VEOLIA WATER PROJECTS LTD
DRAFT WATER RESOURCE MANAGEMENT PLAN 2024
ANNEX TWO - CLIMATE CHANGE AND RESILIENCE

1. Introduction

Tidworth Inset operated by VWPL is located within the West Country region within England. The West Country region is diverse. The findings of a report recently published by the CBI 'Reviving Regions: Empowering Places to Revive and Thrive' stated that water supply companies within our region encounter some strategic disadvantages in terms of infrastructure, innovation and there is a great disparity as to economic, education and social indicators.

The public potable water supply companies within the West Country have an excellent record of managing water resources while protecting the environment, maintaining sustainable, resilient water sources and supporting the local economy during tourist-rich seasons. The wider West Country region is home to 4.7 million people and contributes in excess of £100 billion to the UK's economy, including over £2 billion generated from agriculture, which is a high water demand industry. This equates to approximately 1,400 million litres of water (Ml/d) used every day in the West Country region and approximately 85% of all potable water is used to supply homes and business customers.

The Wessex area where VWPL Water Resource Zone (WRZ) is located was previously classified as a low to moderate water stress area. Climate change has influenced how much water is available and therefore the severity of future droughts for both the wider environment and for the potable water supply. Following a recent assessment undertaken by the Environment Agency (EA), the Wessex area within England is now classified as a water stressed area.

Water supply companies in the West Country (VWPL regional plan area) currently prepare to be resilient in a repeat of the worst recorded drought events; these events occurred in 1921, 1933/34 and 1975/1976.

To reflect the challenges that water supply companies are currently facing with increasing population and climate change, the WRMP 2024 guidance requires water supply companies to prepare resilience to more extreme drought conditions (a 1 in 500 year event) that actively has the potential to affect VWPL operations and water supply.

There is regulatory expectation that VWPL will have achieved resilience to a 1 in 500 year drought event by 2039.

2. Hydrogeological Background of the Water Resource Zone

2.1. Geology of the Water Resource Zone

VWPL Water Resource Zone (WRZ) is underlain by three geological bedrock formations which include the Lewes Nodular Chalk Formation, the Seaford Chalk Formation and the Newhaven Chalk Formation. No superficial deposits are recorded within the WRZ as weathered bedrock is present from the surface. However, given recent development within the wider WRZ, it is likely that a limited thickness of Made Ground may be present.

The topography of the WRZ is undulating. The surface elevation of the Chalkpit abstraction borehole is approximately 150 mAOD whereas the surface elevation of abstraction boreholes 2 and 3 is approximately 120 mAOD.

The original geological logs produced at the time of boring and supplementary CCTV surveys have stated that abstraction boreholes 2 and 3 are drilled through approximately 10 m of Newhaven Chalk Formation, 68 m of Seaford Chalk Formation and terminate approximately 32 m into the Lewes Nodular Chalk Formation, as shown in Figure 5. Chalkpit abstraction borehole is bored through 40 m of the Newhaven Chalk Formation and terminates approximately 45 m into the Seaford Chalk Formation, as shown in Figure 1.

A geological cross-section (Figure 2) of the River Bourne within the wider Wessex Basin shows the general trend of the units, including Lewes Nodular Chalk Formation and Seaford Chalk Formation within the wider Chalk Group (BGS 2019). In addition to the stratigraphy of the Chalk Group, the cross section identifies certain features which have significant importance to groundwater and surface water flow in the WRZ and wider catchment area. An example of this is the spatial distribution of the hard rock bands at approximately 28 to 36 m above the base of the Seaford Chalk at Tidworth (located within the VWPL operated WRZ). This is potentially associated with the base of the Stockbridge Rock and is described as 'assumed Stockbridge Rock', which is considered to have an important influence on both groundwater movement and groundwater-surface water interaction.

Figure 1 - Cross section of the geological formations of VWPL operated abstraction boreholes.

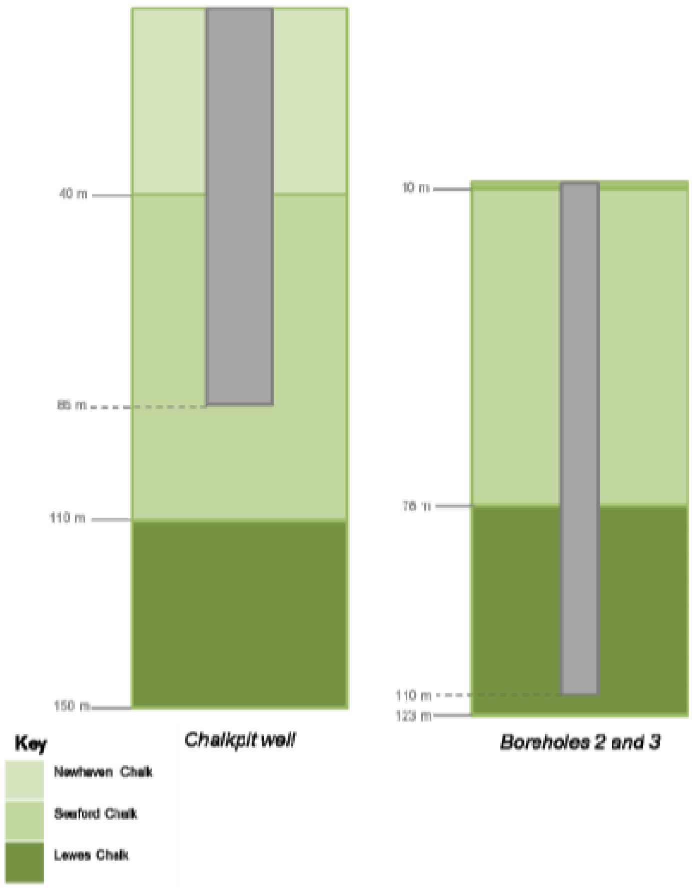
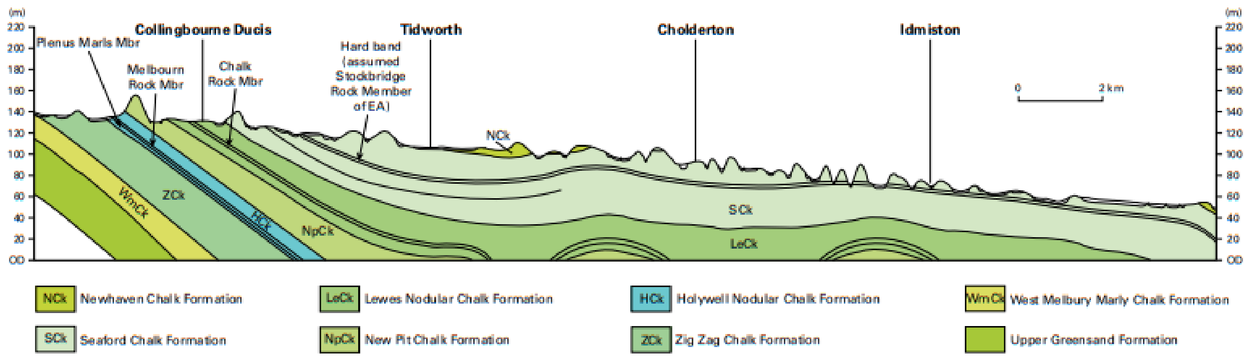


Figure 2 - Cross section of geological formations of the wider Wessex Basin (BGS 2019).



The porosity of the underlying chalk aquifer is generally very low as it was measured between 2% to 3%. However, in localised areas of the aquifer, the chalk is fractured allowing for secondary migration forming dual porosity, which enables flow throughout the aquifer. The porosity of the chalk aquifer underlying Tidworth is significantly lower than that of other chalk aquifers in the south east of England. The transmissivity and porosity of the VWPL operated abstraction boreholes are shown in Table 1. In addition, the chalk aquifer underlying Tidworth is highly permeable.

Table 1 - Summary of pump tests undertaken on abstraction boreholes 2 & 3 by Thames Water Utilities Ltd in April 2005

Borehole Location		Borehole 2	Borehole 3	Thames Basin (Median)
Storativity		1.2 x 10 -3	1.2 x 10 -3	2 x 10 -3 to 7.5 x 10 -3
Transmissivity (m2/d)	**Lower Range**	1150-2450	1450-2000	230
	Upper Range	4700-6250	3200-5150	860
Porosity (%)		2-3 (effective)	2-3 (effective)	26 (total)

2.2. Groundwater levels within the Water Resource Zone

There are approximately six observation boreholes within the wider Tidworth network which are monitored monthly by VWPL to determine the levels of the groundwater at abstraction boreholes 2, 3 and Chalkpit. These observation boreholes are located up and down hydraulic gradient of the abstraction boreholes, this is to provide VWPL with a full understanding of the underlying hydraulic regime.

In addition, the British Geological Society (BGS) in accordance with the EA operates an observation borehole at Clanville Lodge Gate, which has been monitored since 1963. Due to the reliability of this groundwater monitoring data, VWPL has considered that it represents the most efficient dataset to use within the following climate change and vulnerability assessments.

The Clanville Lodge Gate observation borehole is approximately 10 km away from the VWPL WRZ and the hydrographs for the period in which the records overlap are very similar in shape and amplitude of seasonal variation. Therefore, groundwater data recovered from the Clanville Lodge Gate observation borehole has been calibrated with the data obtained by VWPL in OBH1. The groundwater data recovered from the observation borehole were adjusted by 11.48m AOD to align with the Tidworth supply network.

The observed and predicted groundwater levels recorded by the BGS at the Clanville Lodge Gate observation borehole are shown below on Figures 3 and 4.

Figure 3 - Observed and Predicted Groundwater Levels by the BGS for the Clanville Lodge Gate Observation Borehole

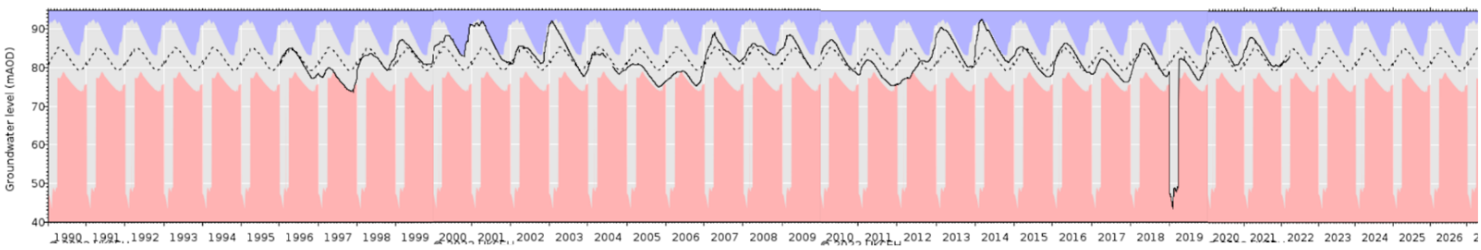
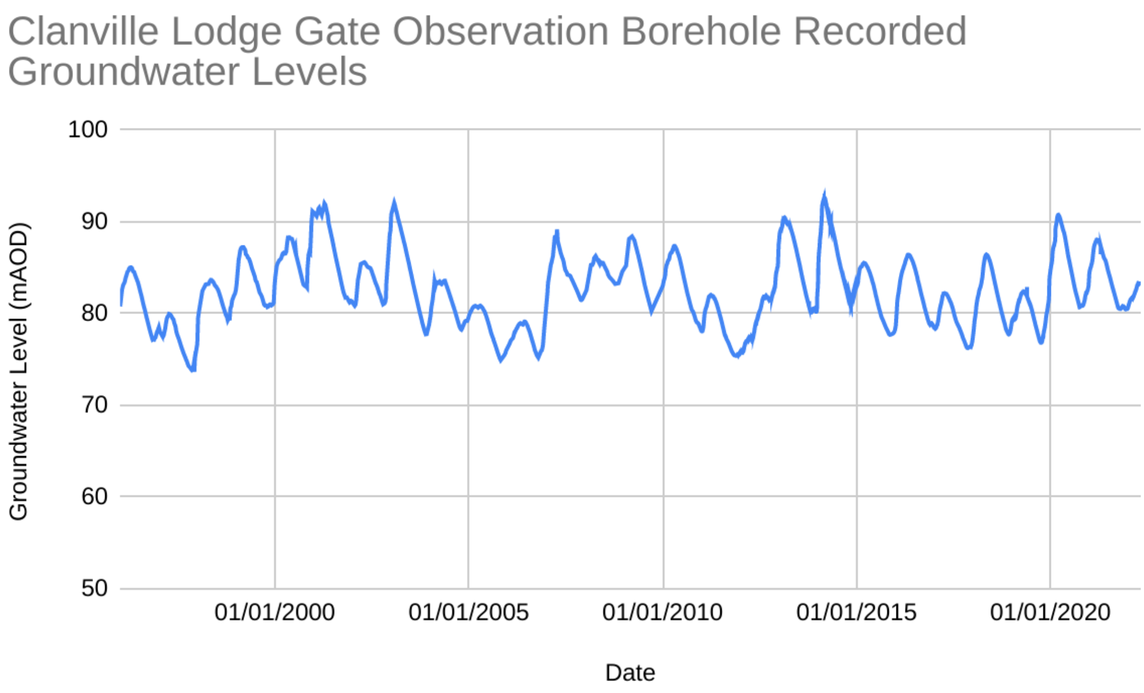
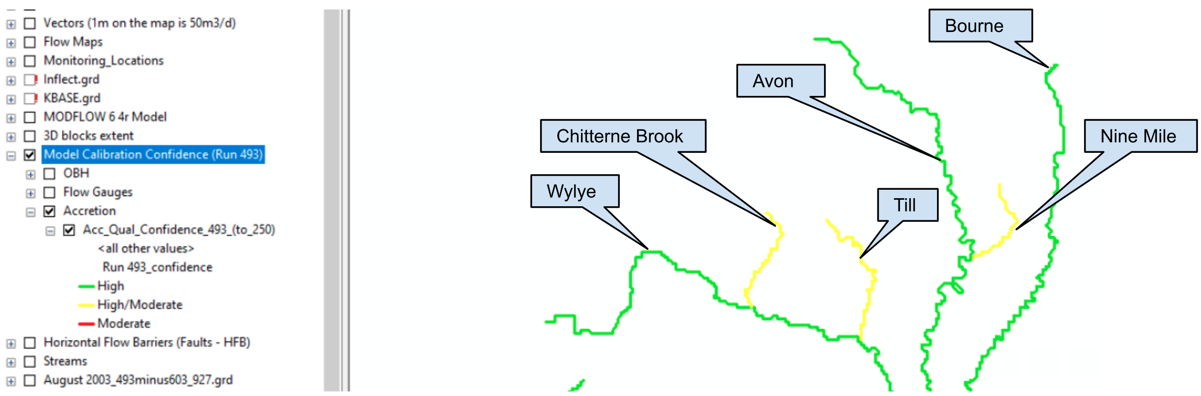


Figure 4- Groundwater Levels within the BGS Operated Clanville Lodge Gate Observation Borehole



In addition, the model created for the Wessex Basin groundwater assessment undertaken as part of the PR19 WINEP AMP7 investigation suggests that there is good calibration within the underlying groundwater regime within the Salisbury Plain, as illustrated on Figure 5. This model encompasses data obtained from the wider Wessex Basin, including the chalk aquifers of Salisbury Plain and the River Bourne.

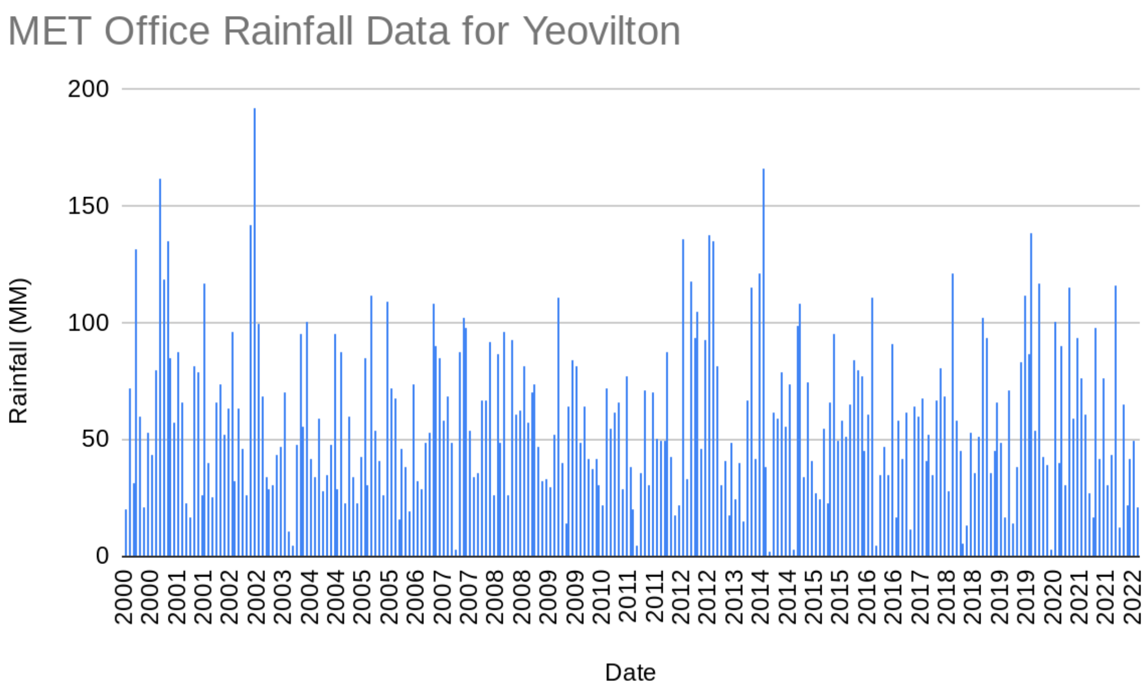
Figure 5- Model Calibration of the Wessex Basin (WINEP 2022).



2.3. Rainwater Levels Within The Water Resource Zone

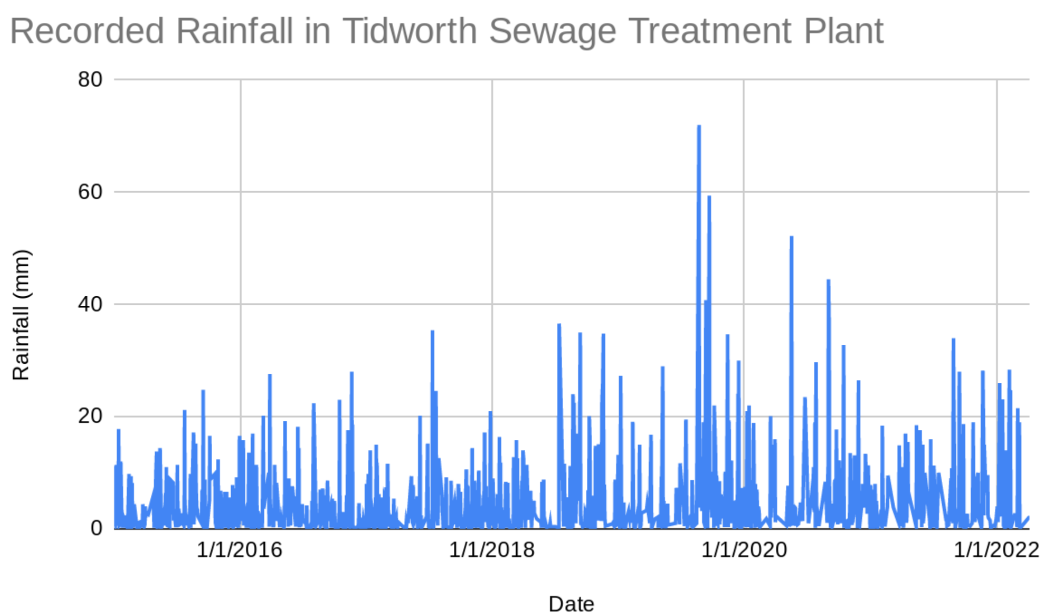
Historical data is available from the MET Office from 1920. The VWPL Tidworth Inset is located between Yeovilton, Oxford and Heathrow Airport MET operated weather stations. The rainwater trends from these stations are shown on Figure 6.

Figure 6 - Recorded rainfall data from the MET Office monitoring station Yeovilton



In addition, VWPL collects rainfall data from a gauge at the STW (Figure 7). This data is collected by the EA to assist with the water resource situation within the wider Wessex Basin.

Figure 7 - Recorded rainfall data from the VWPL STW gauge



For the purpose of the climate change and vulnerability assessments produced as part of this WRMP, the rainwater data obtained from the Tidworth STW will be utilised. However, where this is not possible, for example when reviewing the critical drought years in 1975/76, VWPL will use the data obtained from the Yeovilton MET Office gauge as this rainwater monitoring station presents the similarities in shape and amplitude of seasonal variation.

3. Climate Change Assessment

The daily operations and services of water companies are affected by weather patterns and as such it is essential to account for the changes that may occur within long-term planning. VWPL has reviewed the impact of changing rainfall, evaporation and temperature patterns and the impact these factors may have on river flows within the wider environment and groundwater recharge and ultimately on the deployable outputs of the abstraction boreholes.

The most recent climate change information available to water supply companies is the UK Climate Change Projects Output (hereby referred to as the 'UKCP2018'). The climate change assessment will incorporate the following scenarios:

- The SRESA 1B Scenario used within VWPL's WRMP19;
- Two different emissions scenarios based upon the findings of the West Country Regional Plan. These include the RCP2.6 and the RCP8.5 which model different levels of future climate change.

The projections, presented in the below sub-sections, suggest that compared to the baseline period between 1968 and 2000, the future climate within the VWPL Inset is likely to be characterised by drier and warmer summers and milder and wetter winters. This will ultimately enable extreme events, such as 1 in 200 year and/or 1 in 500 year drought events, to occur more frequently.

It should be noted that as VWPL supply is recovered from a groundwater source only, no surface water models will be included within the following climate change assessment.

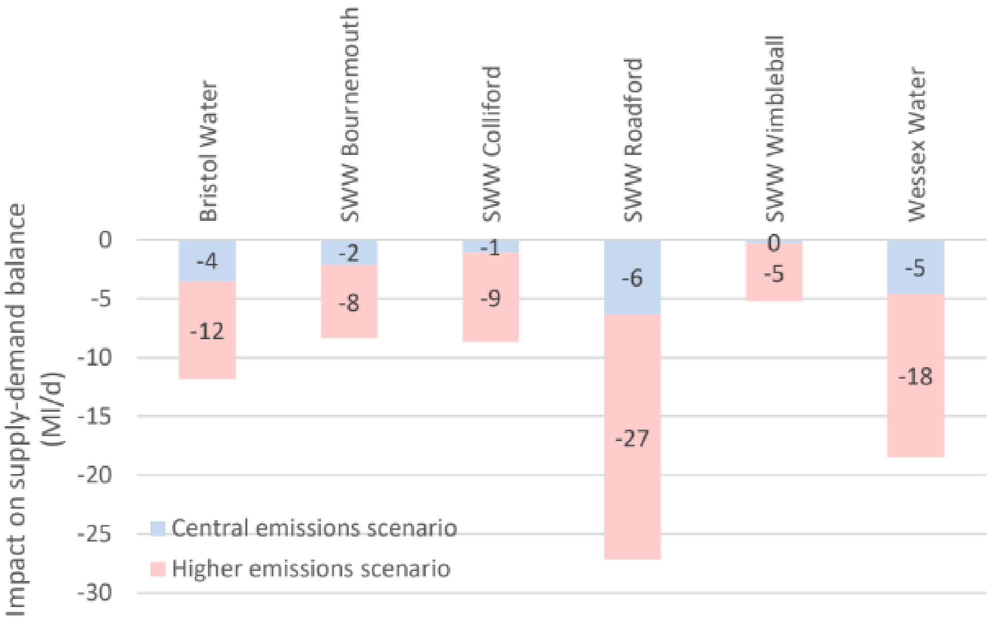
3.1. West Country Regional Plan Climate Impact Modelling

The West Country Regional Plan (Draft V.13 2022) undertook some hydrogeological modelling to further understand the impacts of climate change on the wider region. They used the RCP6.0 probabilistic climate projections for their central emissions scenario, this equated to an average temperature increase of 1.9°C from the pre-industrial baseline through the 2070s. It was concluded by the West Country Regional Plan that emissions peak in 2080 and then start to decline within the RCP6.0 scenario.

The RCP8.5 scenario is considered to be the worst case emissions scenario, with emissions continuing to rise throughout the 21st century. The climate model shows a greater impact on the West Country Region with a temperature increase of 3.7°C by the end of 2070. It is therefore sensible to assume that this scenario represents the expected worst case impact of climate change.

The West Country Regional Plan calculated that if the RCP6.0 central emissions scenario occurs, then the water availability within the wider region will be reduced by 18 Ml/d in 2050. However, if the current projections align in accordance with the RCP8.5 worst case emissions scenario, then water availability within the wider region would be reduced by 80 Ml/d by 2050, as shown on Figure 8.

Figure 8 - Results of the West Country Regional Plan Modelling.

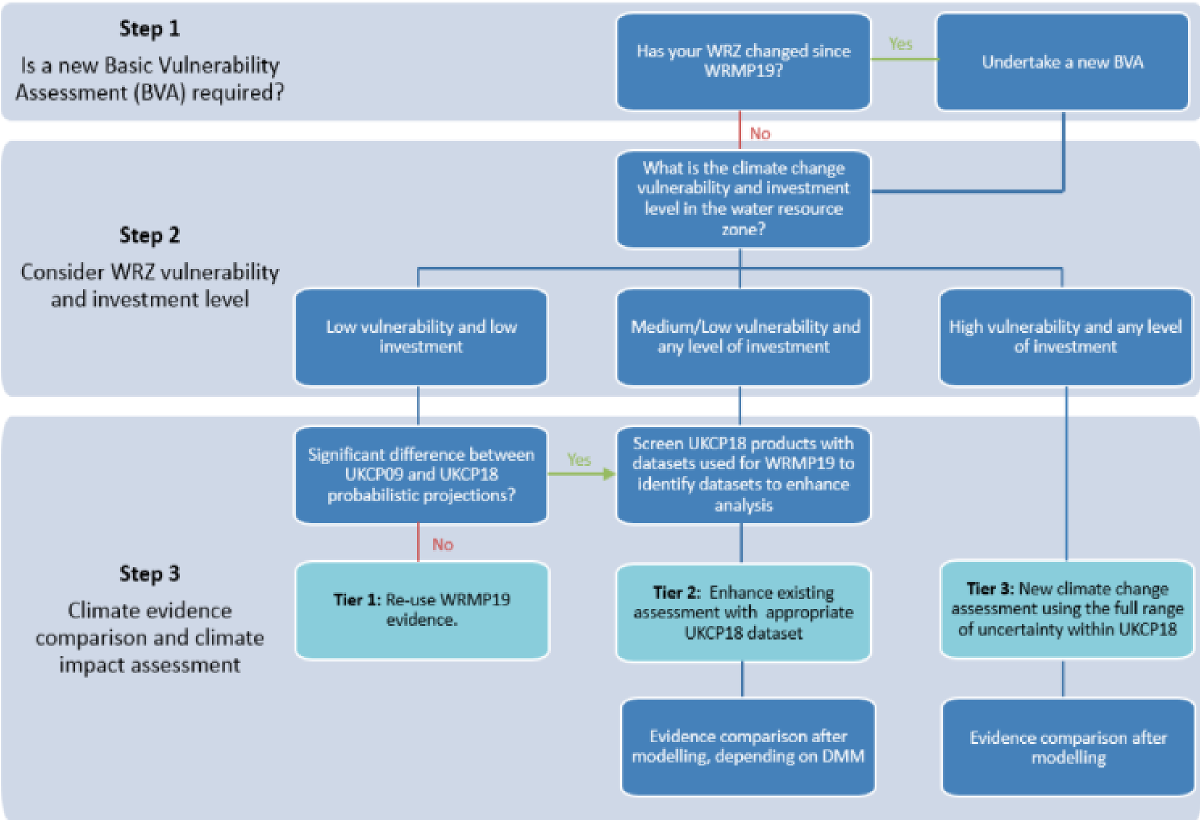


3.2. Climate Change Vulnerability/Basic Assessment

Water companies and regulatory bodies already consider the sensitivity and vulnerability of water resource zones. In accordance with the Climate Change Act (2008), water companies need to consider the risks associated with climate change.

The methodology used for climate change vulnerability/basic assessment is outlined in Figure 9.

Figure 9 - Flow chart from the Environment Agency WRMP 2024 guidance for climate change assessment process to be undertaken for all water resource zones.



The basic vulnerability (Level 1 in Figure 9) is a largely qualitative activity based on VWPL's current knowledge of the network's vulnerabilities available from the preparation of drought plans and the water resource management plans. In addition, the WRZ assessment, which is discussed within Annex Three of this WRMP, has not changed since the production of the WRMP19 report and associated assessments.

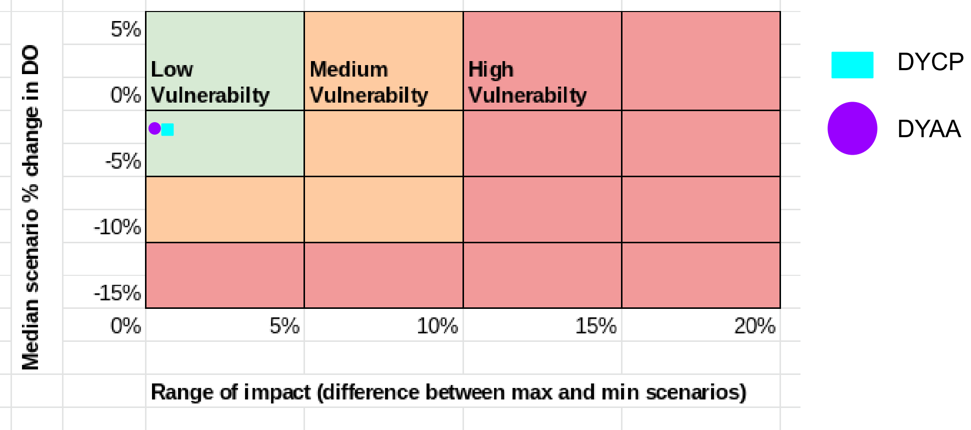
Table 2 - Climate Change Vulnerability Assessment

	Source	Comment
Critical Drought Years	Drought Plan	1921, 1933/34 and 1975/76 have been identified as significant drought events in studies of historical rainfall and the analysis of their impact on deployable output (DO). The referenced years were identified as the lowest drawdown levels in the single source reservoir simulations and the lowest simulated groundwater levels in models.
Type of Water Supply Sources	WRMP	100% of VWPL supply is recovered from groundwater from a single unconfined chalk aquifer.
Period Used for	Drought	The critical drought years were identified from rainfall,

Analysis	Plan	reservoir and groundwater level simulations. These events were considered to have occurred within 1921, 1933/34 and 1975/1976.
Supply/Demand Balance (base year)	WRMP	The annual review of the Water Resource Management Plan for 2019/20 (the base year for the assessment) was 9.00Ml/d. This figure indicates a satisfactory resource position with demand patterns. This baseline figure also provides satisfactory resources within a 1 in 100 and 1 in 200 year drought event.
Critical Climate Variables	Drought Plan	The supply network is sensitive to multi-season droughts, for example the dry summer-dry winter-dry summer drought during 1975/76. The groundwater recharge during the drought event of 1975/76 was extremely low (effectively zero). Therefore, the only way that climate change could impact this further is if summers become longer. However, there is no evidence of this, only that summer temperatures will increase by 1.1°C to 5.8°C. In addition, the latest UKCP18 data has suggested there is a likelihood that the intensity of heavy summer rainfall events will increase in the future.
Climate Change DOs (Dry Scenario)	WRMP	Overall therefore, the baseline impact of climate change in the 2030s is estimated to be -0.84 Ml/d on average (0.3% of deployable output) and -0.83 Ml/d for the peak scenario (0.2% of deployable output).This is discussed in more detail within section 3.4 of this annex.
Adaptive Capacity	WRMP/ Drought Plan	A list of all of VWPL's available sources are detailed within Annex 1 of this WRMP. VWPL Drought Plan (2022) details VWPL drought planning steps.
Sensitivity **(low/medium/high)**	WRMP	The magnitude versus sensitivity plot (Figure 18) suggests the VWPL single WRZ is of low vulnerability to climate change.
Action Needed	Given the VWPL low vulnerability status and as there is no significant difference between the UKCP09 and UKCP18 datasets, the Tier 1 climate change assessment method is considered adequate. However, to further delineate the potential impact from climate change, VWPL will enhance the existing assessment with appropriate UKCP18 dataset.	

Figure 10 shows the magnitude-sensitivity plot of information for the VWPL Inset. The change in deployable output for the median impact scenario is plotted against the uncertainty as represented by the range of change in deployable output (the difference between the maximum and minimum impact scenarios). The impact of the median impact climate change scenario on deployable output is low for both dry year annual average and dry year critical period scenarios, and the uncertainty associated with this projection was less than 5%. As a result, the WRZ is assessed as low vulnerability to climate change.

Figure 10 - Climate change magnitude-sensitivity plot.



In accordance with Step 2 of the climate change methodology (Figure 9), after evaluating the vulnerability of the WRZ to climate change, VWPL considered whether the level of investment required for maintenance of the network is influenced by the effects of climate change. VWPL concluded that the level of investment was low as climate change does not drive investment within the network.

3.3. Step 3 - Climate Impact Assessment and Evidence Comparison

The UKCP18 climate change projections indicate a change in the severity of impact at particular locations within the United Kingdom compared to the assessments for WRMP19 based on the UKCP09 dataset. However, future climate change projections are highly uncertain and therefore the following assessment has indicated a wide ranging uncertainty in future supply, demand, MoD activities, the supply-demand balance, levels of service and investment plans.

As mentioned earlier, the climate change basic vulnerability assessment categorised Tidworth WRZ as having low vulnerability to climate change. This is due to factors such as all of the supply being abstracted from groundwater. While in accordance with EA guidance (Figure 9), there is no need for VWPL to undertake a climate impact assessment, VWPL has completed it, due to the increasing severity of climate change across the wider region,

For the purpose of this impact assessment, a limited number of climate change scenarios were produced and considered within the analysis. This is due to the data-processing involved as the groundwater sources must be assessed manually by VWPL as there are known difficulties relating to modelling the impacts of climate change on groundwater-only water supply systems.

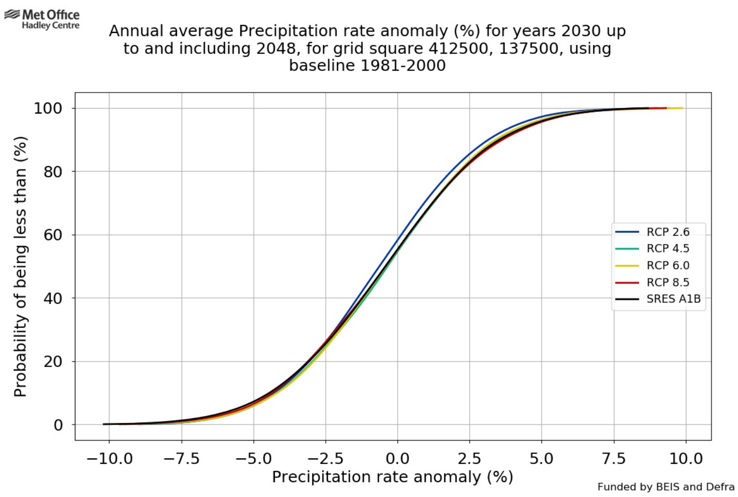
3.3.1. Comparison between UKCP09 and UKCP18 Datasets

In accordance with the climate change impact assessment methodology, VWPL compared the UKCP08 and the UKCP18 probabilistic projections to see if there were any significant differences. A selection of comparisons, including annual average precipitation rate anomaly (%) over two selected time slices from 2030 to 2048 and 2060 and 2078 are shown in Figures 11 to 14.

The WRMP guidance states that water companies can re-use the climate change analysis undertaken in WRMP19 if there are no significant differences between the UKCP18 and UKCP08 probabilistic projections.

The comparison concluded that there were no significant differences between the UKCP08 and the UKCP18 probabilistic projection databases for the Tidworth region. Therefore, VWPL will use the scenarios used in the WRMP19 climate impact assessment for the basis of the WRMP24 assessment. However, for completeness, VWPL has chosen to supplement the WRMP19 assessment with the updated findings of the UKCP18 dataset to ensure accuracy within the climate change forecasting.

Figures 11 (below left) - The annual average precipitation rate anomaly (%) graphs for both the UKCP09 and UKCP18 datasets for time slice- 2030 to 2048



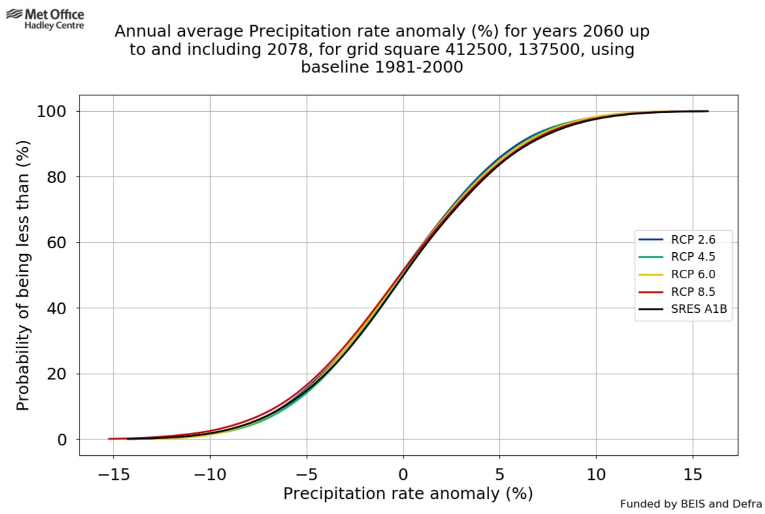
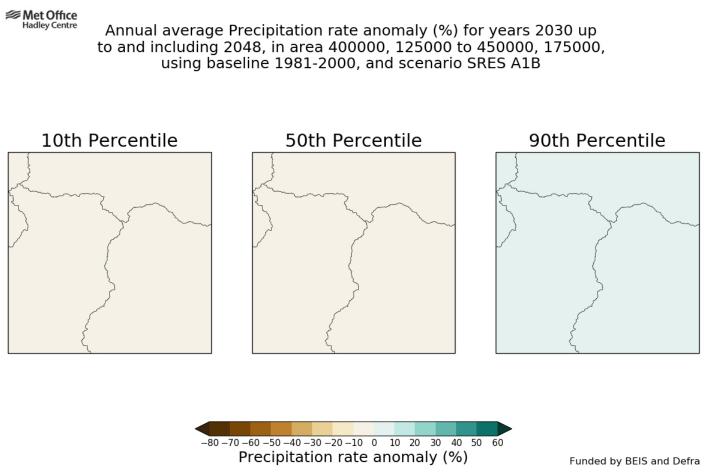


Figure 12 (above right) - The annual average precipitation rate anomaly (%) graphs for both the UKCP09 and UKCP18 datasets for time slice 2060 to 2078

Figure 13 (below left) - The annual average precipitation rate anomaly (%) maps for the UKCP09 for time slice 2030 to 2048



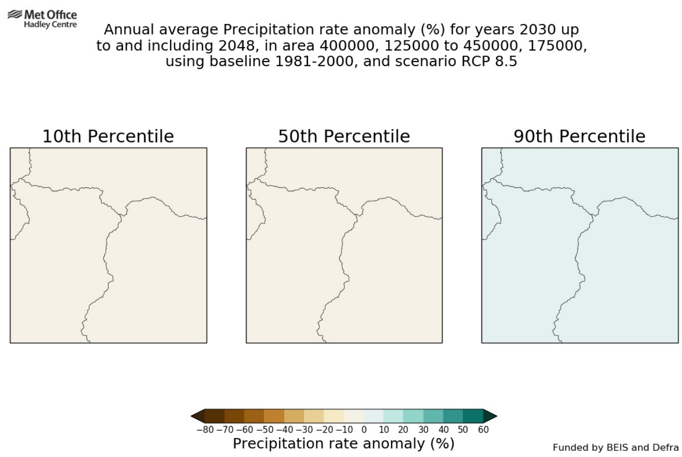


Figure 14 (above right) - The annual average precipitation rate anomaly (%) maps for the UKCP18 datasets for time slice 2030 to 2048.

3.3.2. Medium Emissions Scenario (SRES A1B)

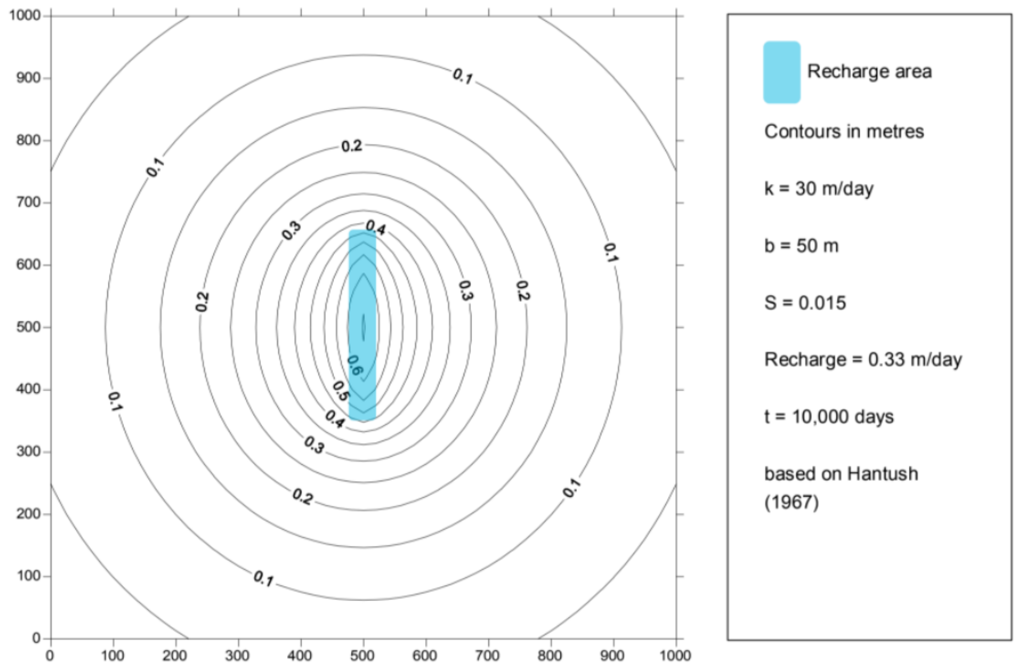
During the completion of the WRMP 2019 cycle, VWPL used the UKCP09 medium emissions scenario (hereby referred to as SRES A1B) to understand the potential impacts associated with climate change. The modelling work was undertaken by AECOM in November 2018 to undertake climate change modelling on the VWPL operated Sewage Treatment Works (STW) within the defined WRZ.

It should be noted that the work undertaken by AECOM was initially focused on the lagoon water levels within the Tidworth STW, however, information was obtained from the observation borehole which is used to monitor the wider water levels and water availability within the VWPL operated WRZ. Therefore, the results can be transposed for the wider WRZ.

In order to undertake the climate change modelling, AECOM had to undertake preliminary modelling on the groundwater mounding beneath the VWPL operated WRZ. There are a number of methods used for groundwater mounding modelling.

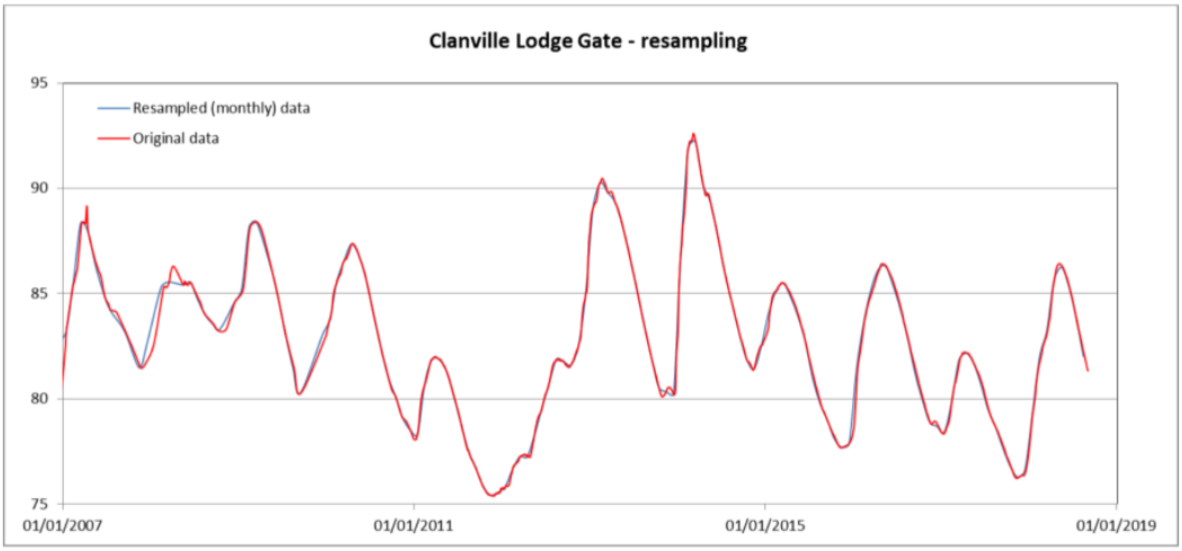
The preliminary model (Figure 15) used by AECOM was set up on a 50 by 50 grid representing an area of 1 km by 1 km with a rectangular recharge area in the centre of 300 m by 30 m. The recharge rate used by AECOM was 0.33m/day to give a total discharge to ground of 2,970m^3/day, which is the same figure outlined in the EA permit. The conditions for the analytical models apply to the wider underlying aquifer of the VWPL operated WRZ. An initial transmissivity of 1,500 m^2/day was used and input into the model as an aquifer with a saturated thickness of 50 m and a hydraulic conductivity of 30 m/day. These values are consistent with those referenced above from the Aquifer Properties Manual and those used in the Wessex Basin Groundwater Model.

Figure 15 - Groundwater contours for mounding beneath the VWPL operated STW and wider aquifer within the WRZ.



To refine the preliminary model, AECOM resampled the long-term hydrograph to select data from monthly intervals as they noted irregular time steps within the original hydrograph. The resampled hydrograph was plotted against the original data to confirm that the overall trend had not changed (Figure 16).

Figure 16 - Graph of resampled data of the long-term hydrograph.



The MET Office Hadley Centre Regional Climate Model (HadRMS) is used as part of climate change experiments. The HadRM3-PPE experiment was designed to simulate the regional climate for the UK in the period 1950-2100 for the historical and medium (known as the SRESA 1B) emissions scenario. The model was run for the wider European area and the UK data extracted from it. The ‘Perturbed Physics Ensemble' (‘PPE) consists of an 11 member ensemble, each member driven by the same historical and SRESA 1B emissions, with one unperturbed member and 10 members with different perturbations to the atmospheric parameterisation. The standard forcings include historical levels of greenhouse gas emissions (including methane), sulphur and tropospheric/stratospheric ozone.

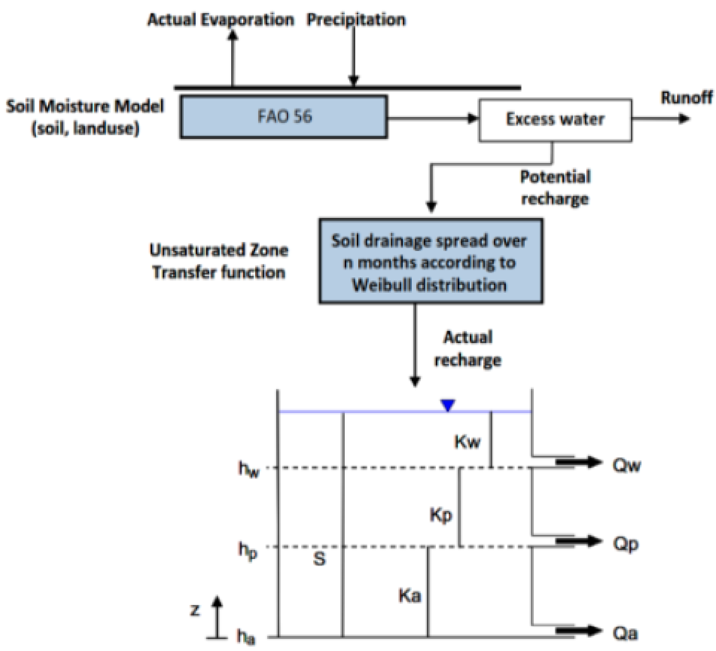
The 11-member ensemble represents daily river flow and monthly groundwater levels for 283 river catchments and 24 boreholes across the UK. The data set was derived in March 2012. The Future Flows Hydrology time series are generated using conceptual hydrological models driven by Future Flows Climate within the time period of 1951-2098. Each ensemble contains 11 members, all equally likely, that together account for climate variability, climate modelling uncertainty and climate forcing under the SRES A1B emissions scenario. As the Future Flows Hydrology datasets are outlined by climate model outputs, they do not replicate historical weather but are possible realisations of river flow and groundwater levels within the projected time period.

Drawing on the results of HadRM3-PPE, the Future Flows and Groundwater Levels (FFGWL) project has applied a consistent methodology to the assessment of the impact of climate change on river flows and groundwater levels across England, Wales and Scotland using the 11-member PPE13.

The HadRM3-PPE time series are provided at a 25-km grid spatial resolution and daily time temporal resolution. However, analyses of precipitation and temperature time series for the historical (pre-2000) period showed systematic differences from observations because their coarse spatial resolution does not allow for small-scale atmospheric processes to be adequately reproduced for the purpose of modelling river flow and groundwater levels. The HadRM3-PPE daily outputs were modified using a statistical technique so that their statistical properties match those of the observations for the same periods and a spatial downscaling was applied to incorporate the spatial heterogeneity observed in precipitation within each 25km grid square. Potential evapotranspiration at 5km resolution was generated using the HadRM3-PPE climate time series, based on the FAO-56 Penman-Monteith method. Groundwater levels were simulated using R-Groundwater, a simple lumped catchment groundwater model developed to model groundwater level time series at observation boreholes by linking simple algorithms to simulate soil drainage, the transfer of water through the unsaturated zone and groundwater flow.

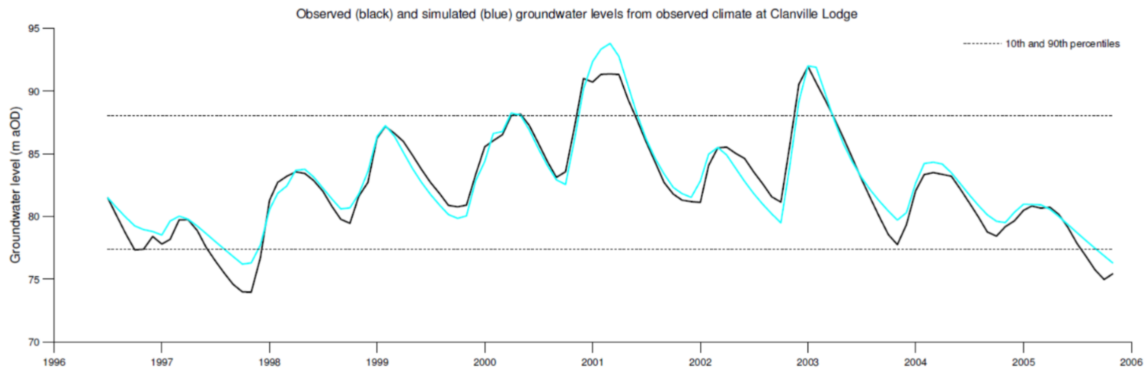
The R-Groundwater model consists of three components (Figure 17): a soil moisture balance model producing a time-series of potential recharge (soil drainage), a simple transfer function representing the delay in the time of the arrival of recharge from the base of the soil to the water table, and a lumped catchment groundwater model based on a simple Darcian representation of flow out of a series of aquifer ‘outlets’.

Figure 17 - R-Groundwater Model used to simulate groundwater level hydrographs (Jackson & Wang, 2011).



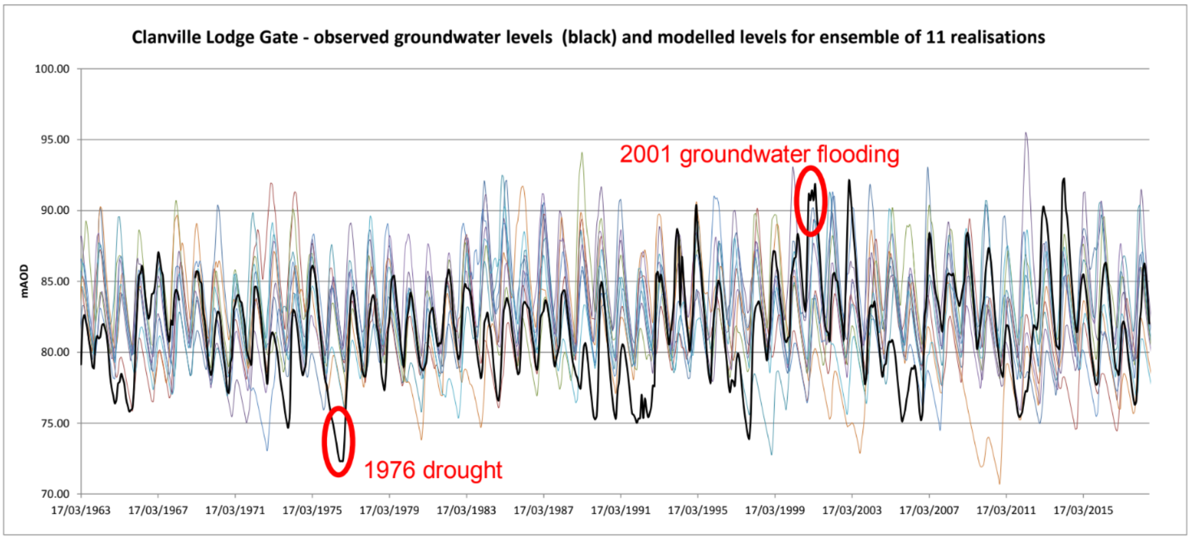
Future Flows Hydrology (FF-HydMod-PPE) represents an 11-member ensemble projection of daily river flow and monthly groundwater levels time series (1951-2098) for 282 rivers and 24 boreholes in Great Britain. The calibration of the lumped groundwater model for Clanville Lodge gate OBH is shown in Figure 18.

Figure 18 - Calibration of R-Groundwater model for Clanville Lodge Gate



A comparison of the 11 simulated hydrographs for Clanville Lodge Gate with the observed record is shown in Figure 19 for the period 1963-2018 (note that the ensemble of simulated hydrographs covers the period 1951-2098). It is important to note that the observed groundwater levels do not correspond to any of the simulated levels since they are all based on simulated climate data (real data were only used for the purposes of calibration of the lumped groundwater model). It is also interesting to note that some of the specific extreme events in the observed data (1976 drought and 2001 groundwater flooding event – circled) fall outside the range of the ensemble for these periods but similar extreme events are represented in other years.

Figure 19 - Observed groundwater levels for the ensemble of 11 relisations



Some initial analyses of potential changes under climate change projections are given in the ‘Catchment Fact Sheet’ for the Clanville Lodge Gate observation borehole. One figure is given, which compares the mean monthly groundwater levels for each of the 11 members of the ensemble for the period 2041-2070 with the equivalent data for the period 1961-1990 (control). The difference between levels for the two periods (for each month and each realisation) is given in Figure 19 and is an indication of the potential impacts of climate change on this borehole site.

Figure 20- Change in monthly average groundwater levels.

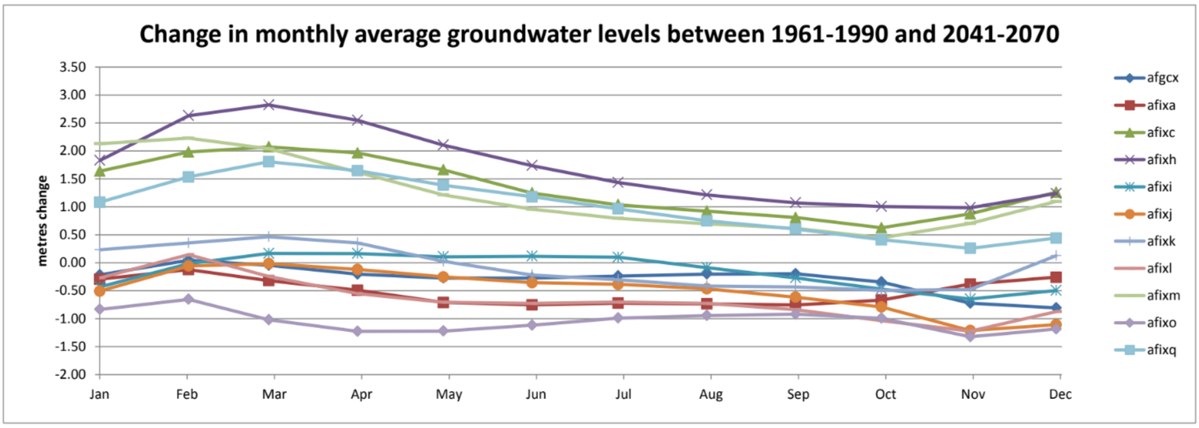


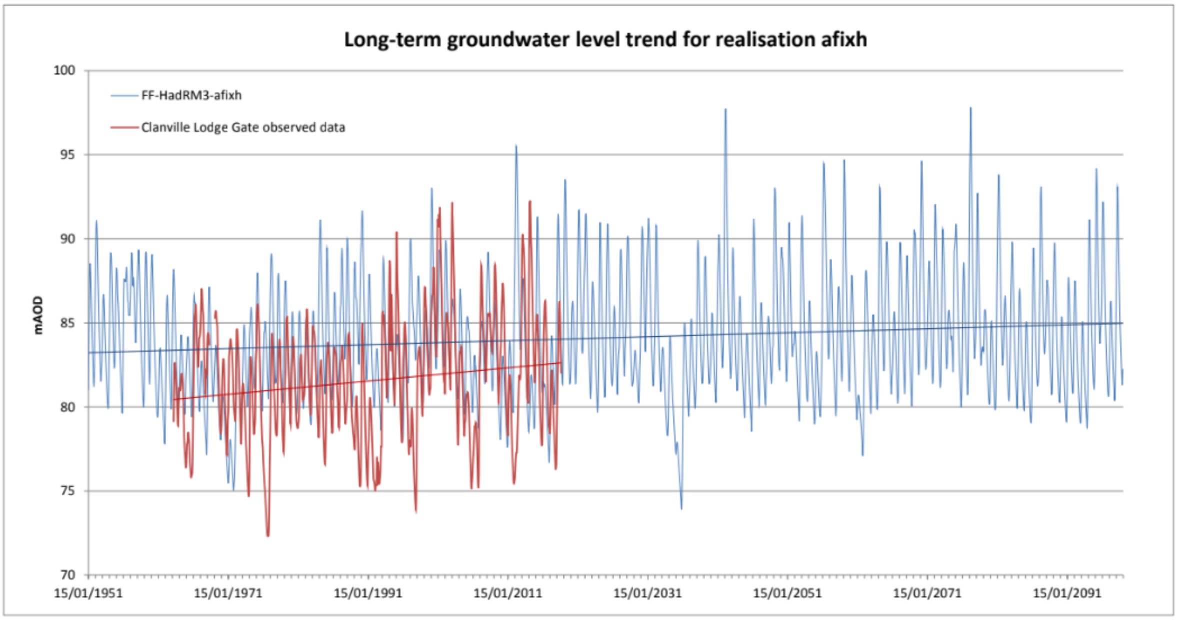
Figure 20 highlights a number of key points that should be noted within the assessment. The modelled ensembles show an overall increase in levels compared to the assessment baseline. The reported average increase for all months across all realisations is 0.19m.

The trends shown in Figure 21 suggest that winter groundwater levels are more likely to be higher in the future while summer levels are more likely to be lower. The trend shows the average change for all realisations as +0.56m for the period between February and May and -0.16m for the period between September and December. Due to the recharge lag period experienced within the cycle, the term winter typically refers to high groundwater levels while summer refers to low groundwater levels. It should be noted that the lag period is more exaggerated on the interfluves in chalk environments. This exaggerated trend is reported within the VWPL WRZ as the groundwater peaks and troughs are typically recorded one month sooner than the UK-wide trend.

The maximum increase in groundwater levels for March between the 30-year periods is 2.82 m (realisation afixh).

Overall, the SRESA 1B scenario analysis suggests that groundwater levels are likely to rise within the time period leading up to 2080. However, significant rises are predicted within the winter months of the cycle with groundwater levels having the potential to increase on average by approximately 2 to 3 metres higher than the baseline used within the assessment.

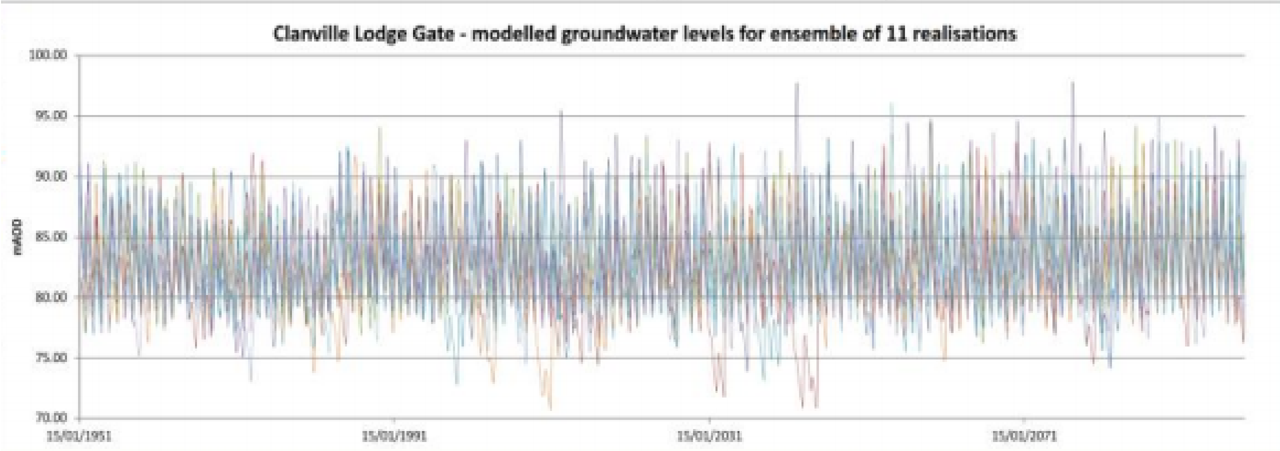
Figure 21 - Trend in groundwater levels for realisation ‘afixh’ compared with trend observed levels.



The groundwater predicted levels are shown in Figure 21 from the SRES A1B. The overall trend suggests that groundwater levels will continue to rise within winter months. However, the predicted groundwater level trend shows a significant reduction in groundwater levels within the summer months and potential drought conditions occurring more frequently. The data suggests a potential drought event in 2030/31 similar to the conditions experienced in 1975/76.

The groundwater level trend (Figure 22) is given for the 148 year record for each realisation and varies from an average fall of 6.8 mm/year to an average rise of 13.1 mm/year. This loosely correlates with the realisations which give the higher exceedances, though it is the realisation called ‘afixh’ with an upward trend of 11.8 mm/year, which gives the most frequent and longest duration exceedances. This realisation is shown in Figure 28 with the corresponding trendline. Although this upward trend is marked, it is worth noting that it is less than the trend on the observed record for the 55-year period 1963-2018.

Figure 22 - The groundwater level trend for a 148 year period for each realisation.

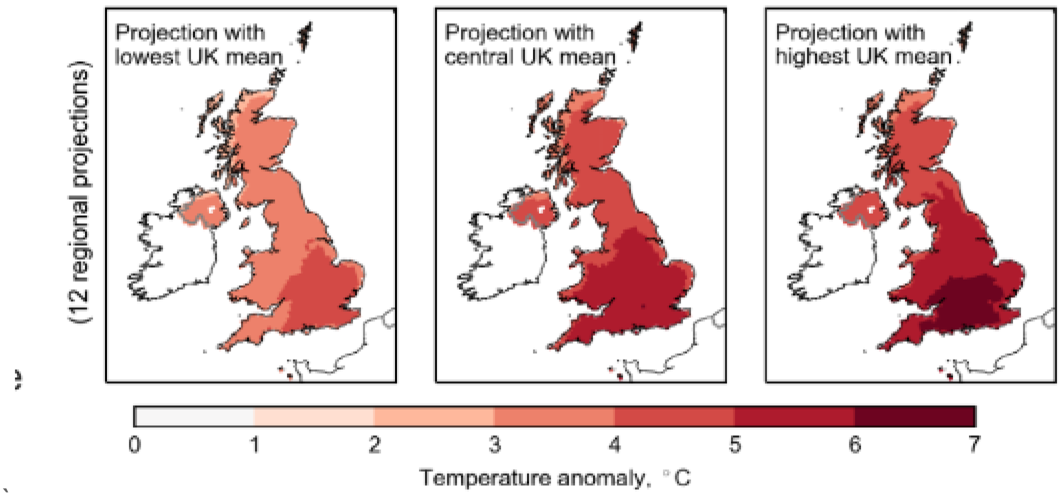


3.3.3. UKCP18- National Climate projections Emission Scenarios

Since the production of the UKCP climate change data has been updated in accordance with the WRMP guidance. During the preparation of this management plan, VWPL consulted with the UKCP18 databases and supplemented the WRMP19 climate change impact assessment.

UKCP18 has predicted that all areas of the UK are likely to experience warming temperatures within summer months, as outlined in Figure 23. However, the UKCP18 have noted that the increase in temperature will directly correlate with the amount of greenhouse gases that the world/ UK emitted into the atmosphere.

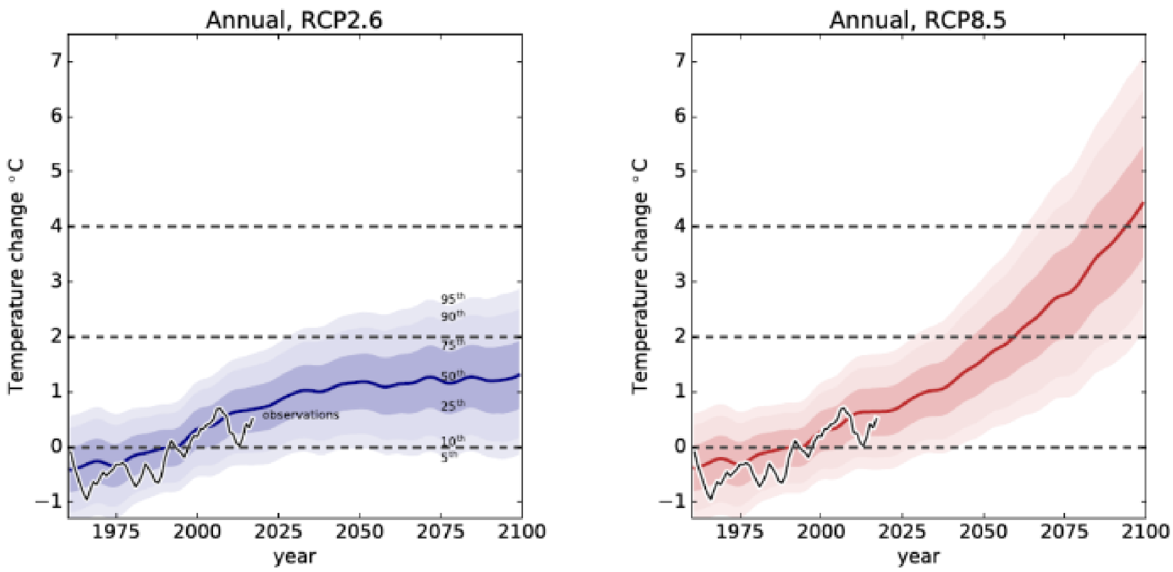
Figure 23 - A plan showing the increase of regional temperatures across the three emission projections.



During the summer months of 2018, VWPL encountered an increase in demand associated with the prolonged hot and dry summer that the wider region was experiencing. Depending on future greenhouse gas emissions scenarios, by 2050, the summer months could be similar to the conditions encountered in 2018 and could occur on average every other year.

The RCP2.6 scenario represents the fastest rate of change in the not so distant future, whereas the RCP8.5 scenario represents the fastest rate of change at the end of the century (between 2090 and 2100), as shown in Figures 24 and 25.

Figures 24 and 25 - graphs for two different emissions scenarios (RCP2.6 and RCP8.5)



The predicted groundwater levels for both the different emissions scenarios show an overall trend suggesting that groundwater levels will continue to rise within the winter period, with the potential risk of climate induced flooding to occur within certain zones of the network (please see section 5.2). The groundwater levels during summer months are likely to reduce significantly with potential drought conditions occurring more frequently. In particular, within the RCP8.5 scenario, drought-like conditions, similar to what was experienced within the network in critical years including 2011/12, 2018 and the summer months of 2022 will be experienced at a higher frequency, approximately every other year.

3.4. The Effects of Climate Change on Deployable Output

In accordance with the WRMP guidance, VWPL has assessed the effects of climate change on the existing DO for the network. The assessment takes into consideration the effects on the DO of DYAA and DYCP scenarios to represent the range of potential impacts on the DO around the 'mid' impact estimate.

The assessment has confirmed that by 2030, the DO for a DYAA scenario will have reduced by -0.84 Ml/d which represents a 0.30% reduction of the overall DO. In addition, the assessment concluded that by 2030, the DO for a DYCP scenario will have reduced by -0.83 Ml/d, which represents a 0.20% reduction on the overall DO for the network.

The reduction of DO has been included within the planning sheets of the WRMP24 from 2030.

4. Vulnerability Assessment

As per the EA WRMP24 guidance, VWPL needed to demonstrate the resilience of our services to drought conditions encountered in a 1 in 500 year event and/or to the implementation of exceptional demand restrictions on customers. The regulatory expectation is that VWPL will have achieved such a level of resilience by 2039.

In August 2021, VWPL commissioned John Woods Plc to undertake hydrogeological modelling to confirm the vulnerability of the Tidworth groundwater regimes within the wider Wessex Basin.

4.1. Methodology of Vulnerability/ Resilience Assessment

Conventional hydrogeological modelling typically estimates return periods within the cycle by using the Extreme Value Analysis (EVA) based on the standard distribution curves and pooled gauge data sets. However, for drought vulnerability assessment, this approach is inaccurate as drought hydrogeological modelling uses large spatial scales.

The guidance does not specify the level or type of analysis that VWPL is required to use within the production of the WRMP. VWPL has adopted an inverse-ranking approach to estimate return periods, rather than adopting a formal extreme value analysis.

The observation borehole (OBH1) is monitored by VWPL to determine the levels of groundwater at Chalkpit abstraction borehole and BH2 and BH3 abstraction boreholes. While the data is available from 1968 when the local Tidworth supply network was created, VWPL used Clanville Lodge Gate as explained in 2.2 to carry out its vulnerability assessment.

In order to align the drought modelling with the existing data set obtained from the Clanville Lodge Gate observation borehole and to have intervening reset years with correctly aligned leap years, the set-up shown in Figure 26 was used by John Woods Plc within the vulnerability assessment.

Figure 26 - The alignment used by John Woods Plc within the vulnerability assessment.

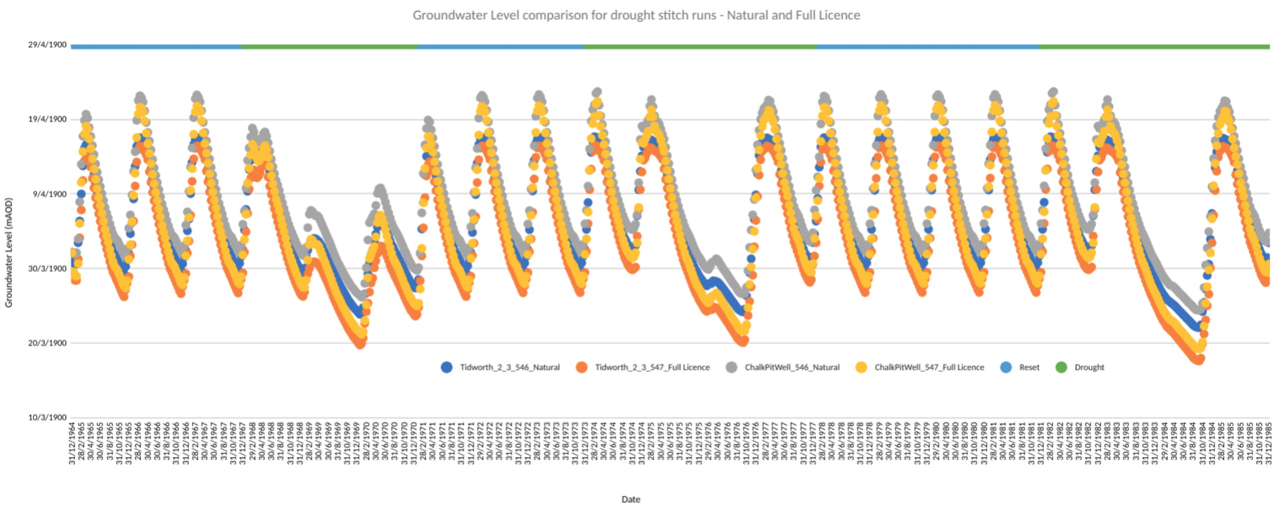
Existing Model Year	Year Modelled	Comment
1965	1995	Average year warmup/reset
1966	1995	Average year warmup/reset
1967	1995	Average year warmup/reset
1968	1920	Drought Episode 1_1920 (check matching month vs leap)
1969	1921	Drought Episode 1_1921
1970	1922	Drought Episode 1_1922
1971	1995	Average year warmup/reset
1972	1995	Average year warmup/reset (29th Feb = 28th Feb)
1973	1995	Average year warmup/reset
1974	1974	Drought Episode 2_1974
1975	1975	Drought Episode 2_1975
1976	1976	Drought Episode 2_1976
1977	1977	Drought Episode 2_1977
1978	1995	Average year warmup/reset
1979	1995	Average year warmup/reset
1980	1995	Average year warmup/reset (29th Feb = 28th Feb)
1981	1995	Average year warmup/reset
1982	1974_1_500	Drought Episode 3_1974_1 in 500
1983	1975_1_500	Drought Episode 3_1975_1 in 500
1984	1976_1_500	Drought Episode 3_1976_1 in 500
1985	1977_1_500	Drought Episode 3_1977_1 in 500

4.2. Assessment Findings

The groundwater level comparison for drought stitch runs, both natural and full licence models for the VWPL operated Chalkpit abstraction borehole and the Tidworth abstraction boreholes are shown in Figure 27. Both the natural and full licence models show a significant decrease in available groundwater levels within critical drought event years.

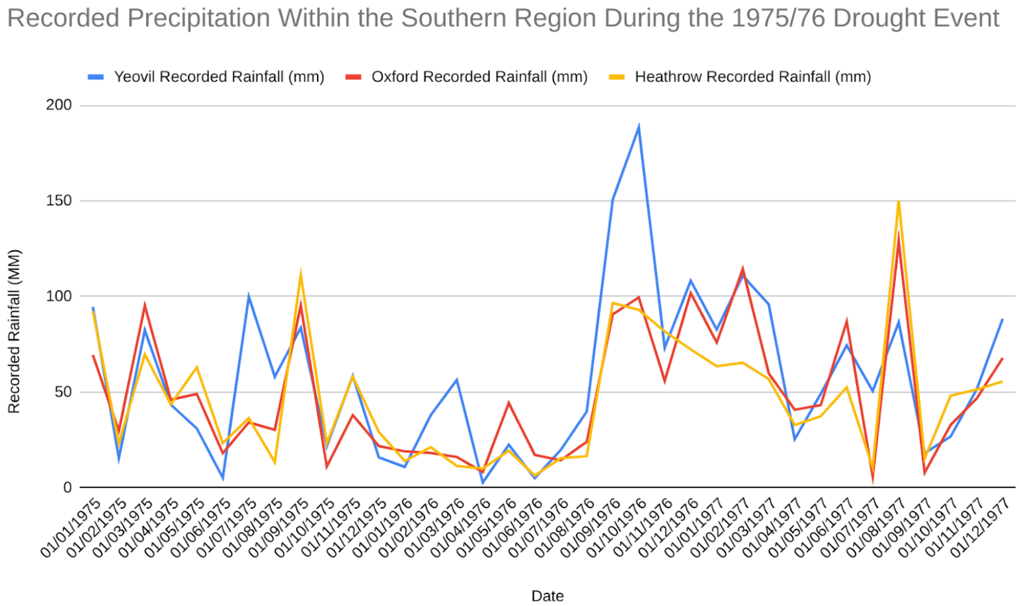
The groundwater recharge during the extreme drought event of 1975/76 within the VWPL operated WRZ and the wider Wessex Basin was recorded to be extremely low. No groundwater recharge was documented within a number of the monitored months. Therefore, it would be sensible to assume that the only way climate change could negatively impact this event further, is if the summer months were prolonged. However, there is no evidence of this within the UKCP18 datasets, only that summer temperatures will increase by 1.1°C to 5.8°C.

Figure 27 - The model runs for the VWPL operated abstraction boreholes (Chalkpit, BH2 and BH3) produced by Woods Plc.



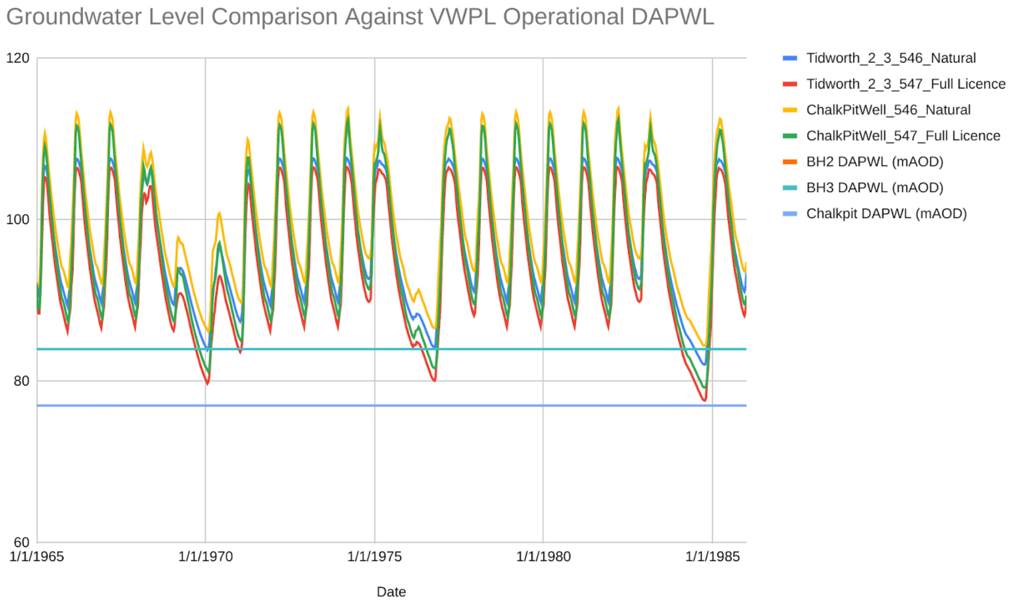
There is, however, evidence within the UKCP18 dataset to suggest that there is a possibility that the intensity of heavy summer rainfall events will increase within the future. This is a trend that was noted at the Yeovilton MET office weather station within the 1975/76 drought event, where significant quantities of rain fell during June and July in 1975 and July and August in 1976 (blue line in Figure 28).

Figure 28 - Graph showing recorded precipitation in the south region of the UK.



The 1975/76 drought event is considered to be representative of a changing climate as the recorded groundwater recharge during this period was extremely low, effectively zero. Therefore, the only way that climate change could further impact the model, is if the summer within England and Wales become longer. However, there is no evidence to support this within the UKCP18 climate projections, only that summer temperatures will increase by 1.1°C to 5.8°C.

Figure 29 - Graph of the vulnerability model when transposed onto VWPL operations.



The modelling analysis indicates that groundwater sources only start to show strain when the WRZ has encountered two or more consecutive dry-multi year events; for example dry-winter dry-summer dry-winter dry-summer. This scenario occurred within the WRZ in 1975/76 and 1984 when the groundwater level dropped below 84 m AOD.

Figure 29 demonstrates when the vulnerability model is transposed into VWPL daily operations and the DAWPL of the active abstraction boreholes are applied. The modelling demonstrates that VWPL are resilient throughout a 1 in 100 and a 1 in 200 year drought event.

However, the vulnerability model suggests with the current DAWPL data, that abstraction borehole BH3 water source is likely to be made redundant in both a 1 in 100 year and a 1 in 200 year event as the groundwater level falls below the active DAWPL. The groundwater level in abstraction borehole BH2 and Chalkpit remains above the active DAWPL. In these events VWPL supply-side actions will focus on maximising the abstraction primarily from BH2 and Chalkpit to compensate for the loss of BH3 should the groundwater level drop below the bottom of the well*.

**Note: the supply side actions would not require drought permits in both a 1 in 100 and 1 in 200 year drought event as the abstraction sites will continue to be operated within permitted abstraction limits. Also the environmental impacts of those actions should be limited to those already identified within the abstraction licence.*

The modelled data (Figure 29) suggests that the groundwater sources in abstraction borehole BH2 and Chalkpit abstraction borehole will come under strain in a 1 in 500 year event as the predicted groundwater level will fluctuate around the active DAWPL for both borehole wells. However, with careful demand management and the implementation of temporary use bans (TUBs), the agreed reduction of the Leckford Bridge export (see section 3.3 of Annex One) and if possible non-essential use bans (NEUBs), VWPL are confident that we can maintain normal service to all customers.

To confirm VWPL's confidence in the dataset, a series of in-house tests was undertaken during the prolonged period of hot/dry weather between late July and August 2022 to simulate the groundwater pumping conditions expected within a 1 in 500 year event. It was discovered during this exercise that the pumps within all three abstraction boreholes had the potential to pump groundwater at levels lower than the recorded DAWPL with no adverse effects to daily operations or drinking water quality (i.e coliforms or turbidity).

VWPL subsequently liaised with the pump manufacturer to confirm safe working levels and other key operational factors of the current abstraction pumps used within the network. The pump manufacturers provided VWPL with a series of figures that could be carried forward and used within DAWPL calculations.

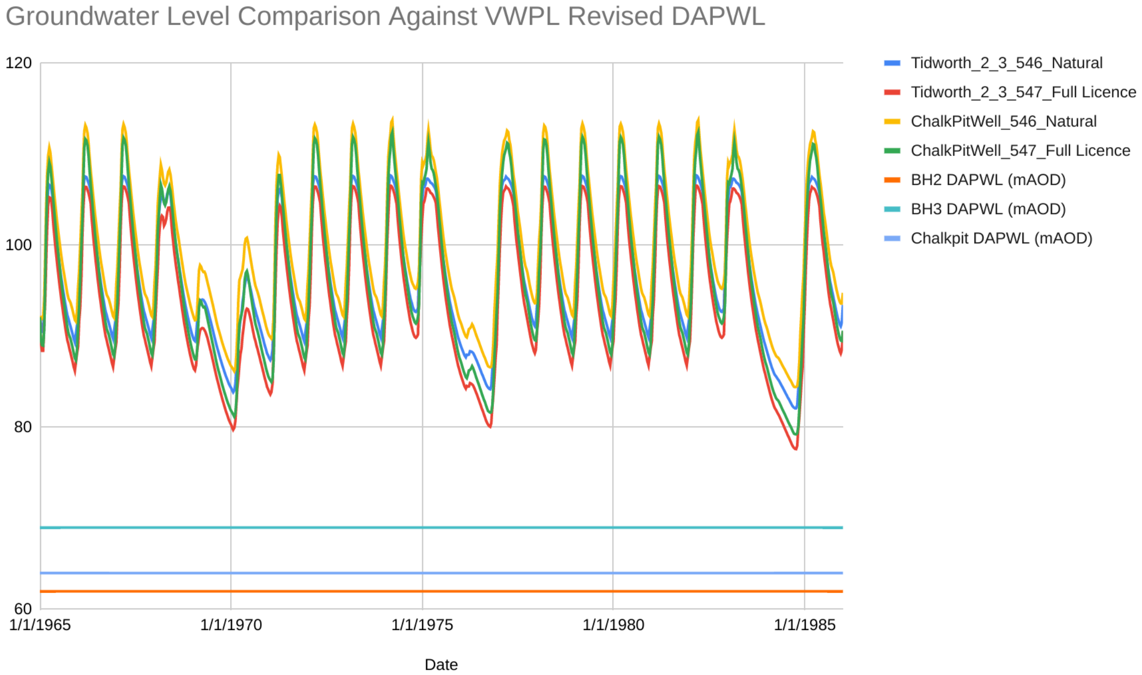
Taking the above into account and giving due consideration to DO, borehole yield and other factors relating to borehole performance. VWPL has revised our DAWPL and the following figures have been established*.

- Chalkpit abstraction borehole revised DAWPL- 64m AOD
- Abstraction borehole BH2 revised DAWPL- 62m AOD
- Abstraction borehole BH3 revised DAWPL- 69 m AOD

**Note: the revised DAWPL figures are currently draft and are in the process of being reviewed by the pump manufacturer and may differ in the final version of the WRMP.*

The revised DAWPL figures* illustrate that VWPL would be resilient in a 1 in 500 year event and are presented on Figure 30.

Figure 30 - Graph of the vulnerability model with the revised DAWPL.



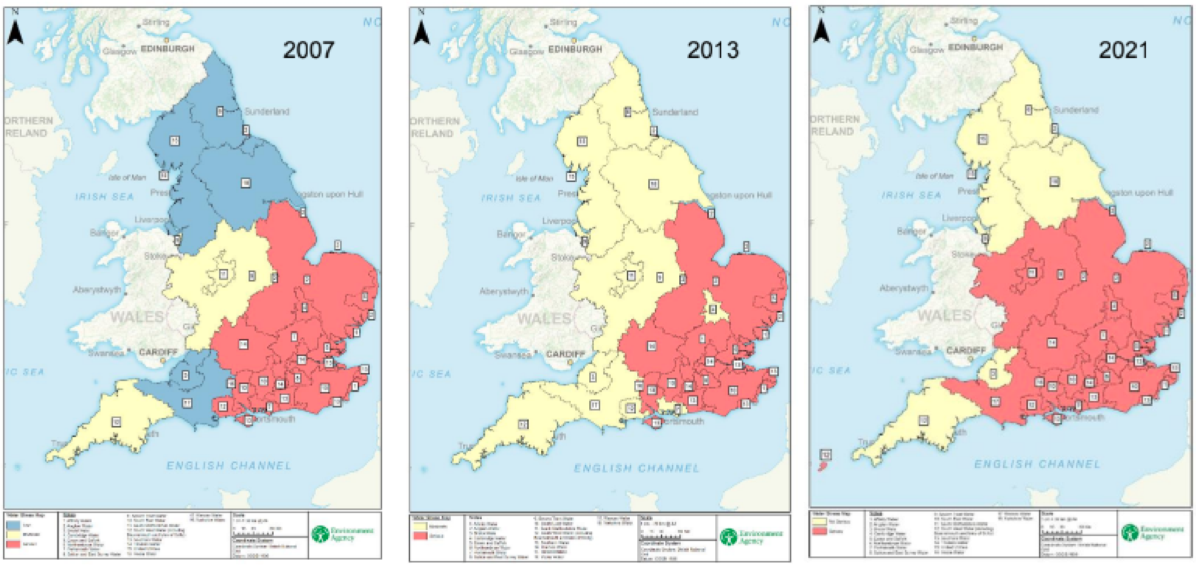
In addition to the above, if further action from VWPL is required within a 1 in 500 year drought event, then VWPL has the following options that could be implemented to increase supply. These include:

- If the 1 in 500 year event is the result of a multi-season drought, then VWPL would rest pumping within the Chalkpit abstraction borehole for longer periods of time (in excess of 12 hours) during non-high demand events to allow groundwater recharge.
- Consider lowering the pumps within the abstraction boreholes to increase the DAWPL.
- Implement TUBs to decrease water consumption within the network.

5. System Resilience Assessment

Historically, the VWPL operated WRZ has had a surplus of available water resources compared to the forecast demand within the network. However, since the production of WRMP19, climate change has started to negatively impact the hydrogeological regime of the Wessex Basin and as such, VWPL WRZ is now located in a water stressed area (Figure 31).

Figure 31 - EA diagram showing the classification of high stress areas.



5.1. Drought Resilience and Level of Service

Resilience to drought conditions is a fundamental aspect of the WRMP process as it has the potential to impact the level of services provided to VWPL customers. The regulatory guidance for the WRMP has placed significant emphasis on drought conditions resilience and states that all documents need to be resilient to historical and future events that could disturb daily operations within the VWPL operated WRZ.

VWPL's approach and planning for drought resilience is outlined in two documents: a drought management plan and the water resource management plan. The two documents share similar fundamental principles, including maintaining a secure and sustainable supply of water for customers. However, the focus of these two documents differs and focuses on separate aspects of drought resilience.

The drought management plan outlines the triggers and measures in response to drought conditions and primarily focuses on the response and recovery aspects of drought resilience. The water resource management plan is a long-term strategic plan to ensure a sufficient balance between supply and demand within a statutory period and focuses on the redundancy of the system to cope with drought conditions.

It should be appreciated that VWPL operates within the Wessex Basin alongside Wessex Water and the MOD. In the event that drought triggers/temporary use bans were required, VWPL would work in conjunction with Wessex Water and the MoD to reduce demand within the networks.

The MOD accounts for the vast majority of all business usage within the VWPL operated network. Therefore, prior to any drought triggers/temporary bans being activated, VWPL would liaise with the MOD to discuss options in relation to reducing their overall demand.

The point of failure within a water supply network is defined as implementing exceptional demand restrictions for customers, typically associated with emergency drought orders. VWPL overall planned level of service is shown in Table 3. The assumptions on implementation frequency of temporary use bans, drought orders, and non-essential use bans within the Tidworth network is based upon drought scenarios modelled as part of the development of VWPL Drought Management Plan.

Table 3- Supply/Demand Action and Planned Level of Service (under full licence)

Plan Restriction	Likelihood	Average Annual Risk (%)
Temporary Use Bans, including hosepipe bans	1 in 75	1.3%
Non-Essential Use Bans	1 in 500	0.3%
Emergency Drought Orders	1 in 500	0.3%
Drought Permits/Orders	*Not applicable*	

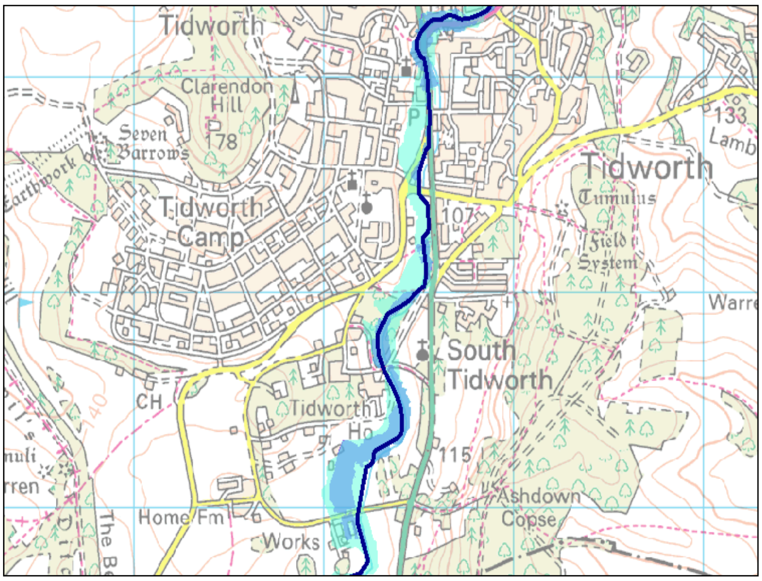
Further information relating to VWPL water saving activities for both civilian customers and the MOD can be sought in the WVPL Drought Management Plan. VWPL's most recent drought plan was approved for publication by DEFRA in August 2022.

5.2. Flood Resilience

As part of the requirements of the WRMP, VWPL needs to establish flooding vulnerability within the network and to determine if any further analysis is required.

Regional flood model maps produced by the EA for Tidworth are shown in Figure 32. The maps show that all of the clean water Above Ground Assets (AGAs) are at negligible risk from flooding.

Figure 32 - Flood risk plan of the network. The dark blue areas represent a 1 to 100 (+) designated flood zone while the light blue areas represent a 1 to 75 year designated flood zone.



The Below Ground Assets (BGAs) are also resistant to the effects of a flooding event as the system is gravity-fed from the reservoirs. However, there is a possibility that the BGAs may be impacted when VWPL operatives access the assets in extreme flood conditions.

A number of VWPL operated waste water assets were considered to be at risk of flooding. These include two pumping stations located within a 1 to 100 (+) designated flood zone.

The VWPL operated STW is at a greater risk of flooding as it is located within a 1 to 75 year designated flood zone. This equates to a 1.3% chance of flooding.

5.3. Freeze-thaw Events

Freeze-thaw is described as a phenomenon which results in burst mains after a prolonged period of cold weather followed by a period of warmer temperatures.

The last freeze-thaw event to occur within the WRZ was after Storm Emma in March 2018 when there was a significant drop in temperature and high localised snowfall. Within the Tidworth network during this event there was no increase in burst mains, however, there was an observed increase in background leakage. The background leakage was likely the result of ageing pipes and valves within properties being damaged by the colder temperatures.

Overall, the leakage levels encountered during the freeze-thaw event in 2018 did not exceed historical levels within the network. This is likely due to the MoD influence and infrastructure within the network, as supply mains have been installed at depths in excess of 2 m below ground level. This reduces the risk caused from dramatic increases in demand due to sudden variations in temperature.

As part of daily operations of the Tidworth network, VWPL monitored weather conditions against demand trends to ensure customer supplies can be maintained.

5.4. Security Emergency Measures Directive (SEMD)

Following the issue of the latest SEMD guidance issued in 2022, VWPL has reviewed its Security Strategy, its Security Delivery Plan and its Security Emergency Management Plan in order to ensure compliance with the new requirements. A five year programme of work including enhancement of the alarm management system, physical sites access and the protection of the water spaces is being implemented to deliver the required improvements.

5.5. Cyber Security

The Network and Information systems directive strategy is implemented by VWPL across the wider network and essential IT systems. VWPL's corporate IT systems are certified to ISO27001.

5.6. Supply Security

The following are considered to represent a failure risk to the supply system. VWPL has methodology and risk management in place to ensure a failure would not negatively impact business operations:

- **Loss of power -** loss of power could result in a loss of supply and a failure in the disinfection process. In such an event, VWPL would be able to mobilise stand-by generators within 48 hours. The storage capacity available at Clarendon Reservoir and Mathew Tanks would enable VWPL to maintain continuous supply until the power is reestablished and the plant back in operation.

- **Disruption in chemical delivery -** the chlorine used in the disinfection process is managed and stored in line with SEMD requirements. In addition, all chemicals are stored in accordance with environmental best practice to reduce the likelihood of an unexpected spillage.

- **Loss of Supervisory Control and Data Acquisition (SCADA) system -** site monitoring and treatment processes can be controlled manually in the event of a failure. This is to ensure that there is no disruption to supply as the systems can be controlled with regular site visits by VWPL's operations team.

5.7. Asset Management and Business Risk

Across the Inset area, VWPL's asset management team manages the condition and life cycle of the VWPL owned and operated assets including the abstraction boreholes, supply mains and reservoirs in accordance with ISO 55000 Asset Management.

VWPL asset condition surveys are carried out every three years on every above-ground asset assessing safety, civil, mechanical and other relevant aspects of the plant and asset. The condition survey assessment takes into consideration civil and mechanical aspects of the plant and assets. The scoring system (as shown in Figure 33) rates the condition of the asset from 1 to 5 with a score of 5 being an asset in poor condition.

Figure 33 - The asset management scoring system.

Asset Rating Score	Asset age (Percent of useful Life Remaining)
1 (Excellent)	Asset new or nearly new 75% - 100%
2 (Good)	Asset nearing or at its midlife point 50%-75%
3 (Acceptable)	Asset has passed its midlife point 25%-50%
4 (Borderline)	Asset nearing or at end of its useful life 0%-25%
5 (Poor)	Asset passed its useful life

The data obtained during the survey is then given a confidence grade from A to D (as shown in Figure 34) with D meaning the information comes from an inconsistent survey based upon unconfirmed verbal reports etc.

Figure 34 - The asset management grading system.

Data Confidence

Grade	Criterion
A	Highly Reliable - Data based on sound records, procedure, investigations and analysis, documented properly and recognized as the best method of assessment
B	Reliable - Data based on sound records, procedures, investigations and analysis, documented properly but has minor shortcomings. For example, the data is old, some documents are missing and reliance is placed on unconfirmed reports or some extrapolation.
C	Uncertain - Data based on records, procedures, investigations and analysis which is incomplete or unsupported or extrapolated from a limited sample for which grade A or B data available.
D	Unconfirmed verbal reports, cursory inspections or analysis.

The asset management team's scoring is then transposed into a localised risk management system which assesses the risks, the potential root causes and any associated impact/consequences.

If the risk to an asset is high/very high, the asset management team will escalate the risk to the senior management team for review and potential acceleration of the investment plan. To ensure the risks associated with VWPL assets are appropriately managed, risk registers are reviewed (at least) on a quarterly basis.