Southern Water WRMP

WRZ Climate Change Vulnerability Assessment and Proposed Methods

Southern Water

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ATKINS

Plan Design Enable

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Table of contents

Tables

Figures

Introduction

In preparing a Water Resources Management Plan (WRMP), water companies must investigate the likely impact of climate change on water supply and demand. The initial step in this investigation is to carry out a basic climate change vulnerability assessment for each water resource zone (WRZ).

In this context, vulnerability is a product of exposure, sensitivity and adaptive capacity, where:

- **Exposure** relates to the variation in climate variables within a WRZ (these are unlikely to vary significantly within WRZs but there may be some variation between WRZs);
- **Sensitivity** relates to characteristics of the WRZ that determine the scale of the impact of the change in climate variables; and
- **Adaptive capacity** relates to the ability to respond to the impacts of climate change within the WRZ.

By considering exposure, sensitivity and adaptive capacity, a high-level assessment of vulnerability can be made for each WRZ. The vulnerability classification is used, alongside information on the timing and scale of any deficit, to determine the appropriate level of climate change analysis for WRZs.

This note reports the results of the vulnerability assessment for WRZs in the Southern Water area and sets out what further work is required in terms of climate change analysis as part of the WRMP.

1. Method

The vulnerability assessment has been conducted following the methodology set out in the Water Resource Planning Guideline (WRPG) (Environment Agency, 2012), with an additional high-level assessment of other factors potentially affecting supply and demand.

The vulnerability classification of each WRZ has been determined by its position on a magnitude versus sensitivity plot. The plots shows the change in deployable output (DO) for the 'mid' climate change scenario against the uncertainty range (calculated as the difference between the 'wet' and 'dry' scenarios) for each of the WRZs. This is based on climate change impact assessments completed for PR09 (Atkins, 2008 and Atkins, 2009 respectively) and summarised at the WRZ level. The vulnerability classification has been identified using the vulnerability scoring matrix given in the WRPG (re-produced in Table 1-1).

Table 1-1 Vulnerability scoring matrix

Uncertainty range (% change wet to dry)	Mid scenario (% change in DO)		
	>-5%	-6 to -10%	<-10%
<5%	Low	Medium	High
6 – 10%	Medium	Medium	High
11 – 15%	High	High	High
>15%	High	High	High

Additional information about the sensitivity and adaptive capacity of WRZs has been collected from Southern Water's last WRMP (Southern Water, 2010) and supporting documents, the Draft Drought Plan (Southern Water, 2011) and Table 10a of the 2011 June Return. Sources of information used in the vulnerability assessment are summarised in Table 1-2. Additional information on exposure has not been presented as there is unlikely to be significant variation in projected climate variables at the WRZ scale.

Table 1-2 Sources of information used in the vulnerability assessment

Element of vulnerability assessment	Sources of information
Sources	Water Resource Management Plan (Southern Water, 2010) Draft Drought Plan (Southern Water, 2011)
Critical drought years	Draft Drought Plan
Supply-demand balance (SDB)	Water Resource Management Plan
Security of supply	Table 10a, June Return 2011
Climate critical variables	Water Resource Management Plan Draft Drought Plan
Climate change DO	Water Resources Management Plan Technical note: Surface water Deployable Output (Atkins 2008) Assessment of impact of severe drought and climate change on groundwater DO (Atkins 2009)
Adaptive capacity	Water Resources Management Plan Draft Drought Plan Climate Change Adaptation Report (Southern Water, 2011a)
Sensitivity	Water Resources Management Plan Draft Drought Plan Climate Change Adaptation Report

2. Summary of results

The magnitude versus sensitivity plot showing WRZs in the Southern Water region is shown in Figure 2-1. A summary of WRZs by vulnerability classification is shown in Table 2-1.

Further information about the vulnerability of each of the WRZs is provided in the following pages. Recommendations for further climate change analysis are also given for each of the WRZs.

Figure 2-1 Magnitude vs. Sensitivity plot all zones

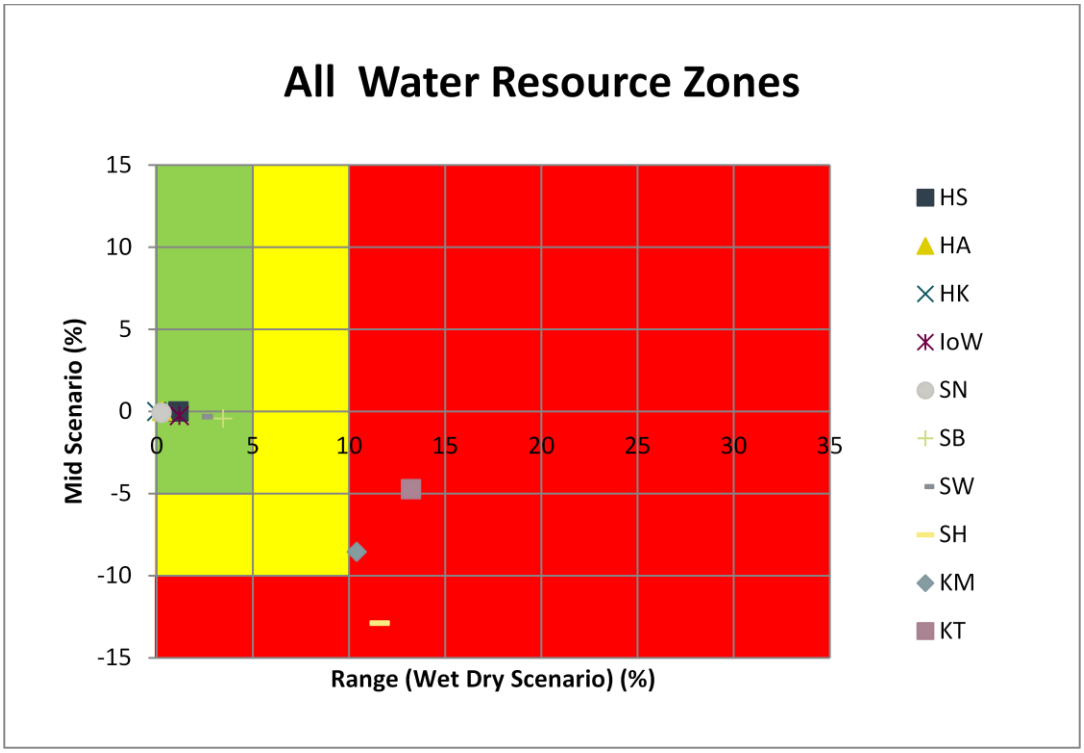


Table 2-1 Summary of WRZs by vulnerability classification

Low	Medium	High
Hampshire South Hampshire Andover Hampshire Kingsclere Isle of Wight Sussex North Sussex Brighton Sussex Worthing		Sussex Hastings Kent Medway Kent Thanet

3. Isle of Wight Water Resource Zone

3.1. Sources

The ratio of groundwater to surface water sources in this WRZ is 47%:23%. Transfers make up 30% of sources in this WRZ.

Sources:

- Eastern Yar river abstraction.
- Chalk aquifer.
- Greensand aquifer.
- Transfer from Hampshire South WRZ via the cross-Solent main.

3.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

3.3. Critical drought years

- 1900-03
- 1920-22
- 1930-3
- 1976
- 2004-06

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts. There was considerable stress on the Isle of Wight sources during the 2004-06 drought.

3.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	0.31	7.30	-5.18	-7.73	Deficit at 10 years after base year
Critical period scenario	-1.35	1.62	-10.63	-16.07	Deficit at 10 years after base year

3.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

3.6. Climate critical variables

- Winter rainfall

3.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

3.8. Adaptive capacity

- Enhanced metering.
- Asset improvement schemes for groundwater sources.
- Optimisation of interzonal transfers (cross-Solent main).
- 1.1 Ml/d further leakage reduction.
- Refurbishment of Ashey and Broadfields boreholes.
- Groundwater augmentation scheme for Eastern Yar abstraction.
- Sandown wastewater recycling.
- Drought permits/orders to reduce MRF controlling abstraction at Bowcombe, Burnt House, Calbourne and Chillerton.
- Drought order to reduce MRF and change operation of Eastern Yar augmentation scheme.
- Rest groundwater sources during early stages of drought.
- Emergency desalination.

3.9. Sensitivity

Climate change impact on DO:

- Climate change could exacerbate environmental impacts of abstraction on the River Itchen, potentially resulting in a further DO reduction for this WRZ.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Storm events leading to contamination of surface water sources with silt or chemical pollution could become more frequent as a result of climate change – particularly affects reliability of the River Yar surface abstraction works.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Several groundwater sources in the WRZ are thought to be at susceptible to a lack of recharge due to small catchment areas.

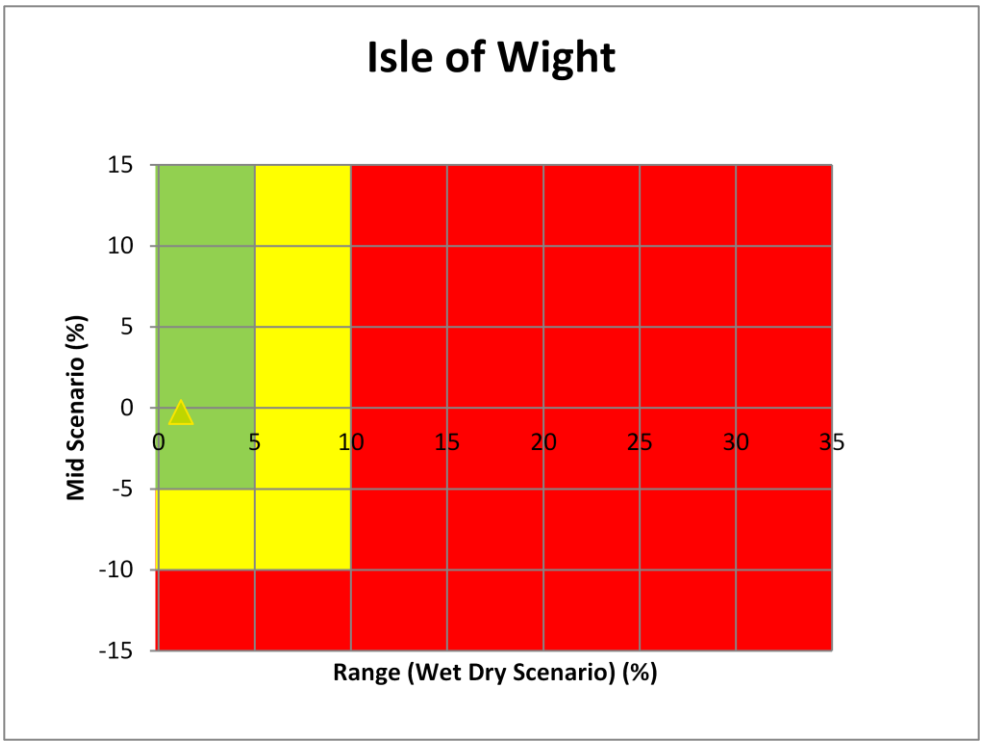
Other factors affecting sensitivity of WRZ to impacts of climate change:

- The WRZ is not self-sufficient in water resources, and relies on transfers via the cross-Solent main from the Hampshire South WRZ to maintain SDB.
- Environmental impacts on protected sites may constrain adaptive capacity.

3.10. Vulnerability classification

The vulnerability classification for the WRZ is low, see Figure 3-1.

Figure 3-1 Magnitude vs. Sensitivity, Isle of Wight WRZ



3.11. Proposed climate change assessment method

Given the nature of the vulnerability, a simple method is suitable. For the surface source, Sandown, the approach at PR09 was to use flow factors. Unfortunately, there are no new suitable flow factors available (e.g. in the UKWIR Rapid Assessment (UKWIR, 2009) or in Future Flows); therefore the rainfall-runoff model of the Eastern Yar will require perturbing with the 20 climate samples from the Rapid Assessment (UKWIR, 2009), which is Approach A1 of the WRPG. Similarly for the groundwater assessment, the Isle of Wight Central Downs Chalk/Upper Greensand 4R Recharge model will require perturbation (it is assumed this Environment Agency model will be available as at PR09). The impacts of climate change on the transfer should also be assessed and incorporated into the SDB.

4. Hants South Water Resource Zone

4.1. Sources

The ratio of groundwater to surface water (river) sources in this WRZ is 37%:63%.

Sources:

- Chalk aquifer.
- Surface water abstraction from the Rivers Test and Itchen.

4.2. Period for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

4.3. Critical drought years

- 1900-03
- 1920-22
- 1930-33
- 1976
- 2004-06

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

4.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	43.96	62.02	0	-26.11	Deficit at 25 years after base year
Critical period scenario	11.77	4.52	0	-56.8	Deficit at 25 years after base year

4.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

Following implementation of the Sustainability Reductions on the River Itchen, the current security of the supply demand balance in the WRZ would be reduced.

4.6. Climate critical variables

- Winter rainfall (groundwater recharge).
- Summer rainfall (surface water).

4.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

4.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Refurbishment and re-commissioning of unused and abandoned groundwater sources (West Tytherly, Broughton).
- Increase Testwood WSW to licence limit.
- Development of the enabling Testwood to Otterbourne transfer.
- Optimisation of interzonal transfers (cross- Solent main).
- Candover & Alre augmentation schemes (augment flows in the River Itchen).
- 7.8 Ml/d of leakage reduction.
- Woodmill Abstraction and treatment at Otterbourne or Gaters Mill.
- New surface water storage at Colden Common Reservoir.
- Drought permit to reduce MRF at Testwood.
- Inter-company bulk transfer with Portsmouth Water.
- Tankering.

4.9. Sensitivity

Climate change impact on DO:

- Climate change could exacerbate environmental impact of abstraction on the River Itchen potentially leading to more severe restrictions.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Storm events leading to contamination of surface water sources with silt or chemical pollution could become more frequent as a result of climate change.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Surface water flows have historically be shown to be robust - need both long term drought and shorter term persistent dry conditions to present a problem, as drought needs to be both intense (to limit recharge) and long (to deplete the groundwater storage).

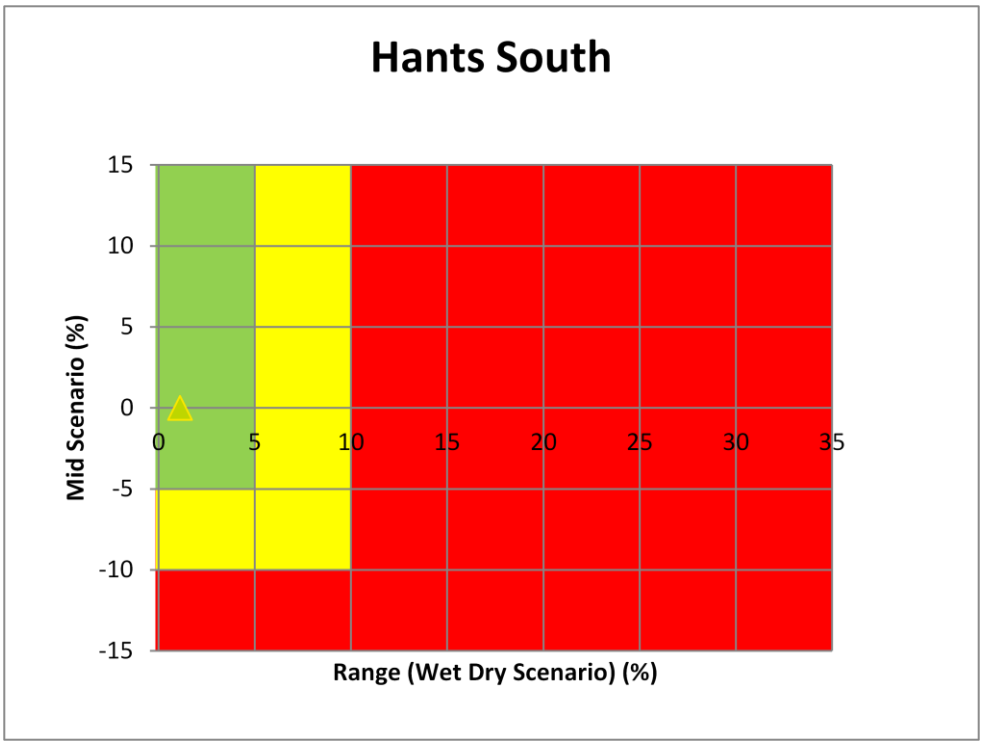
Other factors affecting sensitivity of WRZ to impacts of climate change:

- There are currently no flow-related constraints in the abstraction licences for the Lower Itchen sources - volume of abstraction has been limited by existing licensed quantities and not by hydrology.
- The nature of the Chalk aquifer means that groundwater sources are reliable and that the aquifer provides the baseflow component of flows in the Rivers Test and Itchen.
- Availability of new resources within the WRZ is severely constrained - all surface water and groundwater management units are “over licensed” and some are considered to be “over abstracted”.
- Adaptive capacity measures for groundwater may be constrained by water quality – nitrate.
- Environmental impacts on protected sites.
- Sustainability Reductions on the River Itchen.
- No storage in this WRZ.

4.10. Vulnerability classification

The vulnerability classification for the WRZ is low, see Figure 4-1.

Figure 4-1 Magnitude vs. sensitivity, Hampshire South WRZ



4.11. Proposed climate change assessment method

Given the size of deficit and potential interactions between climate change impact and sustainability reductions, a reasonably detailed approach is recommended. It is proposed that this is driven by perturbing the Test and Itchen Groundwater and 4R Recharge models by the 20 climate samples from the Rapid Assessment (UKWIR, 2009), which is Approach A1 of the WRPG; ideally the full groundwater model will be run with a sub-selection of samples based on for example simpler recharge modelling. If running the groundwater model is not possible, then it may be possible to develop relationships between recharge and levels, initially in the Chalk Dale OBH. As at PR09, levels at local OBHs can be adjusted based on the relationship with Chalk Dale; similarly, perturbed flow timeseries from the groundwater model can be used to assess the impact on the DO of run-of-river sources. Given the uncertainty in terms of sustainability reductions, it may also be prudent to assess the impact of climate change with sustainability reductions in place, as climate change could then impact on revised DO.

5. Hants Kingsclere Water Resource Zone

5.1. Sources

Groundwater makes up 100% of sources in this WRZ.

Source:

- Chalk aquifer.

5.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

5.3. Critical drought years

- 1900-03
- 1920-22
- 1930-33
- 1976
- 2004-06

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

5.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	2.6	2.44	2.46	2.34	Surplus at 25 years after base year
Critical period scenario	0.03	0.55	1.8	1.66	Surplus at 25 years after base year

5.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

5.6. Climate critical variables

- Winter rainfall.

5.7. Climate change Deployable Output

SWS have prepared a report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

5.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources (1.2 Ml/d peak only).
- Tankering.

5.9. Sensitivity

Climate change impact on DO:

- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Source yields have been shown to be robust in previous droughts.

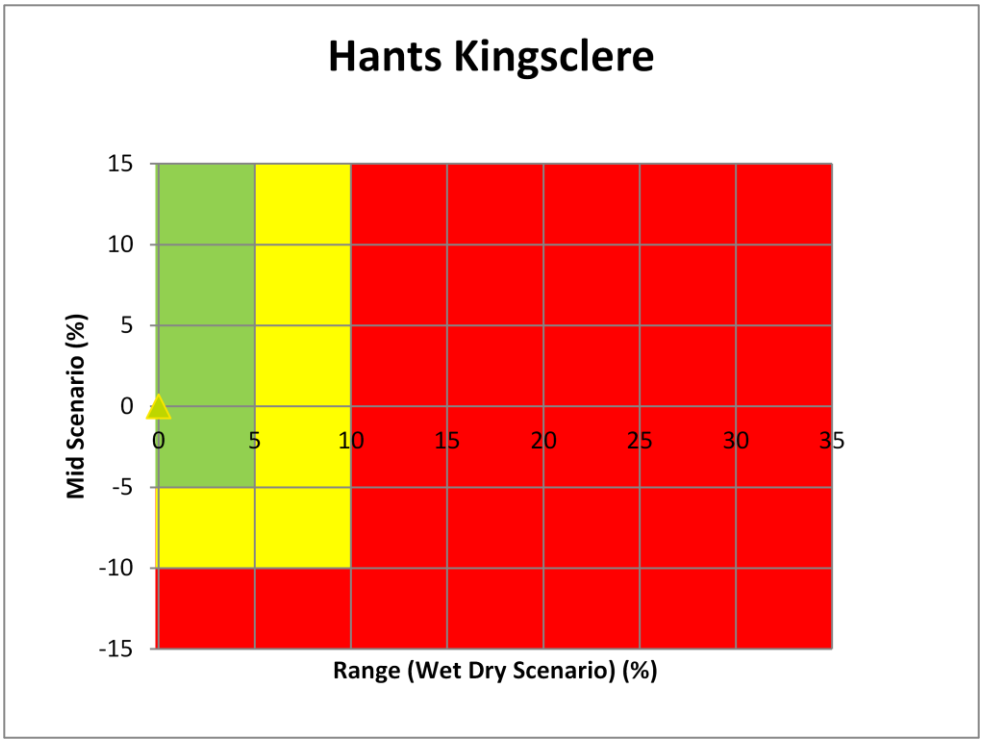
Other factors affecting sensitivity of WRZ to impacts of climate change:

- The WRZ has adequate indigenous supplies.

5.10. Vulnerability classification

The vulnerability classification for the WRZ is low, see Figure 5-1.

Figure 5-1 Magnitude vs. sensitivity, Hampshire Kingsclere WRZ



5.11. Proposed climate change assessment method

Given the low vulnerability and lack of deficit, it is questionable whether any further analysis is beneficial, but following the WRPG some analysis is required. The simplest approach (A4) would be to use groundwater level change factors from Future Flows but unfortunately there is no site within this WRZ. It is therefore recommended that a proxy is considered, the nearest of which are Chilgrove House and Clanville Lodge Gate. Note that the data from Future Flows is only based on one GCM and therefore the groundwater level change factors should be compared with previous assessments and other data where available. A more detailed approach would be to use recharge modelling and the 20 climate samples (Approach A1).

6. Hants Andover Water Resource Zone

6.1. Sources

Groundwater makes up 100% of sources in this WRZ.

Sources:

- Chalk aquifer.

6.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

6.3. Critical drought years

- 1900-03
- 1920-22
- 1930-33
- 1976
- 2004-06

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

6.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	3.43	3.38	3.67	3.11	Surplus at 25 years after base year
Critical period scenario	3.20	2.49	2.88	2.33	Surplus at 25 years after base year

6.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

6.6. Climate critical variables

- Winter rainfall.

6.7. Climate change Deployable Output

SWS have prepared a report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

6.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Reduce transfer to Wessex Water.
- Tankering.

6.9. Sensitivity

Climate change impact on DO:

- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Groundwater sources have been resilient to past droughts.

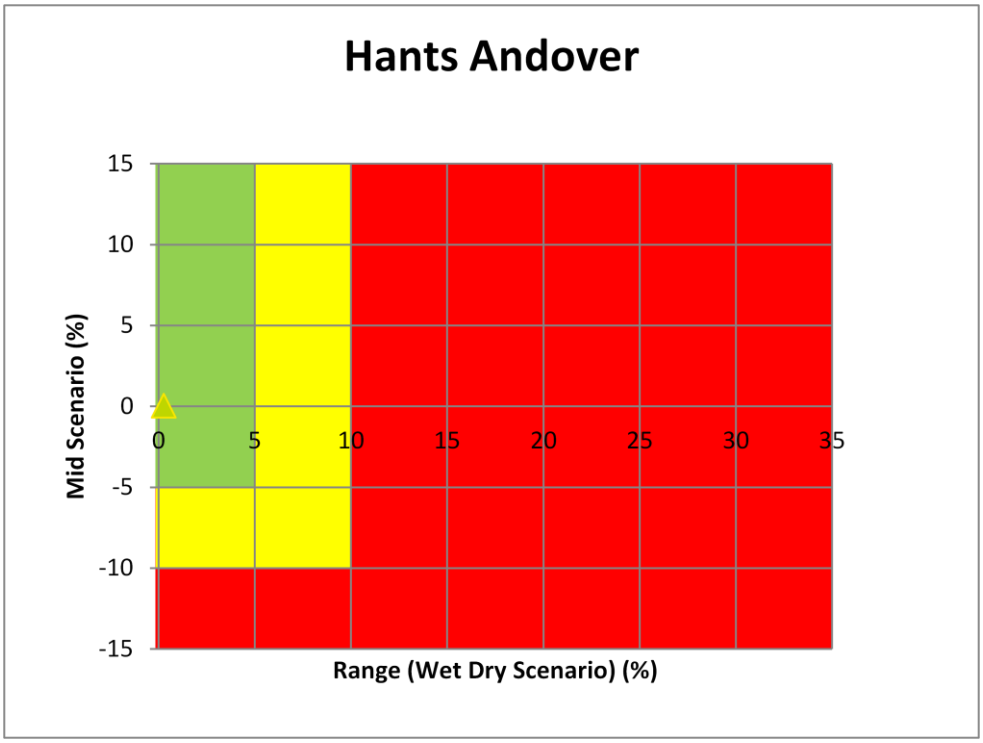
Other factors affecting sensitivity of WRZ to impacts of climate change:

- The WRZ has adequate indigenous supplies.

6.10. Vulnerability classification

The vulnerability classification for the WRZ is **low**, see Figure 6-1.

Figure 6-1 Magnitude vs. sensitivity, Hampshire Andover WRZ



6.11. Proposed climate change assessment method

Given the low vulnerability and lack of deficit, it is questionable whether any further analysis is beneficial, but following the WRPG some analysis is required. The simplest approach (A4) would be to use groundwater level change factors at Clanville Lodge Gate from Future Flows. Note that the data from Future Flows is only based on one GCM and therefore the groundwater level change factors should be compared with previous assessments and other data where available. A more detailed approach would be to use recharge modelling and the 20 climate samples (Approach A1).

7. Sussex North Water Resource Zone

7.1. Sources

The ratio of groundwater to surface water (river and reservoir) sources in this WRZ is 35%:59%, with 6% coming from transfers.

Sources:

- River Arun.
- Western Rother.
- Weir Wood Reservoir.
- Lower Greensand aquifer.
- Transfer from Sussex Worthing WRZ.
- Bulk import from Portsmouth Water.

7.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

7.3. Critical drought years

- 1921 and 1922
- 1933-34
- 1976
- 1989-92

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

7.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	1.03	-0.5	0	0	
Critical period scenario	-1.14	-6.46	-1.91	-5.84	Deficit throughout planning period

7.5. Security of supply

	Zonal security of supply index
Dry year annual average	0.011
Dry year critical period	0.046

Infrastructure has been upgraded to allow Hardham STW to support this area if necessary, which has reduced the vulnerability of the system to specific low rainfall around Weir Wood Reservoir.

The risk profile for the WRZ has been improved by the bulk supply from Portsmouth Water Company, as sources in that area tend to be more robust.

7.6. Climate critical variables

- Winter rainfall.

7.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

7.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Optimisation of interzonal transfers (from Sussex Worthing).
- Maintain abstraction and output from the River Rother at Hardham at as high a level for as long as possible, allowing key strategic groundwater resources to be rested along with Weir Wood Reservoir.
- River Arun Abstraction - construction of a new intake below tidal limit.
- Reduce bulk supply to South East Water. Investigate new inter-company bulk transfer from South East Water.
- Drought permits to reduce summer and winter MRF at Hardham Weir.
- Drought permit for derogation for the license on the River Arun tidal abstraction.
- Increase bulk supply from Portsmouth Water.
- Tankering.
- Purchase abstraction licences upstream of SWS abstraction sites.

7.9. Sensitivity

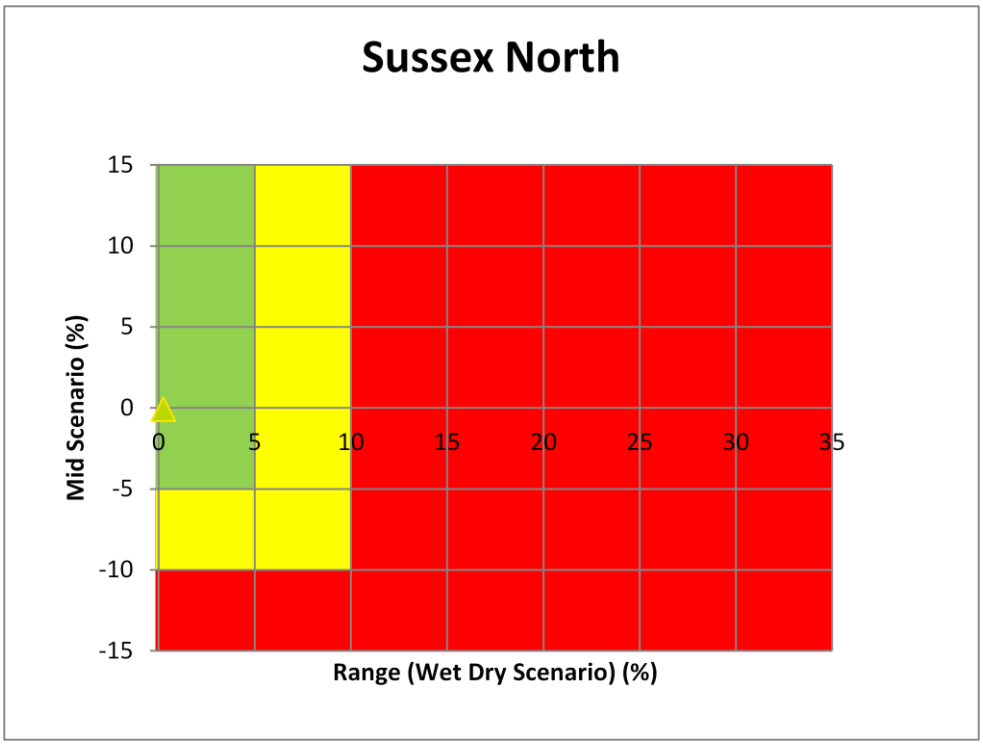
Climate change impact on DO:

- Surface water source is sensitive to single season events due to lack of storage.
- Size and nature of the aquifers feeding the Rother mean that summer baseflow is sensitive to single dry winters, leading to severely restricted river abstraction. This is exacerbated by subsequent dry winters.
- The River Arun is generally considered to be more resilient - only at risk if Horsham WWTW ceases discharge for a significant period of time.
- Storm events leading to contamination of surface water sources with silt or chemical pollution could be exacerbated by climate change.
- Weir Wood reservoir is sensitive to a single dry winter as it only receives water from the catchment directly upstream and cannot be supported by pumped inflow.
- The intercompany transfer from Portsmouth Water is relatively robust to drought.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge). Groundwater levels can be affected if increased abstraction is required for long periods due to lack of surface water availability. This can place supplies in a position of significant risk if there is a second dry winter.

7.10. Vulnerability classification

The vulnerability classification for the WRZ is **low**, see Figure 7-1.

Figure 7-1 Magnitude vs. sensitivity, Sussex North WRZ



7.11. Proposed climate change assessment method

Given the nature of the supplies in this zone, and the lack of surplus, a fairly detailed assessment is proposed. For surface waters this would utilise the 20 climate samples in existing rainfall-runoff models (Approach A1); this should include the transfer. Data from Future Flows is available for the Rother (to Iping Mill) if a comparison of flow changes is required (note that the rainfall model will already provide an alternative sequence of weather events). For the Lower Greensand groundwater, as at PR09 estimates could be made based on the findings of modelling for Sussex Coast (see below), or/and the Future Flows groundwater change factors from the borehole in the Lower Greensand at Lower Barn Cottage (near Lewes) could be used.

8. Sussex Worthing Water Resource Zone

8.1. Sources

Groundwater makes up 100% of sources in this WRZ.

Sources:

- Chalk aquifer.

8.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

8.3. Critical drought years

- 1921 and 1922
- 1933-34
- 1976
- 1989-92

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

8.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	3.21	0	5.24	1.29	Surplus at 25 years after base year
Critical period scenario	0	0	0	0	

8.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

8.6. Climate critical variables

- Winter rainfall.

8.7. Climate change Deployable Output

SWS have prepared a report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

8.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Optimisation of interzonal transfers (to Sussex North and Sussex Brighton).
- Rest groundwater sources using any spare winter/spring water available from the Hardham river abstraction.
- Inter-company transfer from Portsmouth Water.
- Tankering.
- Drought order to increase abstraction at Madehurst (only in severe droughts) and Northbrook.

8.9. Sensitivity

Climate change impact on DO:

- Groundwater sources are susceptible to one, two and three season droughts.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- The Brighton and Worthing aquifers are heavily abstracted and actions during a drought year can significantly affect water resources in subsequent drought years. Although Sussex Worthing may be used to support Sussex North, this should not be at the expense of greater risk during longer term droughts.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Transfers between Sussex North and Sussex Worthing to support summer/autumn output are unlikely to be realistic during a severe drought. Transfer from Sussex North to Sussex Worthing may be possible in the winter/spring leading into a drought.
- Nature of the sources in the WRZ means that it is more drought resilient than the Sussex North and Sussex Brighton WRZs.

Other factors affecting sensitivity of WRZ to impacts of climate change:

- The transfer from Portsmouth water is reliable, but availability to Sussex Worthing is likely to be limited by Sussex North requirements.

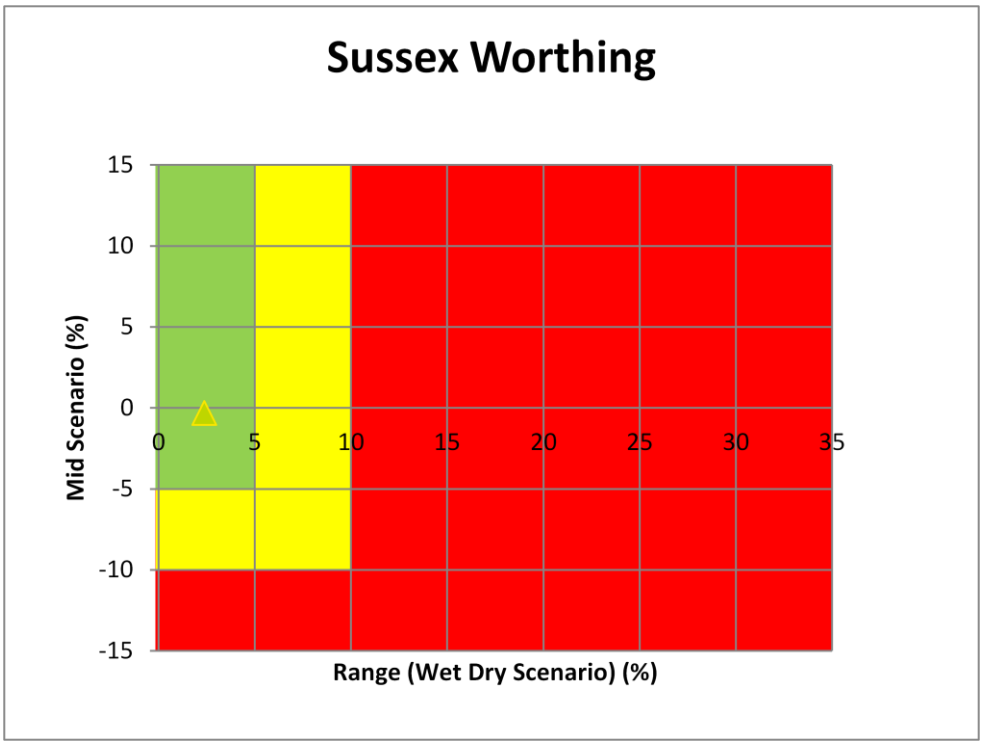
8.10. Vulnerability classification

The vulnerability classification for the WRZ is low, see Figure 8-1.

8.11. Proposed climate change assessment method

Given the low vulnerability and lack of deficit, it is questionable whether any further analysis is beneficial, but following the WRPG some analysis is required. The simplest approach (A4) would be to use groundwater level change factors from Future Flows but unfortunately there is no site within this WRZ. It is therefore recommended that a proxy is considered, the nearest of which is Chilgrove House. Note that the data from Future Flows is only based on one GCM and therefore the groundwater level change factors should be compared with previous assessments and other data where available. A more detailed approach would be to use recharge modelling and the 20 climate samples (Approach A1).

Figure 8-1 Magnitude vs. sensitivity, Sussex Worthing WRZ



9. Sussex Brighton Water Resource Zone

9.1. Sources

Groundwater makes up 100% of sources in this WRZ.

Sources:

- Chalk aquifer.

9.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

9.3. Critical drought years

- 1921 and 1922
- 1933-34
- 1976
- 1989-92

The critical event for the Western and Central Areas was 1920-1922, as the sources are prone to the effects of relatively short, two year, very severe droughts.

9.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	3.17	0.61	10.21	9.73	Surplus throughout planning period
Critical period scenario	-6.97	-1.68	9.31	10.01	Surplus at 10 years after base year

9.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

9.6. Climate critical variables

- Winter rainfall.

9.7. Climate change Deployable Output

SWS have prepared a report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

9.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Optimisation of interzonal transfers (from Sussex Worthing).
- Rest groundwater sources using any spare winter/spring water available from the Hardham river abstraction.
- Emergency desalination.
- Tankering.

9.9. Sensitivity

Climate change factors affecting DO:

- Hydrogeological nature of the Brighton Chalk block, and the presence of a number of old well and adit systems means that sources can be vulnerable to drought events.
- Groundwater sources are susceptible to one, two and three season droughts.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- The Brighton and Worthing aquifers are heavily abstracted and actions during a given drought year can significantly affect water resources in subsequent drought years.

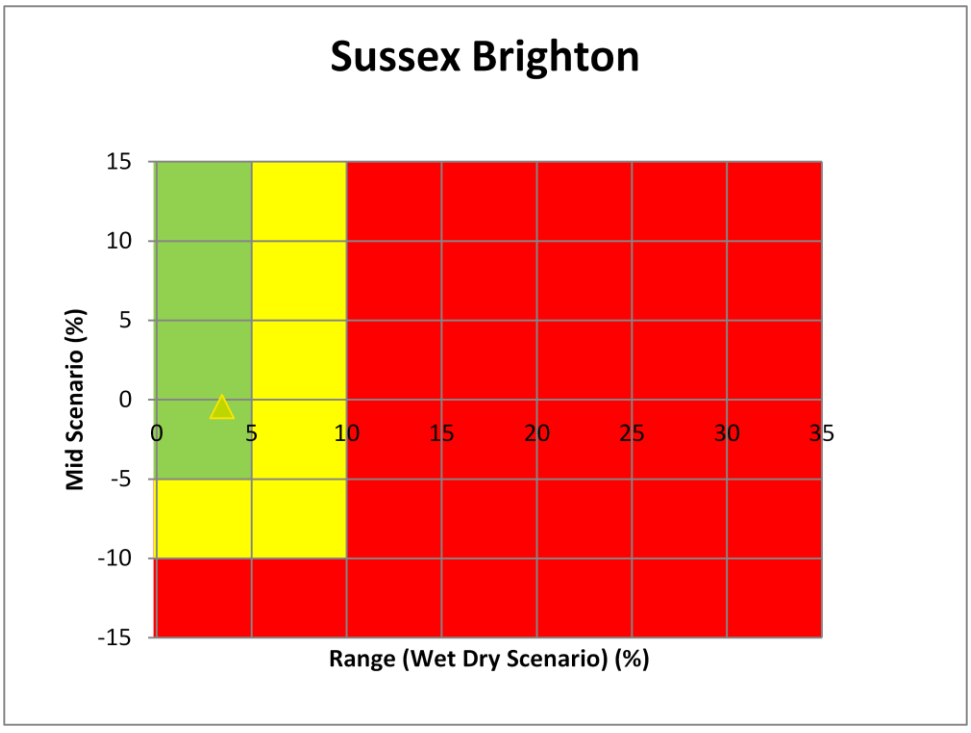
Other factors affecting sensitivity of WRZ to impacts of climate change

- There is limited recourse to Drought Permits/Orders to improve supplies - care needs to be taken when using coastal groundwater sources to support Sussex North, which is more amenable to drought intervention.

9.10. Vulnerability classification

The vulnerability classification for the WRZ is low, see Figure 9-1.

Figure 9-1 Magnitude vs. sensitivity, Sussex Brighton WRZ



9.11. Proposed climate change assessment method

Given the low vulnerability and lack of deficit, it is questionable whether any further analysis is beneficial, but following the WRPG some analysis is required. The simplest approach (A4) would be to use groundwater level change factors from Future Flows but unfortunately there is no site within this WRZ. It is therefore recommended that a proxy is considered, the nearest of which are Chilgrove House and West Dean No. 3 (located between Newhaven and Eastbourne). Note that the data from Future Flows is only based on one GCM and therefore the groundwater level change factors should be compared with previous assessments and other data where available. A more detailed approach would be to use recharge modelling and the 20 climate samples (Approach A1).

10. Sussex Hastings Water Resource Zone

10.1. Sources

Supply in this WRZ is dominated by surface water sources (95% reservoir, 5% groundwater).

Sources:

- Chalk aquifer.
- Ashdown Beds aquifer.
- Darwell Reservoir.
- Powdermill Reservoir.
- River Rother.
- River Brede.

10.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

10.3. Critical drought years

- 1900-03
- 1920-22
- 1934-35
- 1944-45
- 1976
- 1989-92
- 2004-06

The critical event for the Eastern Area was 1900 – 1903 when there was an extended three year drought which progressively eroded reservoir and groundwater storage.

10.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	0.47	0	0	-1.54	Deficit at 25 years after base year
Critical period scenario	0.54	0	0	-2.79	Deficit at 25 years after base year

10.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

10.6. Climate critical variables

- Winter rainfall.

10.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

10.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources.
- Optimisation of interzonal transfers (Bewl - Darwell transfer).
- 0.5 Ml/d leakage reductions.
- Re-commissioning of unused sources – Cadborough.
- Reduce transfer to other water companies.
- Tankering.
- Drought permit to reduce MRF on River Brede.
- Drought permit to reduce MRF on River Rother abstraction at Robertsbridge.
- Drought permit to remove freshet condition on Darwell Reservoir.
- Transfer from Kent Medway WRZ via a transfer main.

10.9. Sensitivity

Climate change impact on DO:

- Darwell and Powdermill reservoirs are prone to the effects of shorter duration droughts, even single winter events.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Groundwater sources are subject to drought effects on surface water and groundwater yields in Kent Medway WRZ.
- The transfer from Bewl Water is sensitive to low winter flows in the Medway catchment which limits refill opportunities for the reservoir.

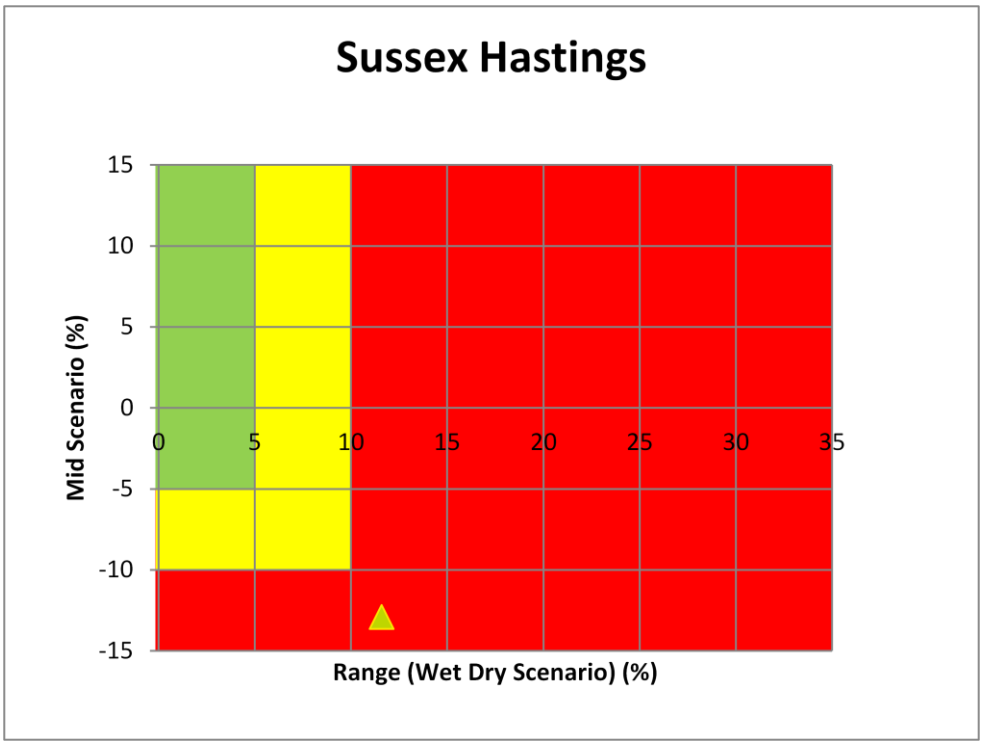
Other factors affecting sensitivity of WRZ to impacts of climate change:

- Potential landscape impacts associated with raising Bewl Water reduce adaptive capacity.
- Limited recourse to Drought Permits/Orders for Darwell and Powdermill Reservoirs.

10.10. Vulnerability classification

The vulnerability classification for the WRZ is high, see Figure 10-1.

Figure 10-1 Magnitude vs. sensitivity, Sussex Hastings WRZ



10.11. Proposed climate change assessment method

The higher vulnerability of this zone, and the delicate supply-demand balance, suggests that detailed modelling is required for this zone. According to the WRPG, this can either be based on 100 climate samples of UKCP09 (Approach B1), or a 'smart' sample of 20 samples, which sub-samples within the 100 to focus on the dry end of the distribution (Approach B2). The latter approach depends on establishing a robust relationship to inform the sub-sampling based on a drought indicator, and this approach will be investigated using an aridity indicator and a measure of reservoir refill potential (note that the EA Science Report Climate change approaches in water resources planning – Overview of new methods found it difficult to implement such an approach in a 'South East' zone, as compared with London). If a robust relationship can be established, then a smart sample of 20 change factors will be applied to the Catchmod models, with a refined selection applied to the water resource zones modelling. Note the assessment will focus on surface sources.

11. Kent Medway Water Resource Zone

11.1. Sources

The ratio of groundwater to surface water sources in this WRZ is 78%:22%.

Sources:

- Chalk aquifer.
- River Medway.
- Bewl Water.

11.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

11.3. Critical drought years

- 1900-03
- 1920-22
- 1934-35
- 1944-45
- 1976
- 1989-92
- 2004-06

The critical event for the Eastern Area was 1900 – 1903 when there was an extended three year drought which progressively eroded reservoir and groundwater storage.

11.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	20.68	-6.76	2.73	-12.30	Deficit at 25 years after base year
Critical period scenario	0	0	9.83	-5.26	Deficit at 25 years after base year

11.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

Kent Medway WRZ, and the River Medway Scheme in particular, is central to the strategic management of supplies throughout the Eastern Area.

11.6. Climate critical variables

- Winter rainfall.

11.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

11.8. Adaptive capacity

- Universal metering.
- Asset improvement schemes for groundwater sources (optimisation of interzonal transfers to Kent Thanet).
- Licence variation to the River Medway Scheme.
- 6.5 Ml/d of further leakage reduction.
- Aylesford wastewater recycling scheme.
- Raising Bewl Water.
- Medway desalination.
- Drought permit to increase winter re-filling and conservation of existing storage of Bewl Water and summer reduction in requirements of releases to support downstream abstraction.
- Drought order to reduce MRF for River Medway Scheme.
- Drought permit to remove seasonal constraints at Kettle Hill, Hockley Hole and Trundle Wood.
- Rest groundwater sources and maximise the use of the River Medway Scheme.
- Reduce transfer to other companies.
- Tankering.

11.9. Sensitivity

Climate change impact on DO:

- Refill potential for Bewl Water can be affected by single season droughts. The reservoir is at significant risk from multi-season droughts, where winter refill cannot be achieved in successive winters.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).

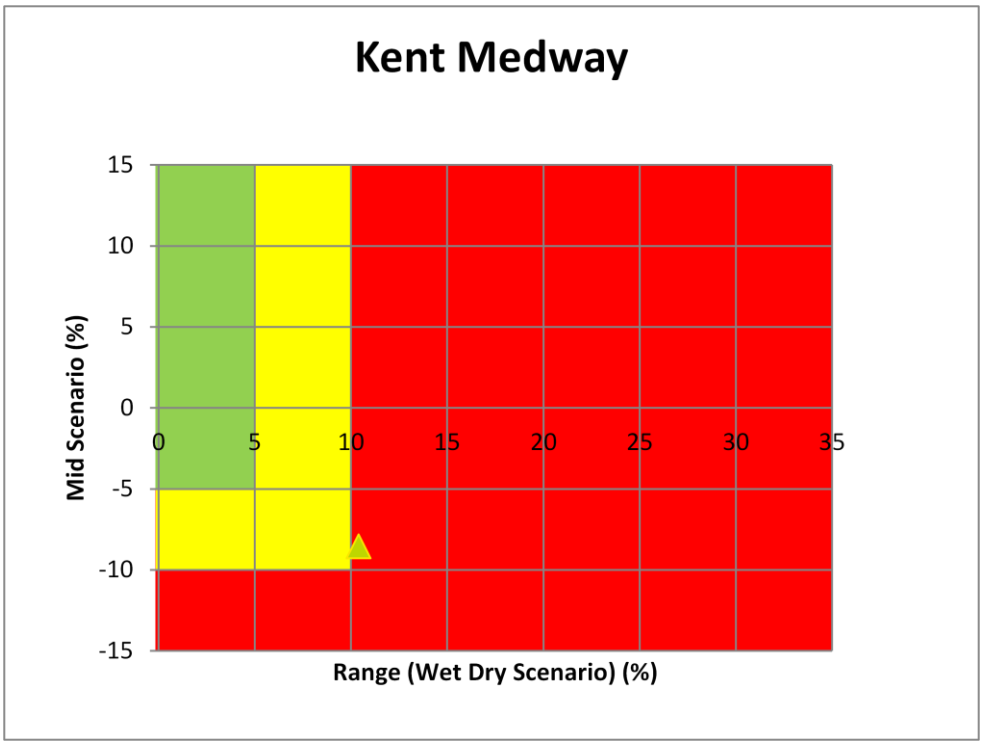
Other factors affecting sensitivity of WRZ to impacts of climate change:

- Operation of Bewl Water is currently constrained by the operational need for a minimum input to Burham of 30 Ml/d.
- Limited recourse to Drought Permits/Orders to improve groundwater supplies.

11.10. Vulnerability classification

The vulnerability classification for the WRZ is high, see Figure 11-1.

Figure 11-1 Magnitude vs. sensitivity, Kent Medway WRZ



11.11. Proposed climate change assessment method

At PR09 fairly detailed modelling was undertaken using the EA's North Kent recharge model for groundwater and Catchmod rainfall-runoff models for surface water. The main impact due to climate change is on surface water, particularly in relation to the River Medway scheme. Given this sensitivity, and the supply-demand deficit, it is proposed that this scheme, and the surface sources in general, are assessed in detail. Use of a 'smart' sample of 20 samples, sub-sampled from within the 100 to focus on the dry end of the distribution (Approach B2), will be investigated using an aridity indicator and a measure of reservoir refill potential (note that the EA Science Report Climate change approaches in water resources planning – Overview of new methods found it difficult to implement such an approach in a 'South East' zone, as compared with London). It may also be useful to compare with Future Flows data, as the catchment to Teston was modelled. Following the hydrological analysis, water resource modelling can be undertaken using a smaller (3-5) sample selected on the basis of hydrological impact (which is an accepted approach in the WRPG). For groundwater, an update of the recharge modelling may be required to assess the impact of UKCP09 (and for consistency with the surface assessment); initially it may be possible to compare the previous work with the groundwater change factors at Little Bucket Farm from Future Flows. Any recharge modelling would be based on the smaller (3-5) sample used in the water resource zone modelling.

12. Kent Thanet Water Resource Zone

12.1. Sources

The ratio of groundwater to surface water (river) sources in this WRZ is 93%:7%.

Sources:

- Chalk aquifer.
- River Stour.

12.2. Period used for analysis

Historic surface water flows have been reviewed and modelled as far back as the 1890s. Realistic, pragmatic assessments of groundwater capability under the identified key surface water droughts were evaluated.

12.3. Critical drought years

- 1900-03
- 1920-22
- 1934-35
- 1944-45
- 1976
- 1989-92
- 2004-06

The critical event for the Eastern Area was 1900 – 1903 when there was an extended three year drought which progressively eroded reservoir and groundwater storage.

12.4. Supply-demand balance

	Base year (Ml/day)	2011 – 12 (Ml/day)	2016 – 17 (Ml/day)	2034 – 35 (Ml/day)	Deficit
Dry year scenario	10.71	7.63	8.17	5.04	Surplus throughout planning period
Critical period scenario	-3.68	-2.78	0	-8.17	Deficit throughout planning period

12.5. Security of supply

	Zonal security of supply index
Dry year annual average	0
Dry year critical period	0

12.6. Climate critical variables

- Winter rainfall.

12.7. Climate change Deployable Output

SWS prepared a summary report on the approach to the calculation of surface water DO - Southern Water WRMP Support, Technical note: Surface water Deployable Output, Atkins July 2008, (Ref: 5050675/70/DG/036).

A complementary report on severe droughts and climate change impacts on groundwater DO has also been prepared - Assessment of impact of severe drought and climate change on groundwater DO, Atkins, March 2009 (Ref: 5050675/70/DG/092). The groundwater report brings together the various elements of work undertaken for the AMP4 Water Resources Investigations and the WRMP (Southern Water 2010).

12.8. Adaptive capacity

- Universal metering.
- Optimisation of interzonal transfers (from Kent Medway).
- 0.1 Ml/d of further leakage reduction.
- Drought permit to increase abstraction from Great Stour.
- Optimising the use of the Selling-Fleete main to transfer water from the Kent Medway WRZ.
- Rest groundwater sources and maximise use of surface water when sufficient surface water is available.
- Reduce transfer to other water companies.
- Tankering.
- Re-commissioning of Rumfields source (water quality permitting).
- Drought permit for summer and winter reduction in MRF at Plucks Gutter.

12.9. Sensitivity

Climate change impacts on DO:

- The WRZ is supplied almost exclusively from groundwater sources - therefore prone to water stress during prolonged periods of low rainfall and drought.
- Risk of saline intrusion in coastal aquifer may be exacerbated by sea level rise due to climate change.
- Chalk groundwater sources tend to be fairly resilient to single dry winters but are at risk of progressive dry winters (decreased groundwater recharge).
- Well and adit sources susceptible to low winter rainfall events. Generally resilient to one dry winter, but sensitivity increases with successive dry winters.
- Surface water abstraction from the River Stour is susceptible to drought when flows fall below the MRF, although a minimum 3.3 Ml/d of yield is protected from drought as it is supported by a wastewater discharge.
- Storm events leading to contamination of surface water sources with silt or chemical pollution could be exacerbated by climate change.

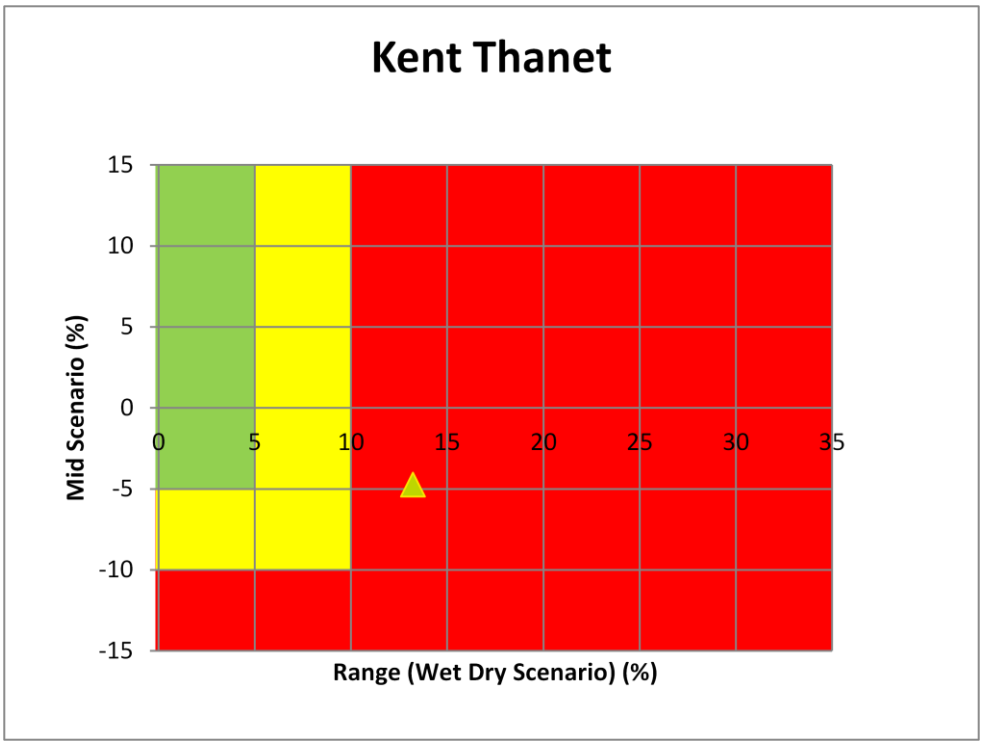
12.10. Vulnerability classification

The vulnerability classification for the WRZ is high, see Figure 12-1.

12.11. Proposed climate change assessment method

Although this source is classified as being of high vulnerability, this is due to the large range in climate change impacts, from a >2% increase in DO in the minimum case, to a 11% decrease in the maximum case; this was based on the PR09 assessment using the UKWIR06 scenarios in the East Kent Groundwater Model. It will be important to establish whether this range of impact exists using UKCP09 data. Initially, the results could be compared with the groundwater change factors at Little Bucket Farm from Future Flows. However, more detailed modelling may then be required (probably limited to 20 climate samples – either Approach A1 or B2). Given the small contribution of surface waters and the absence of an impact on DO (due to the MRF) in the PR09 assessment, no further assessment is proposed for the River Stour abstraction.

Figure 12-1 Magnitude vs. sensitivity, Kent Thanet WRZ



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