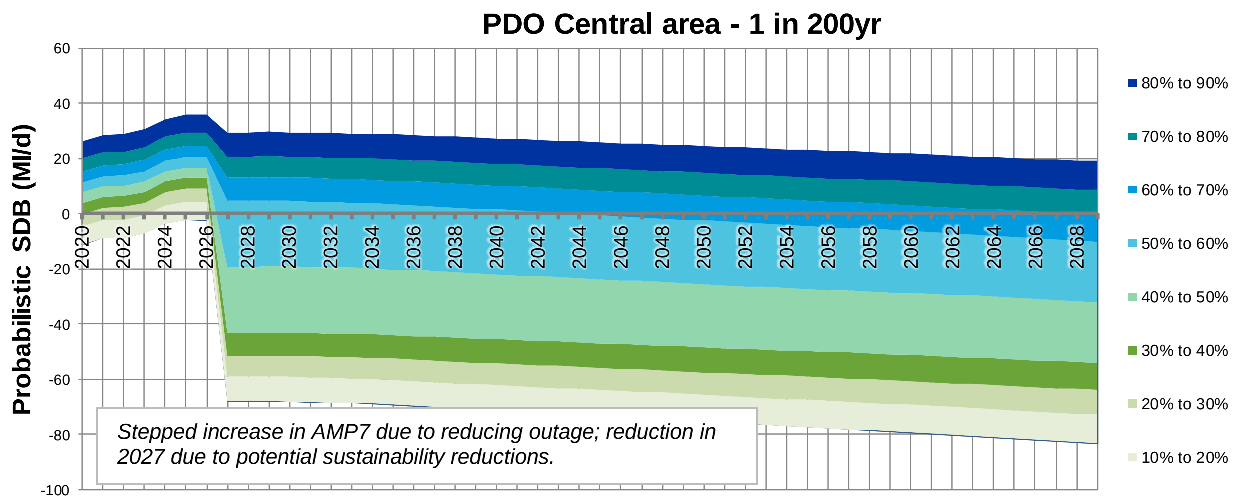
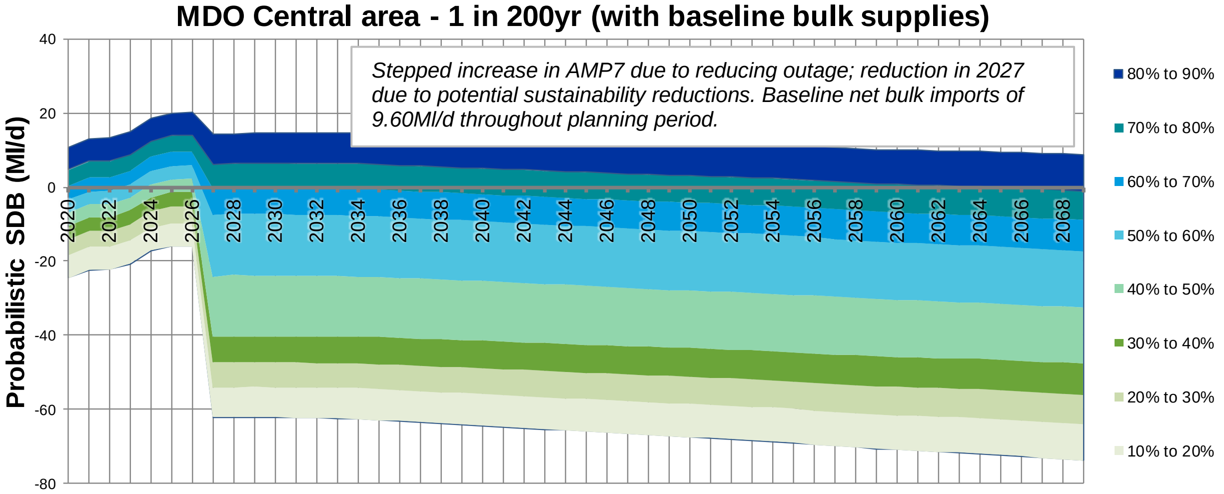


Figure 42 Baseline SDB distribution at the 'severe drought' level for Central area MDO with baseline bulk supplies



5.2 Eastern area

5.2.1 Differences between the draft WRMP and final WRMP

Figure 44 and Figure 45 show the change in the 50th percentile SDB at the severe drought level at ADO and PDO respectively between the draft plan and revised draft plan. At ADO the total Eastern area SDB is lower for the revised plan than the draft plan until 2026, from which point the SDB for the revised plan is higher. The lower SDB for the revised plan until 2026 is predominantly driven by the higher outage forecast for Kent Thanet WRZ, Kent Medway West WRZ and Kent Medway East WRZ, lower DO, higher demand forecast and lower baseline climate change gain for Kent Medway East WRZ.

After 2026 the higher relative SDB is driven by a lower outage forecast for Kent Thanet WRZ, Sussex Hastings and the net impact of a higher demand forecast, slightly lower DO, lower outage and slightly lower Upper sustainability reduction impact for Kent Medway West WRZ.

At PDO the SDB for the revised draft plan is lower throughout the planning horizon than for the draft plan. This is predominantly driven by the higher outage forecast for Kent Medway East WRZ, Kent Thanet WRZ and Kent Medway West WRZ (prior to 2025), lower DO in all zones and higher demand forecast in Kent Medway East WRZ, Kent Medway West WRZ and Kent Thanet WRZ.

Further information on the changes in the individual SDB components is provided in Annexes 2 and 3.

There is no change from the revised draft WRMP.

Figure 43 Eastern area SDBs relative to the draft WRMP - ADO 50th percentile

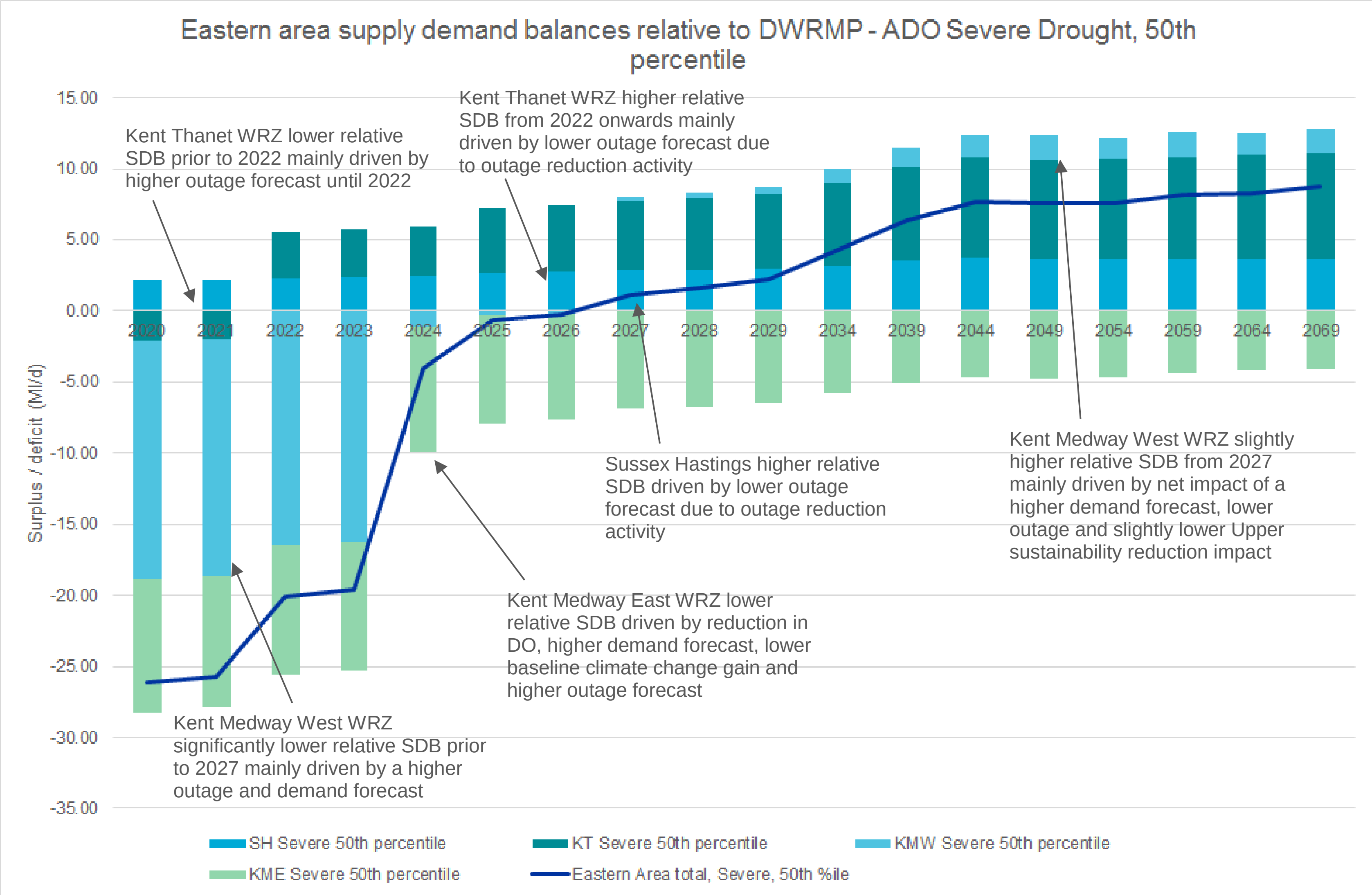
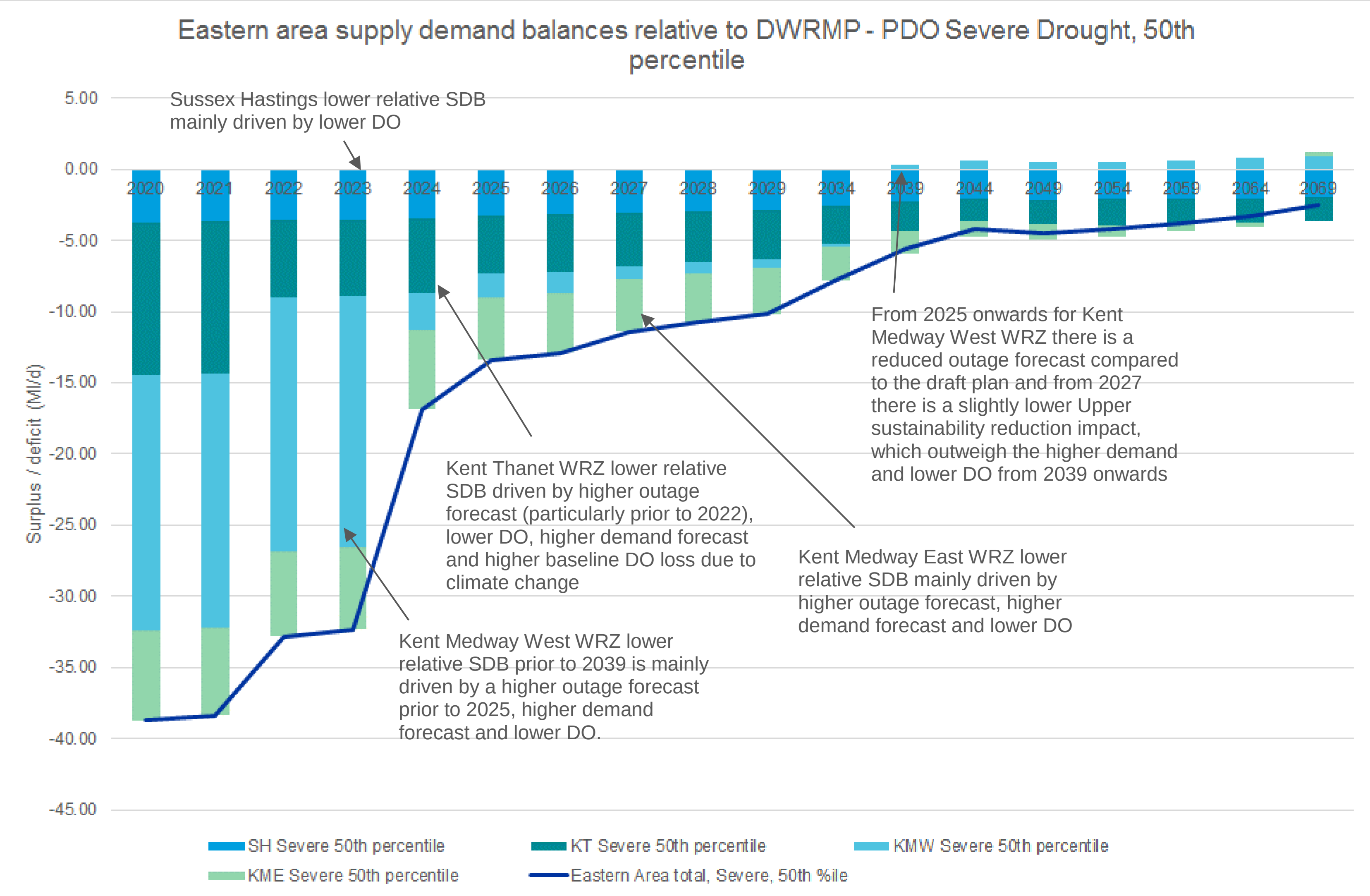


Figure 44 Eastern area SDBs relative to the draft WRMP - PDO 50th percentile



5.2.2 Summary of results

Figure 45 and Figure 46 show the baseline SDB distribution at ADO and PDO respectively. The results show that at the 50th percentile, there is a surplus of 12.6Ml/d at ADO in 2020-21, which increases until 2026-27 and then decreases until the end of the planning period, with a deficit from 2064-65. At PDO there is a surplus throughout the planning period at the 50th percentile until 2027-28, when the SDB reduces significantly due to the modelled impact of potential sustainability reductions.

The 1 in 200 year SDB is lower at the start of the planning period than the equivalent WRMP14 SDB forecast for 2020-21, which was 29.1Ml/d at ADO and 59.6Ml/d at PDO. The decrease in the forecast SDB compared to WRMP14 is due to the net impact of a number of individual SDB components. These can be summarised as follows:

- The DO forecast is higher at ADO and lower at PDO for WRMP19 than for WRMP14 by 1.7Ml/d and 22.3Ml/d respectively
- The dry year demand forecast is higher at ADO and lower at PDO for WRMP19 compared to WRMP14 by 0.3Ml/d and 20.9Ml/d respectively
- Process losses are higher at ADO and PDO for WRMP19 compared to WRMP14 by 4.5Ml/d and 2.9Ml/d respectively
- Outage is higher at ADO and PDO for WRMP19 compared to WRMP14 by 13.69Ml/d and 8.5Ml/d respectively
- Medium climate change impacts are lower at ADO and PDO for WRMP19 compared to WRMP14 by 3.0Ml/d and 2.5Ml/d respectively

Overall, for ADO the impact of the higher demand, process losses and outage forecasts outweighs the higher DO forecast and lower climate change impact. At PDO, the lower DO and higher process losses and outage outweigh the lower demand forecast and lower climate change impact. The reasons for the changes in each component are discussed in Annexes 2 and 3.

In the Eastern area, the net impact of bulk supplies is negative throughout the planning period at (-27.2Ml/d at ADO and -34.7Ml/d at PDO in 2020-21). The WRMP19 baseline SDB distribution including bulk supplies is shown in Figure 47 below. This reduces the surplus such that there is a forecast deficit from 2020-21 to 2023-24 and from 2027-28 onwards at the 50th percentile at ADO.

Figure 45 Baseline SDB distribution at the 'severe drought' level for Eastern area ADO

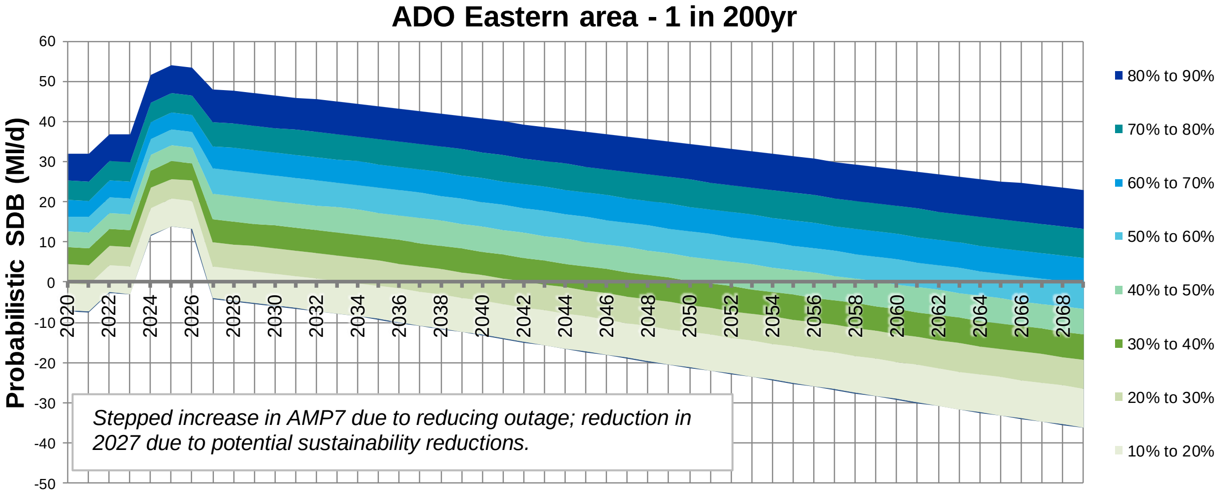


Figure 46 Baseline SDB distributions at the 'severe drought' level for Eastern area PDO

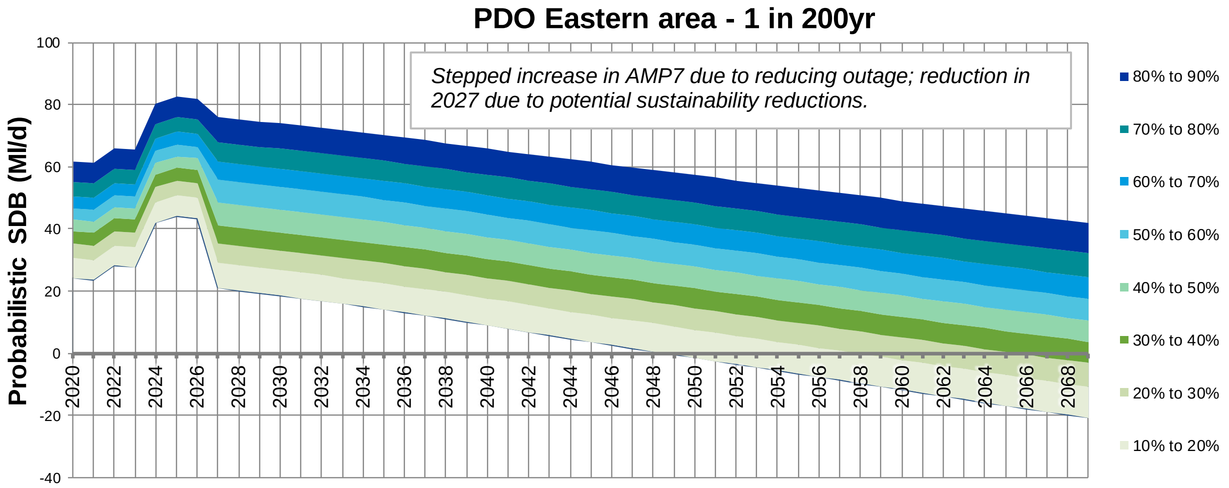
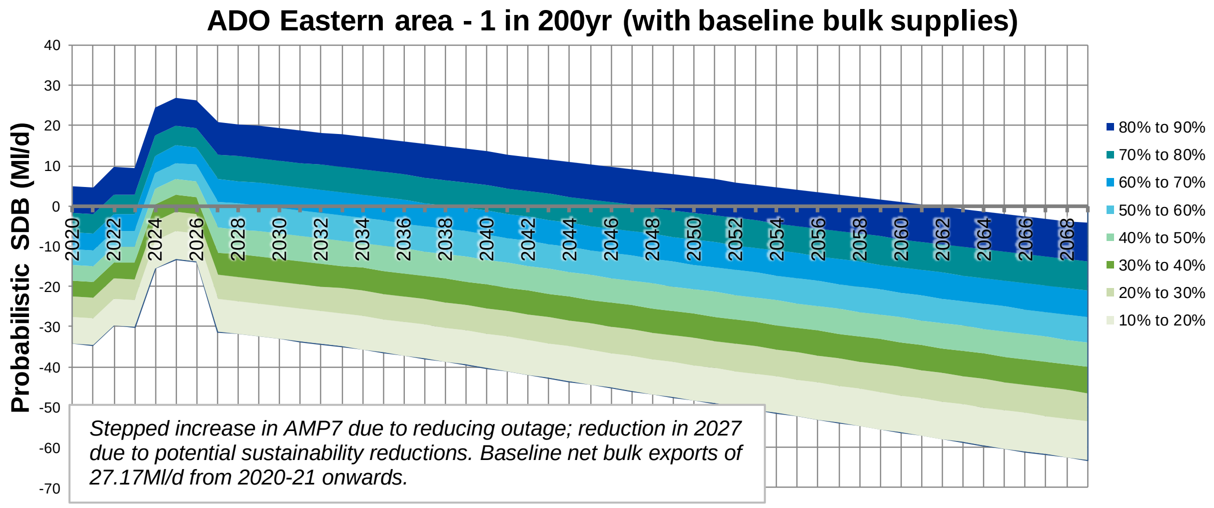


Figure 47 Baseline SDB distributions at the 'severe drought' level for Eastern area ADO with baseline bulk supplies



5.3 Western area

5.3.1 Differences between the draft WRMP and final WRMP

Figure 48 and Figure 49 show the change in the 50th percentile SDB at the severe drought level at MDO and PDO respectively between the draft plan and final plan. At MDO the SDB is higher prior to 2027, with a sharp increase in 2023, a reduction between 2027 and 2039 and a slight increase from 2044 onwards. This is predominantly driven by a higher DO for Hampshire Southampton East WRZ prior to 2024, followed by a reduction in DO due to the potential implementation of the additional Itchen sustainability reduction in 2024. The sharp increase in 2023 is driven by a reduction in the outage forecast from 2023 and a larger DO gain due to climate change until 2027 for Hampshire Southampton West WRZ.

At PDO the SDB is higher throughout the planning period for the final plan compared to the draft plan, particularly prior to 2027, at which point there is no significant difference in the overall SDB. The higher SDB prior to this point is predominantly driven by the higher DO for Hampshire Southampton East WRZ prior to the potential implementation of the additional Itchen sustainability reduction in 2024, and higher DO increase relative to outage for Hampshire Southampton West WRZ prior to 2027. The relative increase in the SDB beyond this point is mainly driven by the net effect of climate change impacts for these two zones.

Further information on the changes in the individual SDB components is provided in Annexes 2 and 3.

Figure 48 Western area SDBs relative to the draft WRMP - MDO 50th percentile

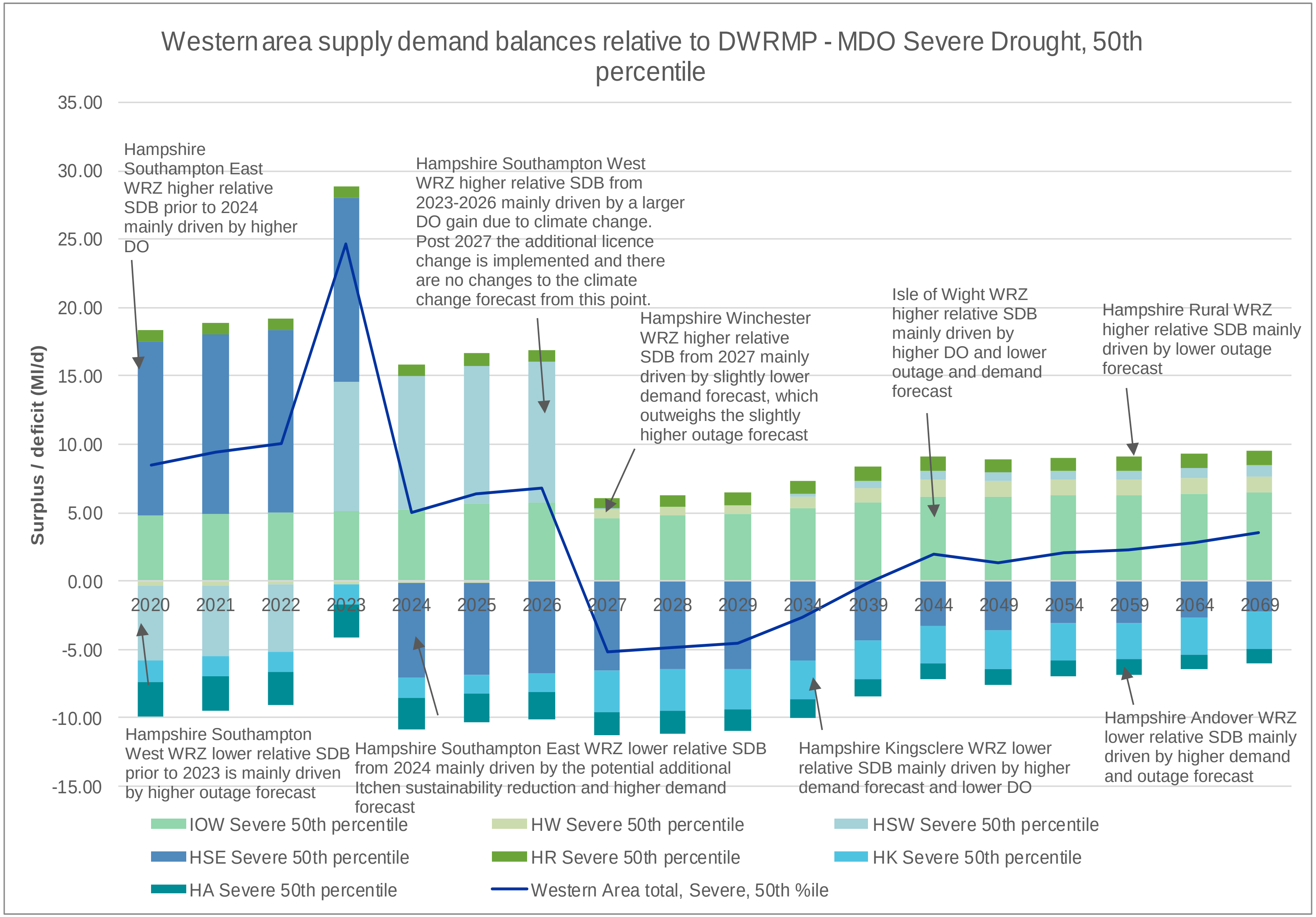
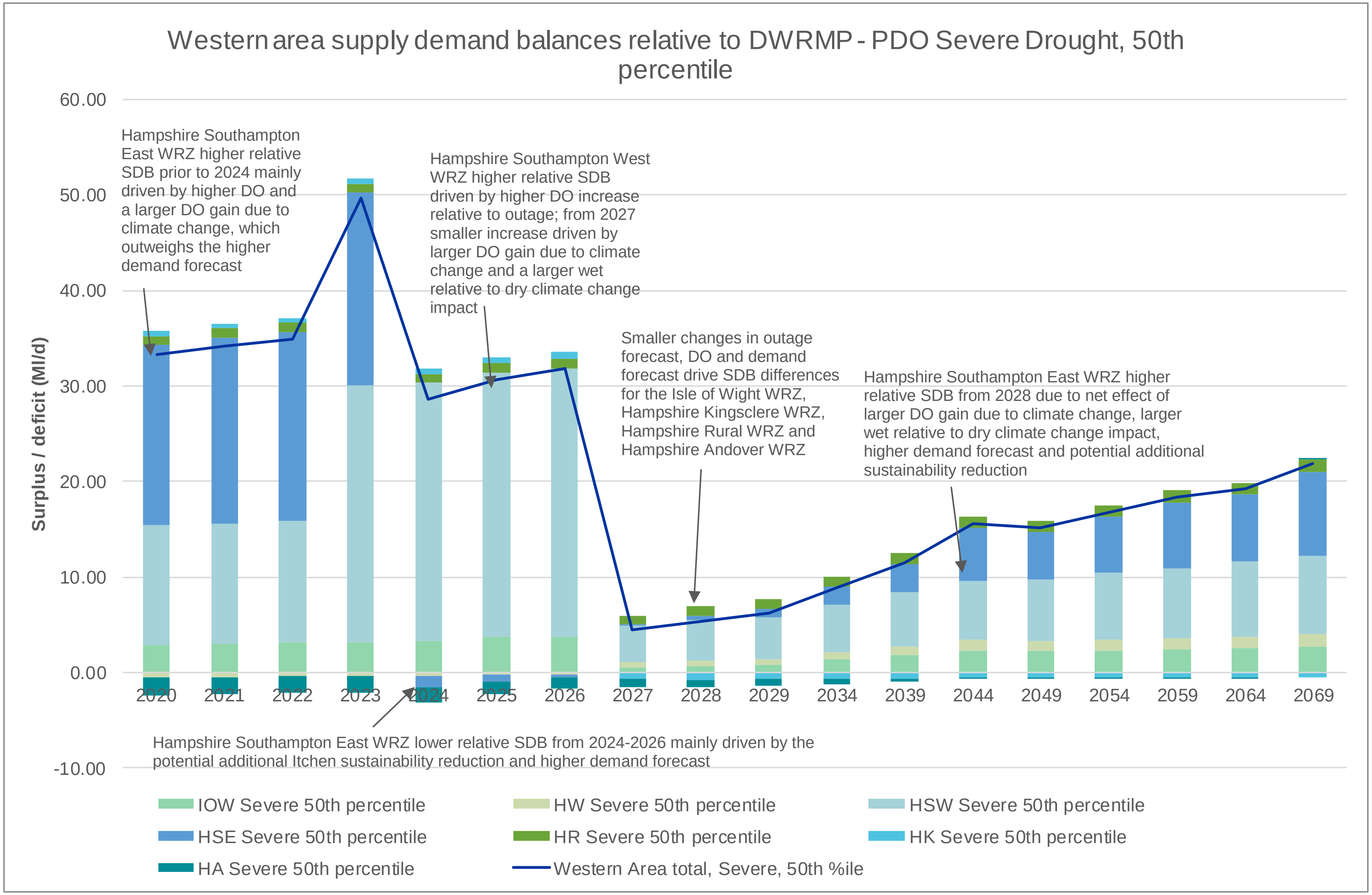


Figure 49 Western area SDBs relative to the draft WRMP - PDO 50th percentile



5.3.2 Summary of results

Figure 50 to Figure 52 show the baseline SDB distributions for the Western area Scenario A at MDO and PDO. The results show that at the 50th percentile there is a deficit of -92.7Ml/d at 2020-21 at MDO and -59.9Ml/d at PDO.

The 1 in 200 year SDB for Scenario A is significantly lower throughout the planning period than the equivalent WRMP14 SDB forecast, which was -7.5Ml/d at ADO and -25.9Ml/d at PDO in 2020-21. The difference in the forecast SDB compared to WRMP14 is due to the net impact of a number of individual SDB components. These can be summarised as follows:

- The most significant impact is from the implementation of the Lower Test sustainability reduction in 2017-18 under Scenario A and a potential additional Itchen sustainability reduction in 2024-25, which were not included in the WRMP14 baseline forecast. This is modelled as an uncertainty distribution
- In addition to this, the DO forecast is lower at both MDO and PDO for WRMP19 than for WRMP14 by 9.3Ml/d and 23.5Ml/d respectively. However, the forecast impact of the Itchen sustainability reduction is slightly lower for WRMP19 by 33.0Ml/d at MDO and 10.3Ml/d at PDO, which partially counteracts the impact of the lower DO forecast
- The dry year demand forecast is lower at MDO by 7.1Ml/d at 2020-21 and significantly lower at PDO (by 32.8Ml/d) for WRMP19 compared to WRMP14
- Process losses are higher at MDO and PDO for WRMP19 compared to WRMP14 by 8.3Ml/d and 9.3Ml/d respectively
- Outage is higher at MDO and PDO for WRMP19 compared to WRMP14 by 13.5Ml/d and 9.5Ml/d respectively
- Medium climate change impacts are lower at MDO and PDO for WRMP19 compared to WRMP14 by 4.8Ml/d and 10.9Ml/d respectively

Excluding the impact of sustainability reductions and DO, the net impact in 2020-21 of the differences in the demand forecast, process losses, outage and climate change is negative at MDO and significantly positive at PDO compared to WRMP14. The main driver behind this change at PDO is a lower demand forecast for WRMP19. The reasons for the changes in each component are discussed in Annexes 2 and 3.

In the Western area, the net impact of bulk supplies is positive throughout the planning period (4.7Ml/d at MDO and 4.6Ml/d at PDO). The WRMP19 baseline SDB distribution including bulk supplies is shown in Figure 52 below for Scenario A. This slightly reduces the deficit such that the forecast deficit at 2020-21 at the 50th percentile at MDO is -88.0Ml/d. There are several Drought Orders and Permits available to address this, although these have not been included in the baseline SDB as they are included within the feasible options set.

Figure 50 Baseline SDB distributions at the 'severe drought' level for Western area MDO under Scenario A

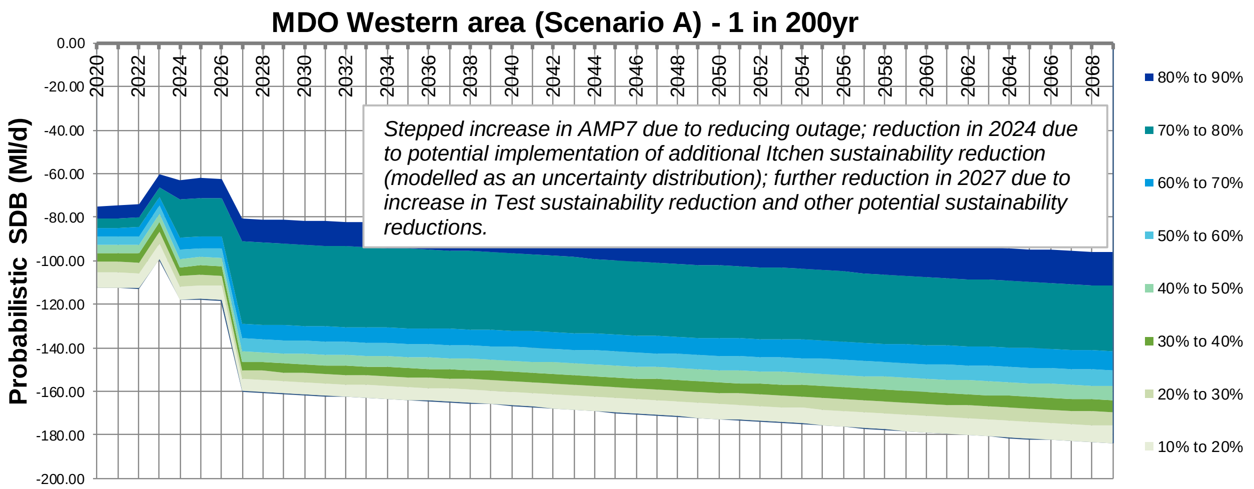


Figure 51 Baseline SDB distributions at the 'severe drought' level for Western area PDO under Scenario A

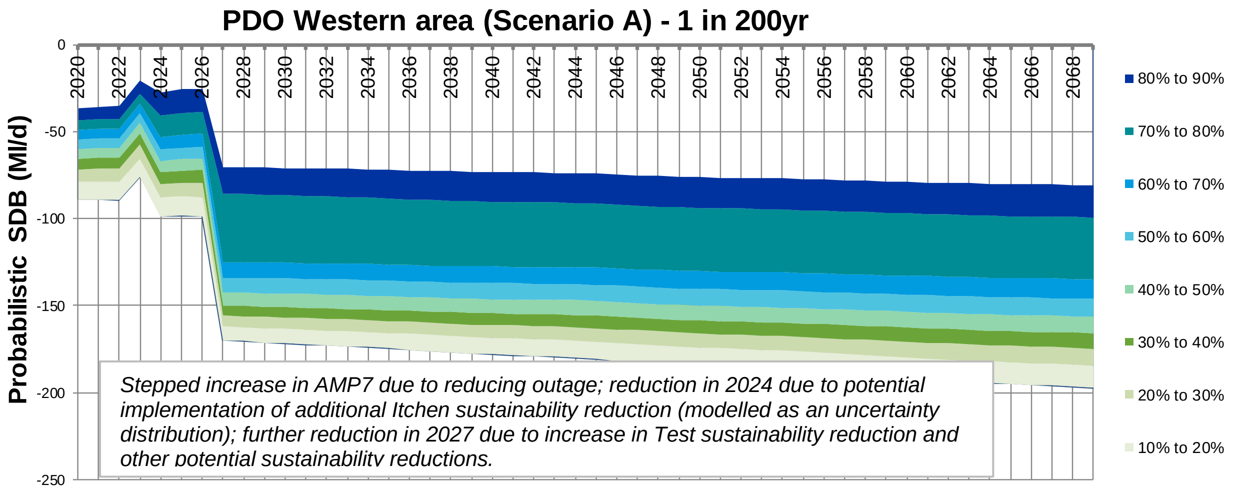
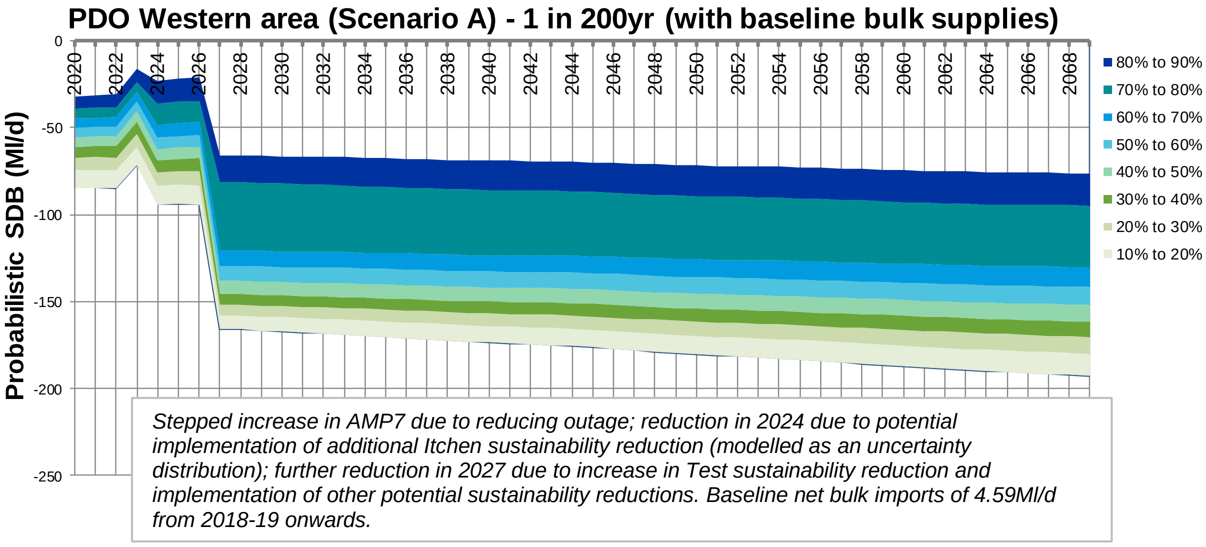


Figure 52 Baseline SDB distributions at the 'severe drought' level for Western area MDO under Scenario A with baseline bulk supplies



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