Environment

Submitted to
Affinity Water Limited

Submitted by
AECOM
Scott House
Alençon Link
Basingstoke
Hampshire
RG21 7PP
United Kingdom

Affinity Water Draft Drought Management Plan Technical Report

Drought Management Scenario Planning

February 2017

Prepared by: Armelle Bonneton
Consultant Hydrogeologist

Stephen Cox
Associate Hydrogeologist

Checked by: Tom Hargreaves
Associate Hydrogeologist

Approved by: Dr P Jane Sladen
Technical Director

Rev No	Comments	Checked by	Approved by	Date
1	First Draft for client's comment	SC		2/12/2016
2	Final Draft	SC		10/1/2017
3	Final Draft with correction to SEW export	SC		12/1/2017
4	Final Report	TRH	PJS	14/2/2017

Midpoint, Alençon Link, Basingstoke, Hampshire, RG21 7PP, United Kingdom
Telephone: 01256 310 200 Website: http://www.aecom.com

60522695 803 – Drought Management Plan February 2017

k:\jobs\60522695 affinity water drought planning\800 deliverables\803 report\01 text\aw drought management plan rev2.docx

Limitations

AECOM Limited (“AECOM”) has prepared this Report for the sole use of Affinity Water (“Client”) in accordance with the Agreement under which our services were performed (C-02808, September 2016). No other warranty, expressed or implied, is made as to the professional advice included in this Report or any other services provided by AECOM. This Report is confidential and may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of AECOM.

The conclusions and recommendations contained in this Report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by AECOM has not been independently verified by AECOM, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by AECOM in providing its services are outlined in this Report. The work described in this Report was undertaken between September 2016 and February 2017 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this Report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

AECOM disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to AECOM’s attention after the date of the Report.

Certain statements made in the Report that are not historical facts may constitute estimates, projections or other forward-looking statements and even though they are based on reasonable assumptions as of the date of the Report, such forward-looking statements by their nature involve risks and uncertainties that could cause actual results to differ materially from the results predicted. AECOM specifically does not guarantee or warrant any estimate or projections contained in this Report.

Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Copyright

Contents

List of Appendices

List of Tables

List of Figures

1 Introduction

1.1 Background

Drought Management Plans (DMP) are a statutory requirement established by the Water Industry Act 1991 (WIA) and as amended by the Water Act 2003, where water companies must show their plans to monitor and manage their water resources, minimising the risk of scarcity of the resource and guarantee the security of supply.

The plan is approved by the Secretary of State (SoS) following public consultation. The process flow diagram for the development of a DMP in England is provided below in Figure 1.

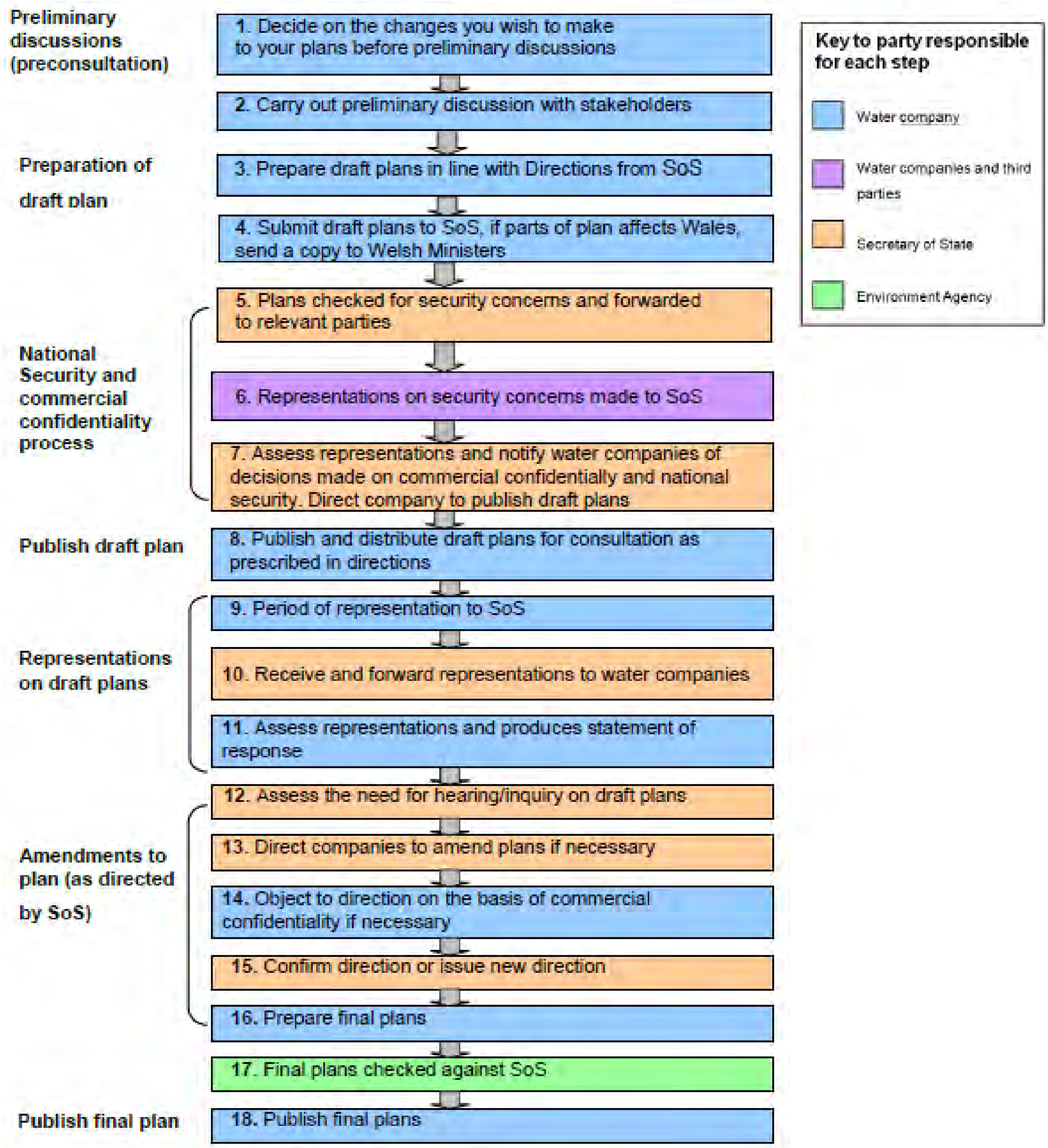


Figure 1: Process flow diagram for water companies in England (Environment Agency, June 2016)

The overall objective for a DMP is to establish a comprehensive set of plans and procedure that defines the processes for managing drought conditions. The DMP includes action plans for how the water company will manage any restrictions on non-essential use, as well as provisions for environmental monitoring and communications.

1.2 Current report

Affinity Water is in the process of writing a new DMP and has commissioned AECOM to develop drought scenario testing to ensure compliance with the Environment Agency guidelines. The tasks included a review of the existing DMP and Water Resource Management Plan (WRMP), the analysis and use of existing data to develop an appropriate presentation of vulnerability to drought for appropriate scenarios, with assessment of actions that would be required to maintain supplies and minimise environmental impact.

This report presents the methodology used to assess the vulnerability of the Water Resource Zones (WRZ) operated by Affinity Water to different drought scenarios and their response to various drought management actions that would be implemented by Affinity Water. Further background on the Affinity Water WRZs is provided below.

1.3 Affinity Water supply areas

Affinity Water supplies drinking water to c. 3.5 million people and 1.4 million properties in the South East of England. Their supply area comprises three distinct geographic regions:

- **Central**, providing water to 3.2 million people in North London and rural part of Essex, Hertfordshire and Buckinghamshire. This region is divided in 6 Water Resource Zones (WRZ) and abstract 60% of its supply from groundwater sources (chalk and gravel aquifers), the remaining 40% being abstracted from surface water sources and imported from neighbouring water companies. Part of this water is also exported to other neighbouring water companies.
- **Southeast;** providing water to 160,000 people in the towns of Folkestone and Dover as well as rural areas including Romney Marshes and Dungeness. This region represents one WRZ and abstract 90% of its water from deep chalk boreholes, with the remaining 10% supplied from the shallow gravel aquifer of the Dungeness peninsular. It can also import water from adjacent water companies.
- **East**; providing water to 156,000 people in North East Essex including the towns of Harwich and Clacton on Sea. This region represents one WRZ and abstract 80% of its supply from groundwater (confined chalk aquifer) with the remaining 20% sourced from the River Colne.

Affinity Water WRZs are presented in Figure 2 below and the methodology for the drought scenario testing of the WRZs is provided in the next Section.

Figure 2: Map of the Affinity Water regions and water resource zones 1-8 (Affinity Water, 2015)

2 Methodology

2.1 Introduction

The methodology for the AECOM drought management scenario planning project is summarised in Figure 3 below. Historical climate data and groundwater levels (GWL) enable the calibration of lumped parameter models, which are subsequently used to create synthetic groundwater levels from synthetic climate data. The synthetic drought profiles of groundwater level and the statistics of the modelled historic groundwater level time series are used in spreadsheet-based models to predict the response of the Water Resource Zones (WRZs) to drought events. The WRZ models have also been populated with Affinity Water (AW) data including (i) Average demand Deployable Output (ADO) and Peak demand Deployable Output (PDO) drought profiles for groundwater and surface water sources, (ii) demand profiles and (iii) details for drought permits and options, demand restrictions and transfer capacities. The output of the analysis is the unfulfilled demand for each drought profile.

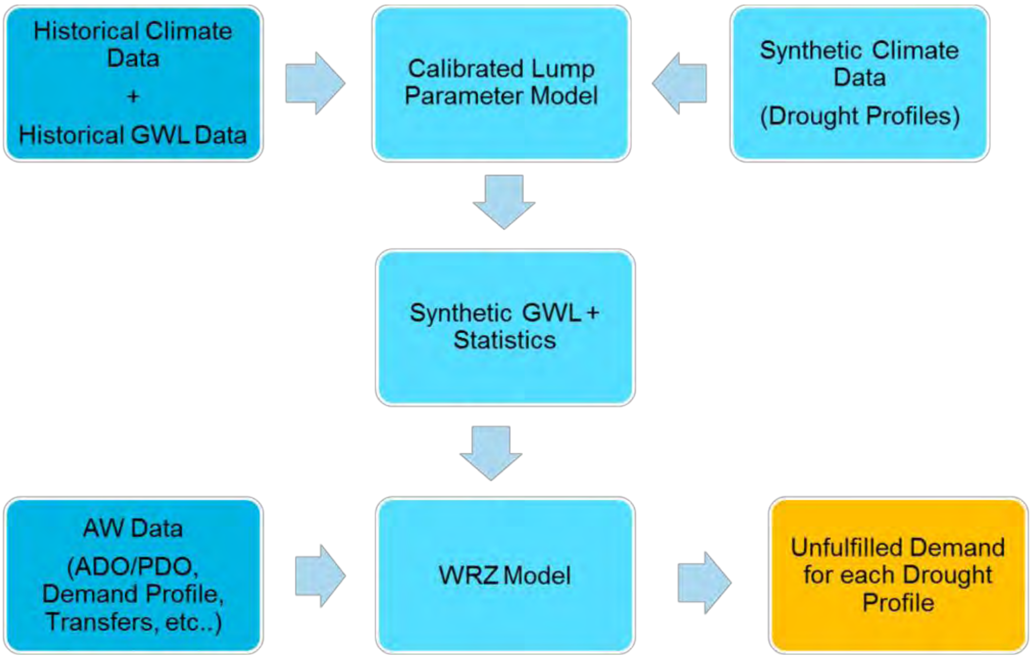


Figure 3: Drought management scenario planning methodology

The development of the lumped parameter groundwater models is described in Section 2.2. Further information on the climate data and the WRZs is provided in Sections 2.3 and 2.4, respectively.

2.2 Development of lumped parameter models

The lumped parameter model is a spreadsheet-based model that predicts regional groundwater level from rainfall and Potential Evapotranspiration (PET), taking into account soil moisture deficit, percolation and potential recharge delays. Models were created using historical climate data for a set of observation boreholes to represent the various WRZs. The models were calibrated by visual inspection of the simulated groundwater levels against observed groundwater levels. Table 2-1 below summarises the observation boreholes, climate data, WRZs and calibration periods.

The selection of observation boreholes is in line with those selected as trigger boreholes in the existing Affinity Water drought plan; see Affinity Water (April 2015). The lumped parameter models for the observation boreholes in the central region have been calibrated based on the long observed rainfall record for Rothamsted, infilled based on Oxford rainfall where necessary, as per Affinity Water (June 2014). The observation boreholes in the other Affinity Water regions have been calibrated using hindcast catchment rainfall for the Dover Chalk coastal area.

Table 2-1. Lumped parameter model inputs

WRZ	Observation Borehole	Groundwater level records used for calibration	Historical Climate Data
WRZ1 / WRZ2 / WRZ4 / WRZ6	Chalfont	Jan 1975 – Sep 2010	Rothamsted and Oxford
WRZ3	Lilley Bottom	Jul 1979 – Apr 2016	Rothamsted and Oxford
WRZ5	Elsenham	Jul 1966 – Sep 2010	Rothamsted and Oxford
WRZ7	Wolverton New	May 1995 – Sep 2016	Dover Chalk
WRZ8	Lady Lane	Sep 1991 – Sep 2016	Dover Chalk

Figure **4** shows the location of the key observation boreholes in relation to the WRZs, based on the presentation in Affinity Water (2015).

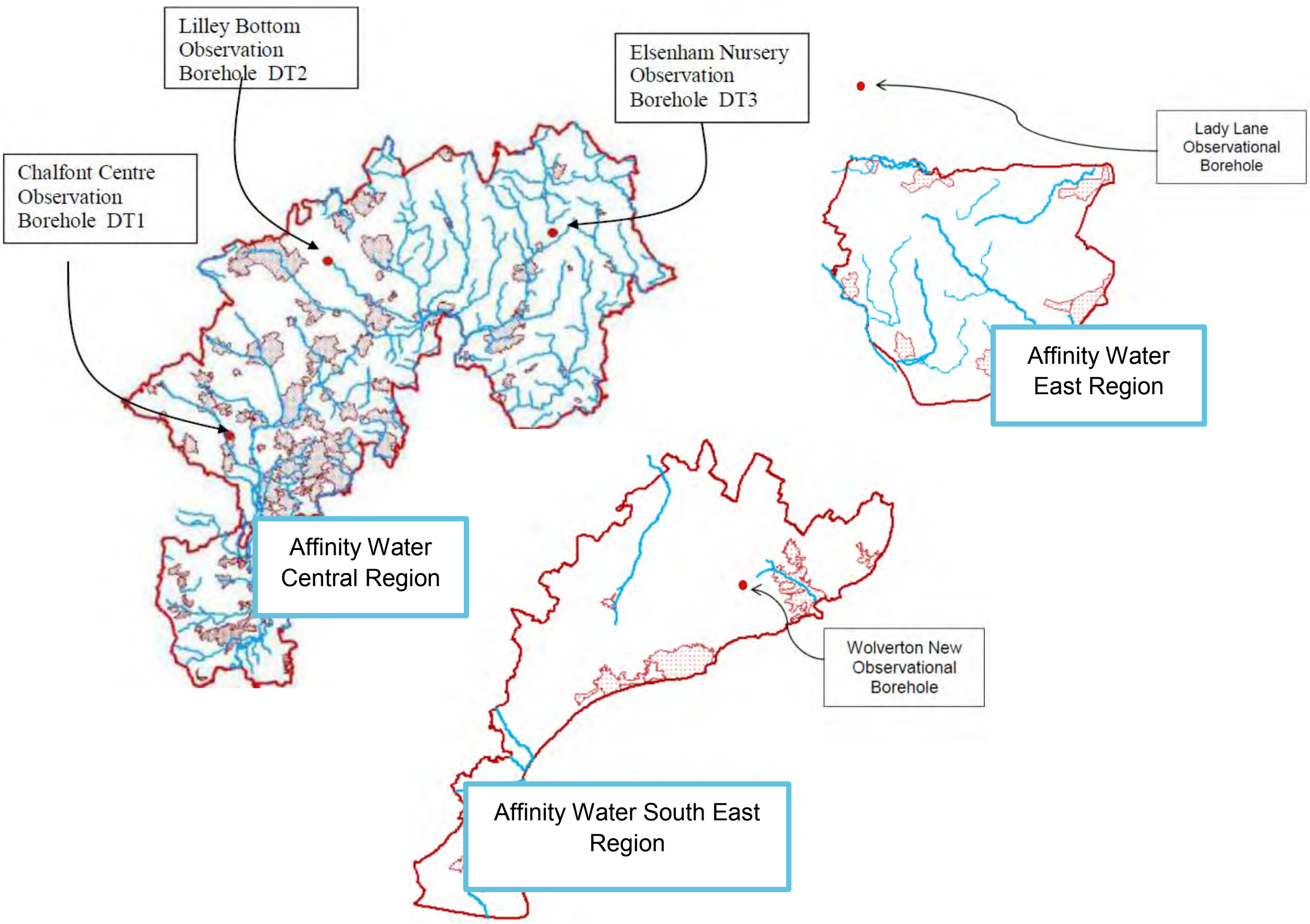


Figure 4: Location of key observation boreholes (adapted from Affinity Water (2015)).

The simulated groundwater levels compared with the historical data in the calibrated lump parameter models are provided in Appendix A. They also show the recession curves that represent a period of no rainfall, which are used to assist with the prediction of severe drought groundwater levels; an exception is Elsenham observation borehole where a recession curve approach is not applicable and instead a second store of water has been used within the model.

Once the models were calibrated, frequency analysis was undertaken on the simulated groundwater level time series (>100 years), using both Weibull and Normal distributions (see Appendix B). This allowed the identification of return periods for each groundwater level associated with the WRZ observation borehole. Drought management actions (e.g. demand restrictions) are linked to specific return periods (trigger levels) within the WRZ models as explained in Section 2.4 of this report.

Synthetic climate data was run through the calibrated lumped parameter models to generate a synthetic groundwater level time series for each of the drought scenarios tested. This is described further in Section 2.3 below.

2.3 Development of synthetic time series data and drought scenarios

2.3.1 Synthetic Climate Data

The drought sensitivity framework used a matrix of rainfall deficit duration and intensities as per the guidelines (Environment Agency, December 2015), where durations are on 6 month increments between 6 months and 5 years, and intensities range between -10% and -80% of the Long Term Average (LTA) rainfall; the LTA values are based on the Rothamsted (with Oxford) and Dover Chalk historic rainfall data for the Central Region and East / Southeast Regions, respectively. In addition seasonality was tested by imposing drought starts either in April or in October and two drought profiles where the deficits are uniform or seasonal i.e. with deficit concentrated in winter or summer. Therefore a total of four different drought profiles exist, each containing 80 different rainfall and PET scenarios. The following conditions are applied to the four different drought profiles:

- October Profile: October start with uniform rainfall deficits and with PET always equal to 100% LTA
- April Profile: April start with uniform rainfall deficits and PET always equal to 100% LTA
- Winter Profile: October start with rainfall deficits concentrated in winter and PET always equal to 100% LTA
- Summer Profile: April start with rainfall deficits concentrated in summer and PET always equals to 120% LTA

The synthetic rainfall and PET values used in the above profiles are presented in Appendix C. The seasonal deficits are calculated using a cosine function as described in *Understanding the performance of water supply systems during mild to extreme droughts*, Environment agency, December 2015. Figure 5 below presents the Rothamsted (with Oxford) synthetic seasonal rainfall deficits with their corresponding rainfall, opposed to the uniform deficits.

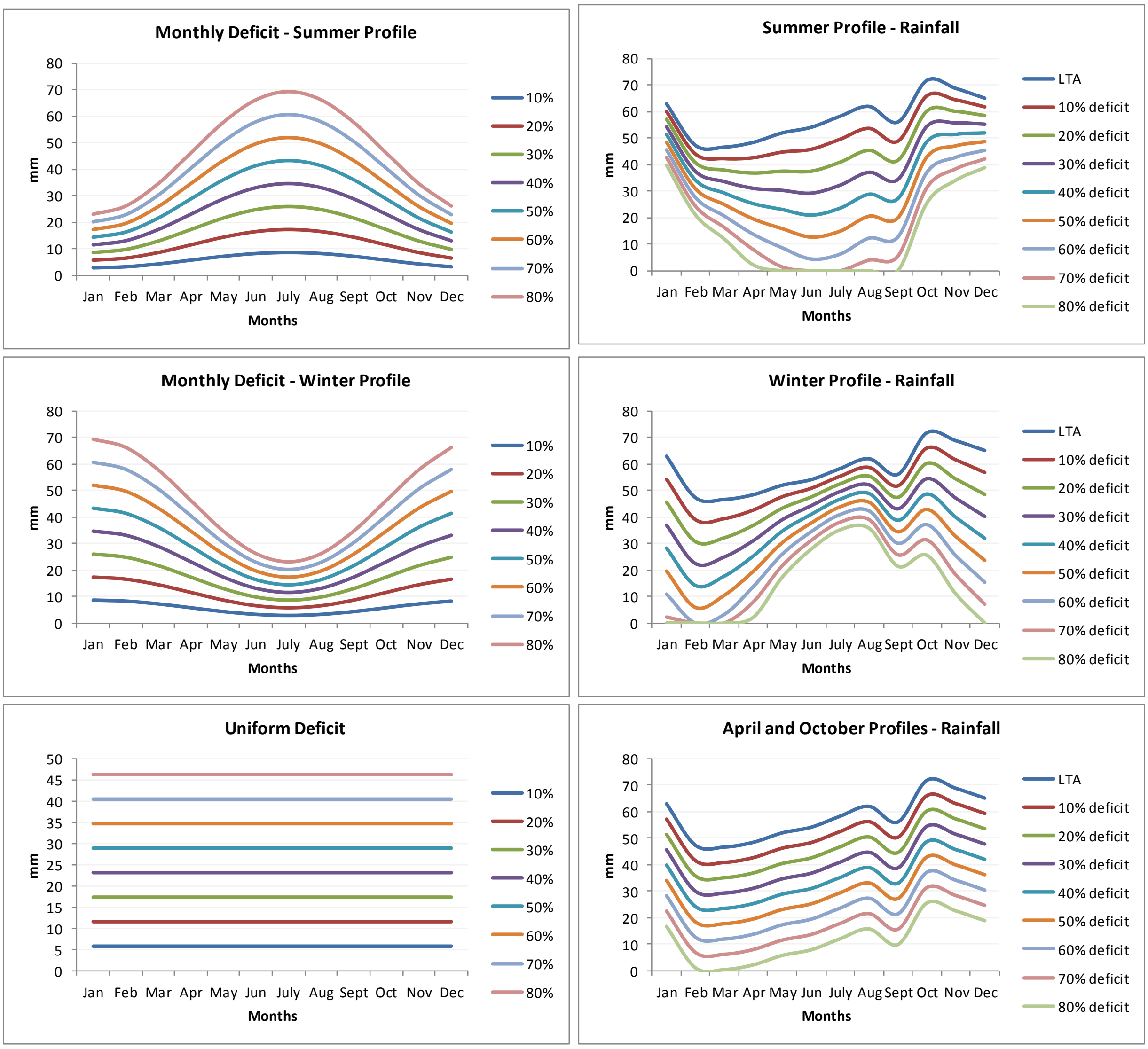


Figure 5: Rainfall deficits and corresponding rainfall profile for the Central Region (based on Rothamsted with Oxford rainfall)

Each drought scenario is inserted within a longer time series of synthetic climate data, resulting in 30 years of data in total; a 10 year run-in that provides similar initial conditions before each drought scenario, followed by the drought scenario varying from 6 months to 5 years length, and then a recovery period of at least 15 years. Each period is characterised by specific rainfall and PET intensities (monthly values). The run-in and recovery periods assume rainfall and PET are equal to their respective 100% LTA.

2.3.2 Regional groundwater level time series data

The 30 year periods of synthetic climate data described above were imported into each of the calibrated lumped parameter models to create the associated simulated groundwater levels for use in the WRZ models. Each of the four drought profiles has 80 different rainfall and PET scenarios, and there is a corresponding groundwater level time series for each of these scenarios.

The first 10 years of the groundwater level series are not imported in the WRZ models as they are only a warm up period necessary to obtain similar initial conditions prior to the drought period.

2.4 Development of water resource zone models to identify drought sensitivity

2.4.1 Summary of data inputs

A unique model was created in a Microsoft Excel spreadsheet for each WRZ and includes the following data inputs:

- 80 sets of synthetic groundwater level time series data (drought profiles).
- Both Weibull distribution and Normal distribution parameters calculated from a frequency analysis of modelled historic data are included within the models (see Appendix B). Available parameters are based on a ranking of groundwater level for each month of the year (i.e. different sets of distribution parameters for each month) and also a ranking of all combined groundwater levels available (one set of distribution parameters).
- Average Deployable Output (ADO) and Peak Deployable Output (PDO) profiles for each groundwater and surface water source in a WRZ, demonstrating drought sensitivity. These originated from the Environment Agency via the Drought Scenarios Pilot in 2014 and were validated by Affinity Water at that time; the DOs have been reviewed by Affinity Water for the current project and now include Asset Management Period 6 (AMP6) sustainability reductions. The ADO and PDO values used in the models are presented in Appendix D. Where a drought scenario results in a return period that is beyond that for which DOs have been provided, the DO with return period relationship is extrapolated based on the Normal distribution parameters in the model; the Weibull distribution parameters were initially trialled, although the return period became meaningless for severe droughts, resulting in a rapid and unrealistic decline of DO to zero.
- Available actual abstraction data for each groundwater and surface water source. This data was provided by Affinity Water and has been used to check the validity of the model for historic droughts.
- A typical demand profile for each WRZ; 7-day running mean data for 2010 in WRZ1 to WRZ6 (apportioned from a Central region total as 10.8% WRZ1, 15.8% WRZ2, 18.3% WRZ3, 26.7% WRZ4, 9.2% WRZ5 and 15.8% WRZ6), for 2014 in WRZ7 and 2013 in WRZ8. Recent years have been selected owing to the significant increase in metering in these areas. The demand data were provided by Affinity Water and they do not contain values for headroom and outage. It is also noted that the demand splits for the Central region do not equal 100%, as the demand from the South East Water export has been excluded from WRZ6; instead this is taken into account within the transfers modelling. The demand profiles for each region are shown in Appendix E.
- Maximum transfer capacities and estimated likely transfer rate ceilings of water imported (or exported) from (and to) other WRZs or neighbouring water companies. The maximum values were provided by Affinity Water and the likely ceilings for use rates were agreed with Affinity Water during the project. The transfers available for use within the WRZ models and the scenario settings are shown in Appendices G and I.
- Assumed percentage (%) reductions in demand and mega litre per day (Ml/d) increases in supply from the implementation of drought management activities (demand restrictions and supply side permits and orders). These were provided by Affinity Water and the trigger levels are set to reflect those in Affinity Water (2015), as explained further in Section 2.4.3.

For each daily time step the model assigns a return period to the corresponding simulated groundwater level, based on the previous analysis of the modelled historic groundwater level from the WRZ lumped parameter model. The ADO and PDO of every WRZ source for that return period is summed per time step to represent the supply available. The available supply (with or without transfers and supply side drought permits and orders) is then compared to the demand profile (with or without demand restrictions) to calculate the proportion of unfulfilled demand.

Further information on the inclusion of transfers and drought management activities is provided below.

2.4.2 Approach to including transfers

Affinity Water has the ability to transfer water between its WRZs and import water from neighbouring water companies. The connectivity for the Central region is described in Affinity Water (2015) and summarised in Figure 6.

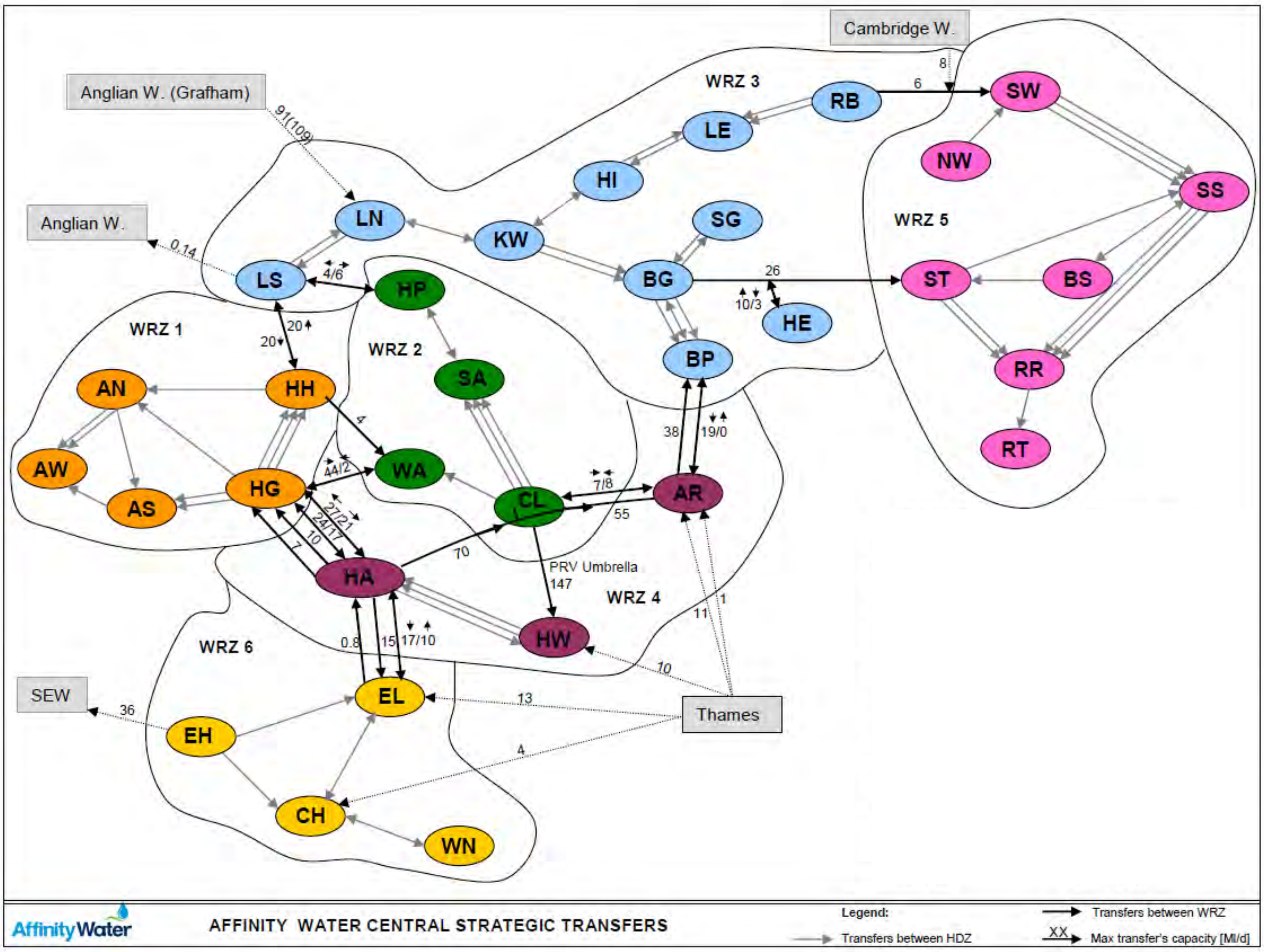


Figure 6: Connectivity and transfers in the Central region (Affinity Water, 2015)

A representation of the Affinity Water Central region transfers has been incorporated within the WRZ models for this study. Transfer rates have been manually adjusted in the WRZ models to minimise or eliminate water supply deficits in the Central region; deficits in the East and South East regions were not large enough to necessitate the use of transfers. It is recognised there are numerous sets of transfer assumptions beyond those presented in this study, which could be used to demonstrate resilience to drought events.

The transfer assumptions used in this study do not represent how Affinity Water operates its transfers under normal conditions, or how Affinity Water might operate and utilise transfers under emergency conditions. Instead they represent two drought related scenarios. The first scenario assumes that drought management plan actions such as demand restrictions and drought permits are not available; this is an unrealistic scenario, although it provides a degree of sensitivity testing. The second scenario assumes that demand restrictions and drought permits can be implemented; it is an example of how Affinity Water could transfer water between water resource zones during a severe drought that is covered by the company's drought plan, in order to meet demand. A summary of the assumed WRZ transfer rates is presented in Appendices G and I.

Imports and exports from / to neighbouring water companies are available in the WRZ models, although they are not all used. Treated water imports from Thames Water are assumed to be zero as it is not known if these are reliable in a drought. However the models assume there is a key import of water from Grafham (Anglian Water) into WRZ3 and a key export of water to South East Water from WRZ6.

It is important to note that the models assume maximum use of groundwater first, and then surface water, before using transfers to satisfy demand in the WRZ. Where there is a net export, the ratio of groundwater to surface water exported is based on the ratio of groundwater DO to surface water DO for the 1 in 10 year drought ADO. This is demonstrated by the charts in Appendix J, which represent the longest duration and most intense drought simulated for each WRZ.

2.4.3 Approach to including drought trigger levels and the impact of drought management activities

Drought triggers levels have been calculated by Affinity Water using historical information during droughts periods, including the severe groundwater drought in 1997, when record low levels were recorded in Affinity Water supply regions. They have been defined as summarised in Table 2-2 below.

Table 2-2. Drought trigger zones and likely outcome (adapted from Affinity Water (2015))

Trigger Zone	Description of trigger	Likely outcome
Zone 1	**90% of LTA groundwater levels (mAOD)**	**Normal Conditions, no additional drought activity**
Zone 2	**Groundwater levels seen in a 1 in 5 year drought event**	**Mild-Medium Drought**
Zone 3	**Groundwater levels seen in a 1 in 10 year drought event**	**Medium-Severe Drought**
Zone 4	**Below the lowest recorded levels of 1997**	**Severe – Extreme Drought**
Zone 5	**Lowest groundwater levels predicted from hindcasting groundwater levels.**	**Unprecedented Drought Historic low levels**

Affinity Water's Drought Management Plan identifies the demand side actions that it would take as a drought advances. These can be summarised as:

Trigger zone 1 – continuation of normal operation
Trigger zone 2 – initiate media campaign and increase water efficiency messaging whilst asking for voluntary reductions in usage
Trigger zone 3 – enhanced leakage activity and implementation of Temporary Use Bans
Trigger zone 4 – continuation of enhance leakage programme, implement Drought Orders for Non-essential use ban
Trigger zone 5 – implement emergency drought orders in line with the Affinity Water Emergency Plan.

Within the Central region these actions are implemented following breaches of the trigger zone at Lilley Bottom regional observational borehole, whilst for the East and Southeast regions this is in response to breaches at Lady Lane and Wolverton New, respectively.

Affinity Water has considered the impact of these actions on demand based on the evidence from relevant UKWIR studies and their own internal data as identified in Section 5.2.6 of their draft Drought Management Plan. The savings being modelled are for the annual average scenario; whilst the actions are likely to have a greater impact on peak demand this complexity is not currently modelled; although the savings are conservative, they are reasonable when compared with summarised data for water companies in England (see AECOM, April 2015).

The impact of demand restrictions is assumed to increase by drought zone within the modelling, as defined by Affinity Water in Table 2-3. The percentage demand saving varies for each of the Affinity Water regions in recognition of the differing metering penetrations, which impacts the current per capita consumption and potential demand saving that could be accomplished along with the current levels of leakage.

Table 2-3. Demand restriction (% reduction in demand) assumed within the WRZ models

Region (WRZ)	Drought Zone 2	Drought Zone 3	Drought Zone 4	Drought Zone 5*
Central (WRZ1-6)	0%	2%	5%	25%
Southeast (WRZ7)	0%	0.05%	5%	25%
East (WRZ8)	0%	0.05%	5%	25%

**Demand reductions include the impact of implementing Emergency drought orders. These are not considered to be within the remit of the Affinity Water Drought Management Plan and instead would be implemented following the enactment of the Affinity Water Emergency Plan, as a drought of this level of severity would be classified as a civil emergency. However for consistency with the severity of the droughts being modelled in this work, it was considered appropriate to include them.*

Supply side increases from drought permits and orders in the Central region are implemented based on trigger levels at the local WRZ observation borehole shown in Table 2-1 (and not Lilley Bottom as per the demand restrictions). Supply side drought permits and orders are prepared in Zone 3, ready for implementation in Drought Zones 4 and 5 (Affinity Water, 2015). Supply side increases are therefore only implemented within the WRZ models when groundwater levels reach the trigger for Zone 4.

Affinity Water has identified ten groundwater sources within the Central region and four groundwater sources within the Southeast region (WRZ 7), which have the capability for increased abstraction via the implementation of supply side drought orders or drought permits. Table 2-4 summarises the sites and the additional supply rates assumed within the models. The East region (WRZ 8) is believed to be robust enough to meet the demand for water during severe droughts, without the use of drought permits and orders. Therefore no increases in supply are modelled in WRZ8.

Table 2-4. Supply side drought permits and orders that are included in the water resource zone models

Source	WRZ	Additional Daily Volume (Ml/d)	Additional Daily Volume by WRZ (Ml/d)
AMER	WRZ 1	8	17.66
HUNT	WRZ 1	2.91	
AMER,GREM,CHAL	WRZ 1	0	
HUGH	WRZ 1	1.75	
PICC	WRZ 1	5	
FRIA	WRZ 2	9.79	15.61
BOWB	WRZ 2	5.82	
WELL	WRZ 3	0.3	28.39
OFFS/OUGH	WRZ 3	1	
FULL	WRZ 3	9.09	
SLIP	WRZ 3		
WHIH	WRZ 3	18	
THUN	WRZ 5	2.73	8.73
UTTL/SPRF	WRZ 5	6	
SLYE	WRZ 7	3.5	8.27
SDRE	WRZ 7	2	
SBUC	WRZ 7	2	
SHOL	WRZ 7	0.77	

2.4.4 Approach to the presentation of model results

The development of a presentation of results has aimed to achieve a similar presentation to that used within Environment Agency (2015). The results from the drought scenarios modelling provide three dimensions of information; drought duration, drought intensity and system performance. Results are presented on a drought 'matrix' displaying the drought characteristics of duration on the x-axis and intensity (rainfall deficit with respect to LTA rainfall) on the y-axis, with the proportion of unfulfilled demand represented by coloured squares (expressed as a percentage). A different drought matrix is provided for each modelled drought profile; Summer, Winter, April and October.

In order to provide some context to the drought scenarios, historical rainfall data have been analysed to calculate the same drought characteristics as those described above. The resulting points have been plotted onto the drought matrices (April profile only) and an example presentation is shown in Figure 7. Return periods from a frequency analysis of the Rothamsted (infilled with Oxford) rainfall data are also shown on Figure 7 to help demonstrate that parts of the presentation matrix represent conditions that are significantly more severe than the climate conditions experienced between 1853-2016 (the zone beyond the historic data and the 1 in 200 year return period line); in this zone the assumptions in the model may no longer be valid owing to a lack of experience with this level of drought severity, although these conditions would be dealt with via emergency planning and not the drought plan (see Figure 8). Therefore the aim is to demonstrate that the resource zones are at least resilient to the rainfall deficits observed in the historic rainfall record.

The results of the modelling are presented in Section 3.

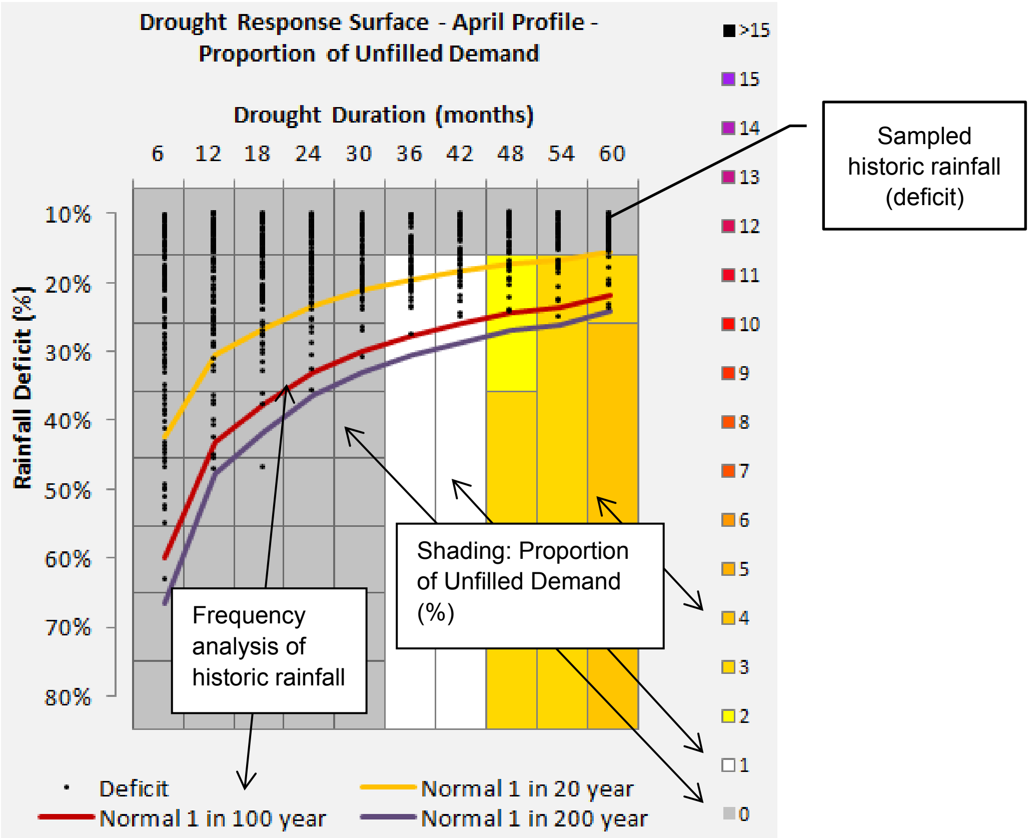


Figure 7: Example matrix presentation

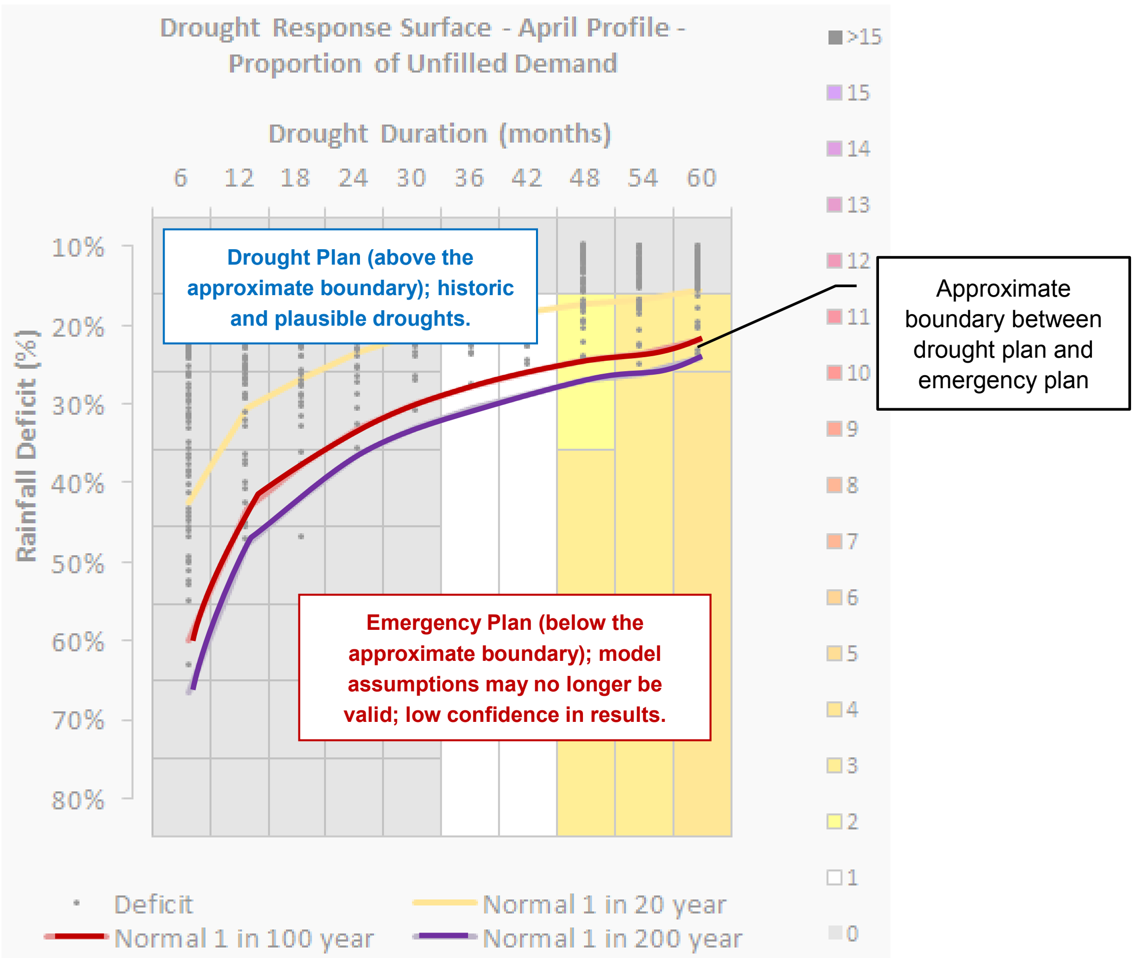


Figure 8: Drought plan versus emergency plan scope

3 Results and assumptions

3.1 Introduction

This section and the supporting appendices present the drought response surfaces of each Affinity Water WRZ according to the four different drought profiles. Three conditions are explored:

- Results without transfers and without drought management activities (see Section 3.2): These results demonstrate the drought resilience of each WRZ when treating it as an 'island', without the ability to move water between WRZs, and without the ability to implement drought management activities. It does not reflect how the WRZs are operated, although it helps to demonstrate the impact of transfers and management activities.
- Results with transfers and without drought management activities (see Section 3.3): These results demonstrate the drought resilience of WRZs when assuming water can be moved between WRZs or imported from neighbouring water companies. However the transfer rate assumptions are based on a scenario where there are no drought management activities; it does not reflect how the WRZs are operated but provides a degree of sensitivity testing.
- Results with transfers and drought management activities (see Section 3.4): These results demonstrate the drought resilience of WRZs when assuming water can be moved between WRZs or imported from neighbouring water companies. The transfer rate assumptions are adjusted to take into account the implementation of drought management activities according to the Affinity Water drought plan; it is one representation of how Affinity Water might transfer water between water resource zones during a severe drought that is covered by the company's drought plan.

A brief description of the results and is provided in the sections below.

3.2 Results without transfers and without drought management activities

Results from the initial runs are presented in Appendix F to illustrate the necessity of imports, exports and demand management activities on a WRZ basis. The results demonstrate that WRZ1 (Misbourne), WRZ2 (Colne), WRZ6 (Wey) and WRZ8 (Brett) are resilient to the most severe droughts tested (based on the assumptions in the models). In WRZ4 (Pinn) there is up to 3% deficit across all of the droughts tested; the consistency reflects the assumption that abstraction from surface water (River Thames) will always be possible regardless of drought condition. In WRZ7 (Dour) there is sensitivity to only the most severe droughts that are significantly worse than those experienced in the historic record.

In contrast to the other WRZs, WRZ3 (Lee) and WRZ5 (Stort) have significant unfulfilled demand across the full range of droughts that have been tested. This demonstrates they are vulnerable to drought under a scenario where there are no transfers or drought management activities i.e. the WRZ is an 'island'.

3.3 Results with transfers and without drought management activities

The models were re-run with transfers enabled and with transfer rates agreed with Affinity Water that aim to avoid supply deficits in droughts within the historic record. Transfer rates assumed in the WRZ models for this approach are summarised in Appendix G and Figure 9.

Results from the model runs with transfers (but without drought management activities) are presented in Appendix H. The set of assumptions in the models, including around transfers, result in all WRZs being resilient to historic and plausible droughts (no unfulfilled demand) with the exception of WRZ3 in longer duration droughts. Whilst the matrices are 'grey' for many of the WRZs (no unfulfilled demand), transferring additional water to WRZ3 was not possible owing to a lack of transfer capacity or a lack of available water.

3.4 Results with transfers and with drought management activities

The models were re-run to include the implementation of drought management actions. The assumptions around transfers were adjusted to reflect how the WRZs might be operated with demand restrictions and supply side permits and orders in place; drought management actions mean that less water needs to be imported from Anglian Water. Transfer rates assumed in the WRZ models for this approach are summarised in Appendix I and Figure 10. The results in Figures 11 to 18 demonstrate that each WRZ would be resilient to all of the historic and plausible droughts tested (i.e. no unfulfilled demand); it is important to note that the model assumptions may not be valid for those scenarios representing extreme drought i.e. matrix squares below the historic data and the1 in 200 year return period line.

Figure 9: Transfer assumptions with no drought management activities imposed

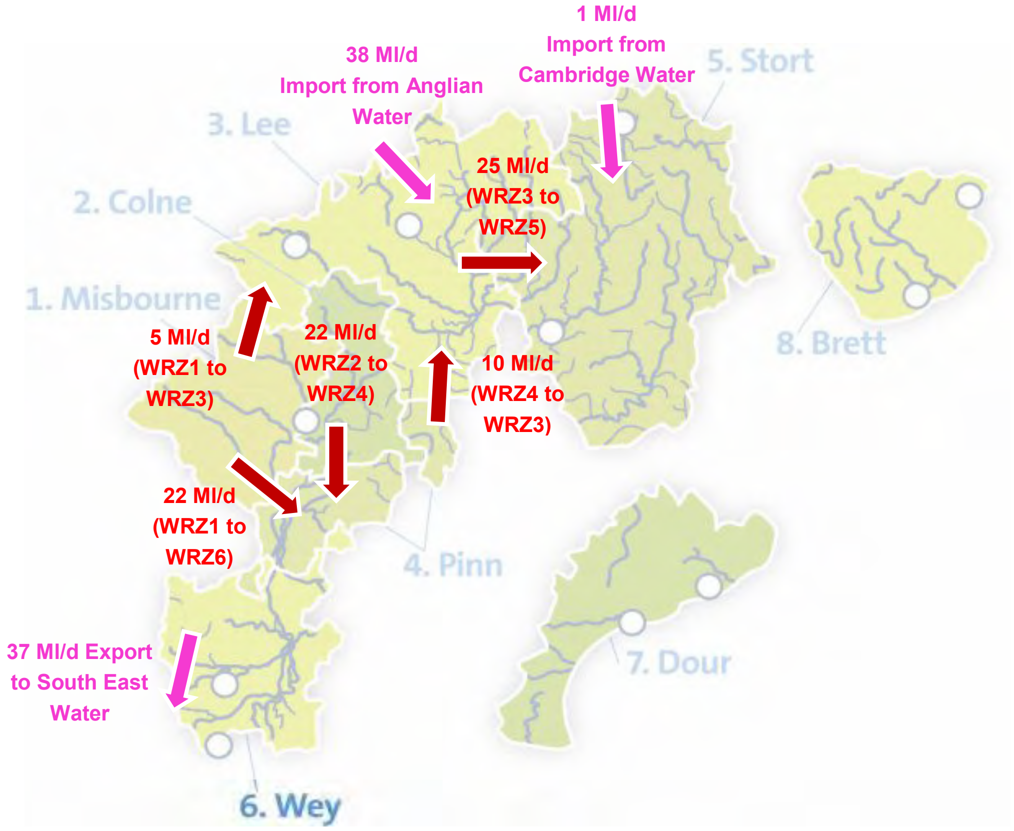


Figure 10: Transfers assumptions with drought management activities imposed

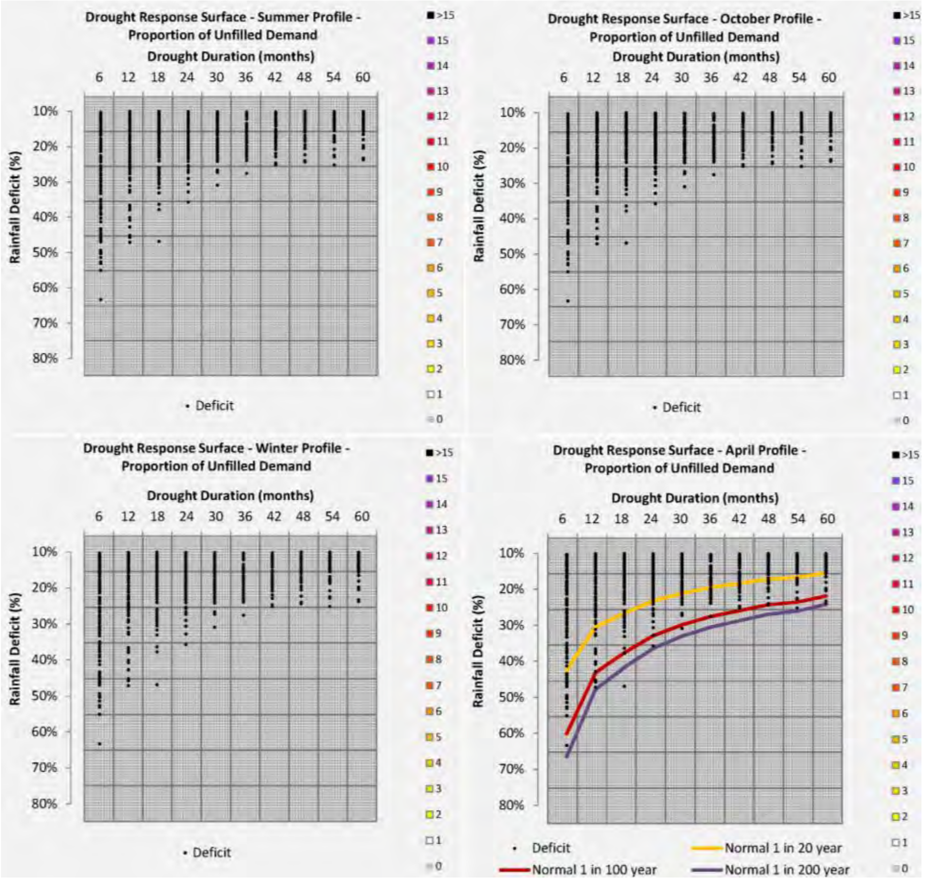


Figure 11: WRZ1 (Misbourne) unfulfilled demand (with transfers and drought management actions)

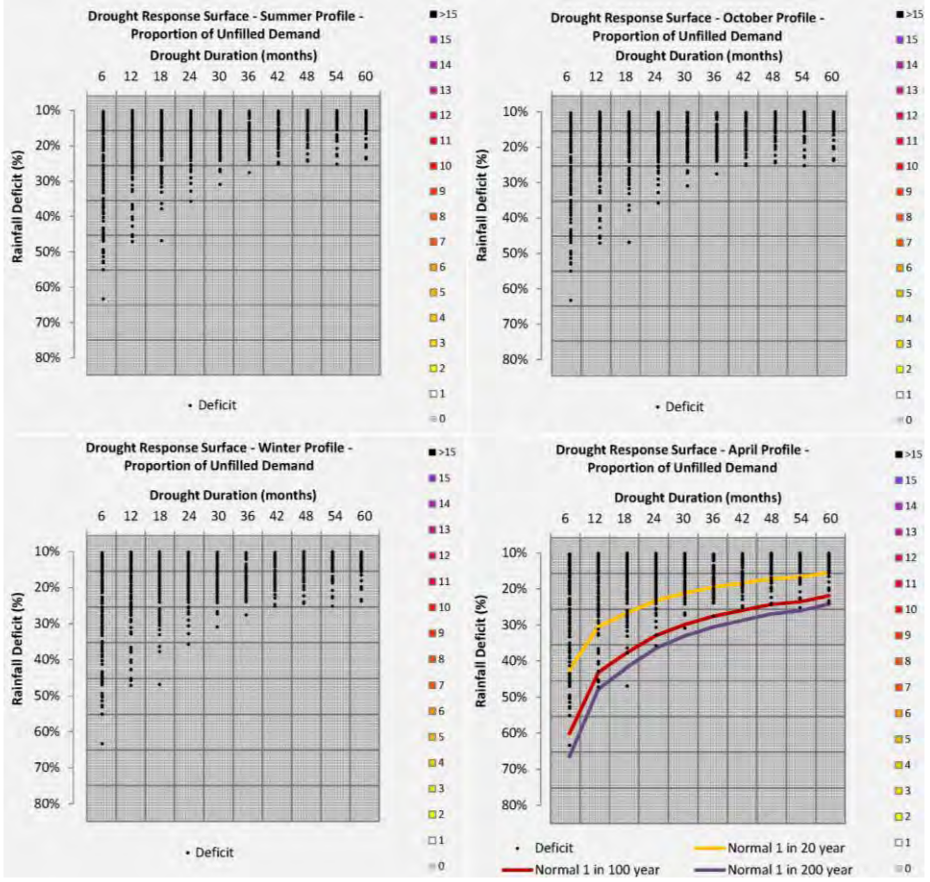


Figure 12: WRZ2 (Colne) unfulfilled demand (with transfers and drought management actions)

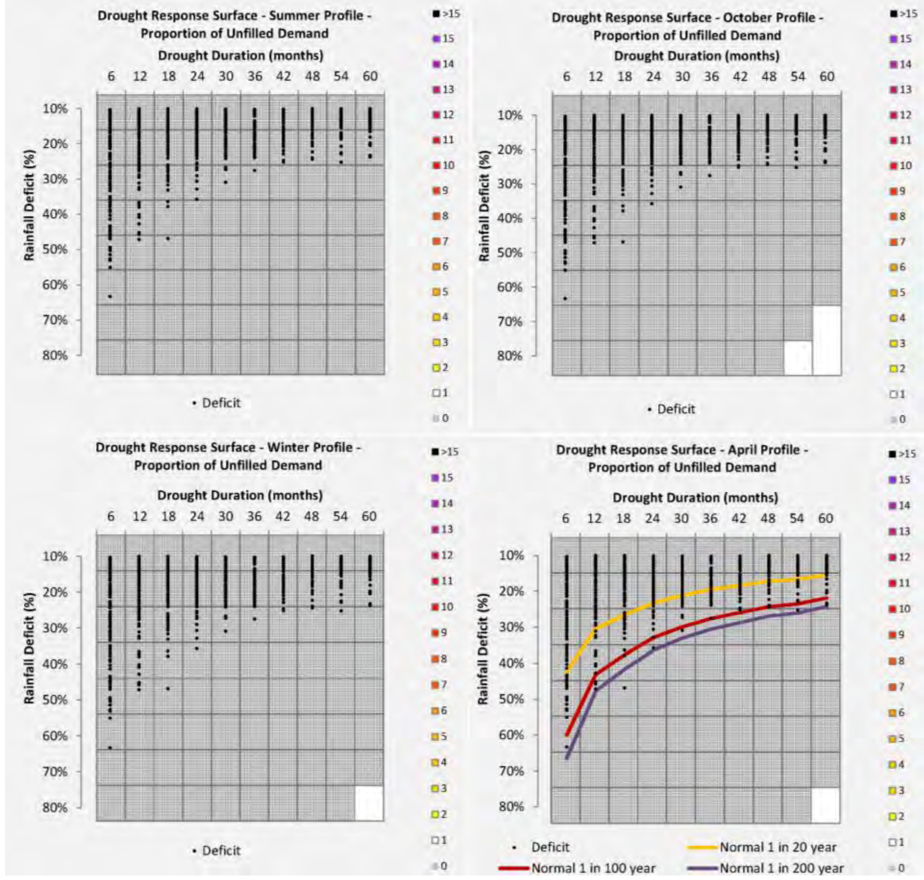


Figure 13: WRZ3 (Lee) unfulfilled demand (with transfers and drought management actions)

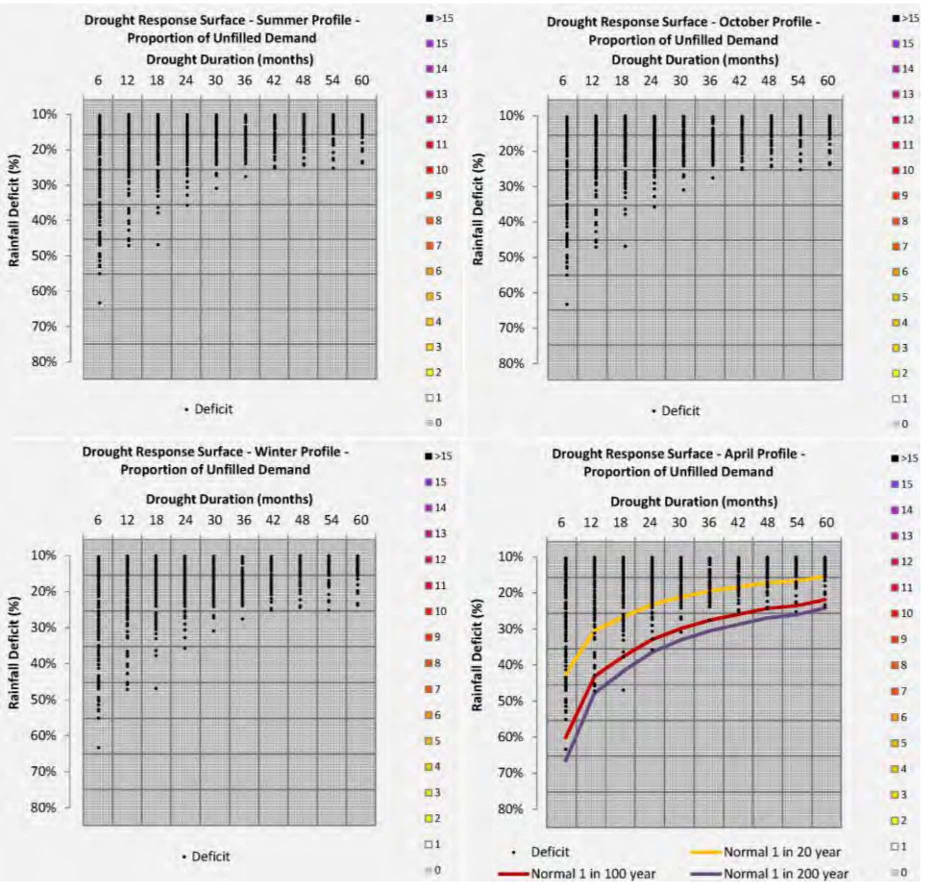


Figure 14: WRZ4 (Pin) unfulfilled demand (with transfers and drought management actions)

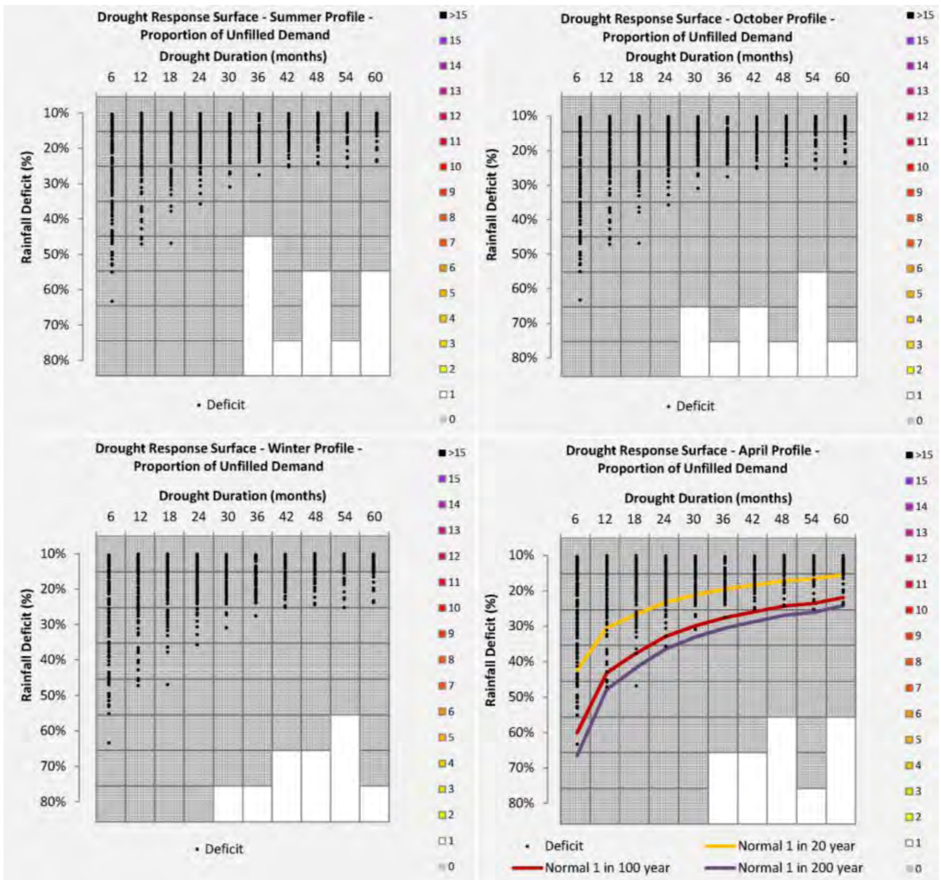


Figure 15: WRZ5 (Stort) unfulfilled demand (with transfers and drought management actions)

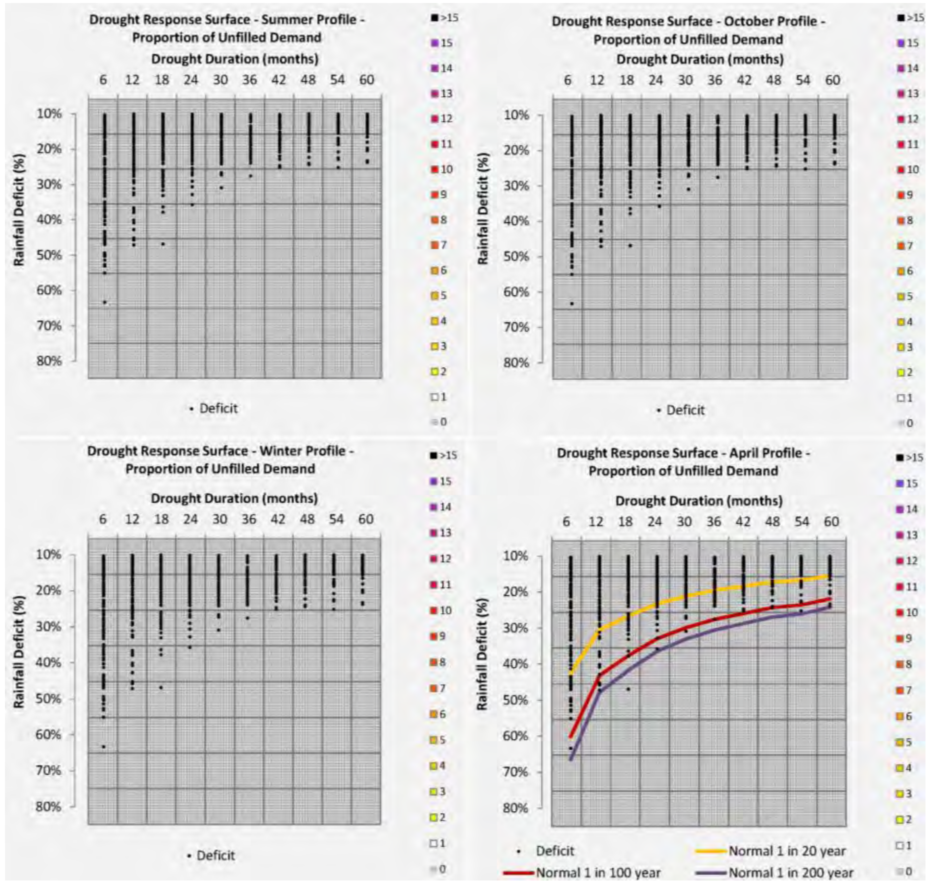


Figure 16: WRZ6 unfulfilled demand (with transfers and drought management actions)

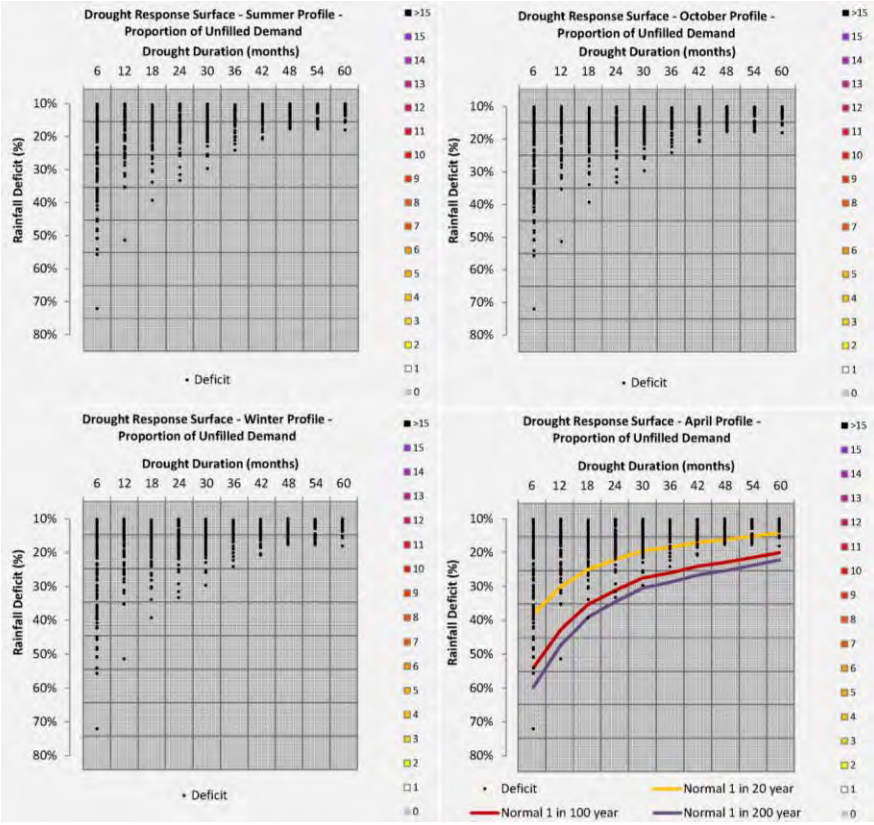


Figure 17: WRZ7 (Dour) unfulfilled demand (with transfers and drought management actions)

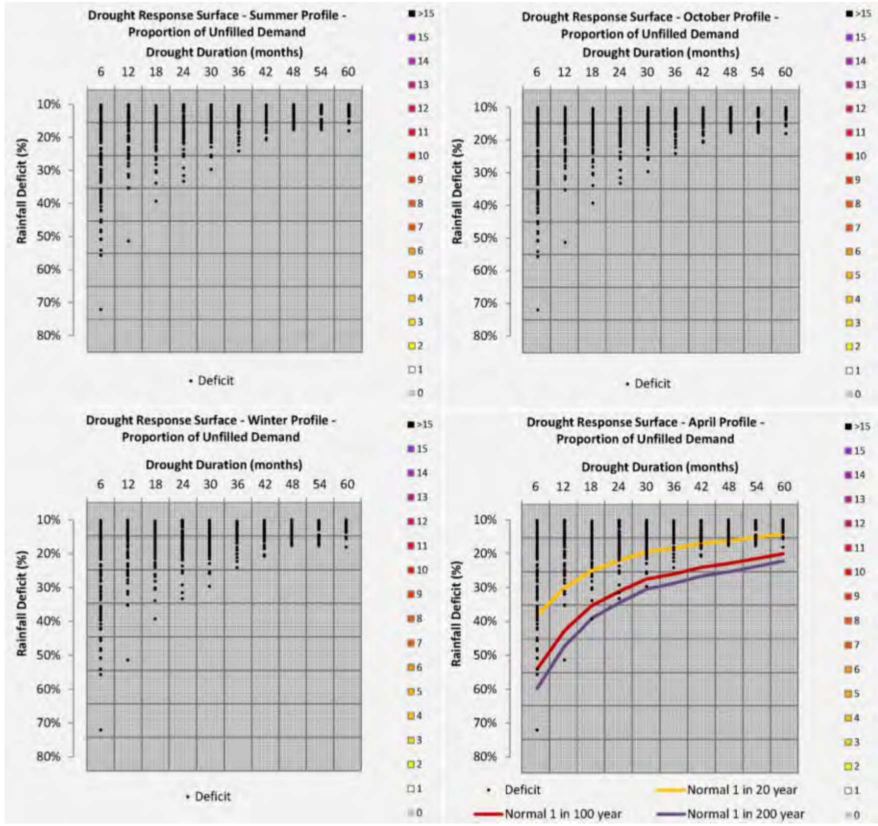


Figure 18: WRZ8 unfulfilled demand (with transfers and drought management actions)

3.5 Key limitations and assumptions

There are a number of important limitations associated with the modelling and results presented within this report. These are described below and should be taken into consideration when interpreting the outputs:

- The rainfall time series data used in the models are monthly values, as agreed with Affinity Water; the company area is largely supported by groundwater abstractions and is less sensitive to daily rainfall than an area dominated by surface water supplies. However it is acknowledged that short and intense rainfall events can result in groundwater recharge, even when there is a significant soil moisture deficit; this effect is not recognised by the lumped parameter groundwater level modelling owing to the monthly time step. This limitation is such that the modelled groundwater level recessions under the extreme drought scenarios are exaggerated by a lack of recharge, and represent a worse-case scenario.
- The WRZ models are based in Microsoft Excel and used for a high level strategic assessment. They are not as sophisticated as models developed in Miser and Aquator water resources software (for example). This limitation may hide localised distribution issues.
- The WRZ models assume that DOs are available at all times for every source. However in reality there may be outage events that would reduce the available supplies within the WRZ, even if only for a limited amount of time (e.g. basic maintenance of filters at treatment works, or pollution events). This limitation means that the results are a best case scenario with respect to outage.
- The WRZ models assume that the statistical likelihood of a groundwater level in the lumped parameter model is the same as the statistical characteristics (return periods) for the source ADO & PDO as assessed by the Environment Agency with Affinity Water.
- The WRZ models assume that treated water is always available for import from Anglian Water under all drought scenarios. The import is subject to agreements between Affinity Water and Anglian Water. It is recognised that some of the drought scenarios are beyond the scope of the drought plan; these scenarios would be covered by emergency planning.
- The WRZ models assume that raw water is available for abstraction from the River Thames under all drought scenarios. This is in line with the Lower Thames Operating Agreement (LTOA), although it is recognised that some of the drought scenarios are beyond the scope of the drought plan; these scenarios would be covered by emergency planning. It is also noted that treated water imports from Thames Water are not included in the modelling, as these may not be reliable during drought conditions.
- The WRZ models link the modelled water level in one reference observation borehole to the PDO and ADO for all sources in a WRZ. In a drought it might be possible to switch off or reduce abstraction at a number of upper catchment sources during an extreme drought, resulting in a positive impact at downstream sources; these effects would only be explored and recognised through distributed groundwater modelling.
- The impact of drought on groundwater PDO and ADO is extrapolated where the drought is extreme i.e. beyond the drought plan and into emergency conditions. There is significant uncertainty around the PDO and ADO values under these extreme droughts and it is uncertain if the extrapolation overestimates or underestimates the available supplies.
- The WRZ models reflect the current Affinity Water company network with AMP6 sustainability reductions in place.

4 Conclusions and Recommendations

4.1 Conclusions

Affinity Water is currently developing a new Drought Management Plan for consultation. Drought scenario testing has been undertaken for the company's Central, East and Southeast regions in line with regulator guidelines. The drought sensitivity framework uses a matrix of rainfall deficit duration and intensities, where durations are on 6 month increments between 6 months and 5 years, and intensities range between -10% and -80% of the Long Term Average (LTA) rainfall.

The results of the modelling demonstrate that the degree to which Affinity Water's WRZs are resilient to drought is dependent on the assumptions around (i) imports and transfers between WRZs, and (ii) the drought management actions that can be implemented. The Affinity Water WRZs 3, 4, 5 (Central region) and 7 (South East region) are the most vulnerable to drought owing to the magnitude of WRZ demand relative to WRZ supplies. However, once available transfers and demand management actions are applied, it can be demonstrated that the Affinity Water regions are resilient to historic droughts as well as plausible droughts a little worse than those in the historic record.

The drought scenario testing has provided some useful high level outputs and an understanding of Affinity Water's resilience to various drought severities and durations. However it is important that the limitations of the modelling outlined in this report are considered when interpreting the results. In particular, the squares in the results matrices that are below the historic data and 1 in 200 year event line represent conditions worse than those covered by the drought plan; these droughts would fall within the remit of the emergency plan and the assumptions within the models may no longer be valid.

4.2 Recommendations

There is an on-going Affinity Water project to test a new deployable output assessment methodology for WRZ2 in the Central region. The new approach is targeted at assessing WRZ DO with Level of Service (LoS) using unrestricted and restricted demand profiles within the Miser water resources model. The analysis may also be rolled out to other WRZs in the Affinity Water company area and include validation of results using distributed groundwater models. Therefore the outputs of the revised DO assessment (based on methods that are more sophisticated than those employed for the current drought scenarios project) should be taken into account within the 2017 annual update.

5 References

AECOM, April 2015. Annex A: Water Availability Assessment. Strategic Water Infrastructure and Resilience. Final Report. Environment Agency.

Affinity Water, April 2015. Drought Management Plan Annual Update (DMP).

Affinity Water, February 2013. Drought Management Plan, Central Region.

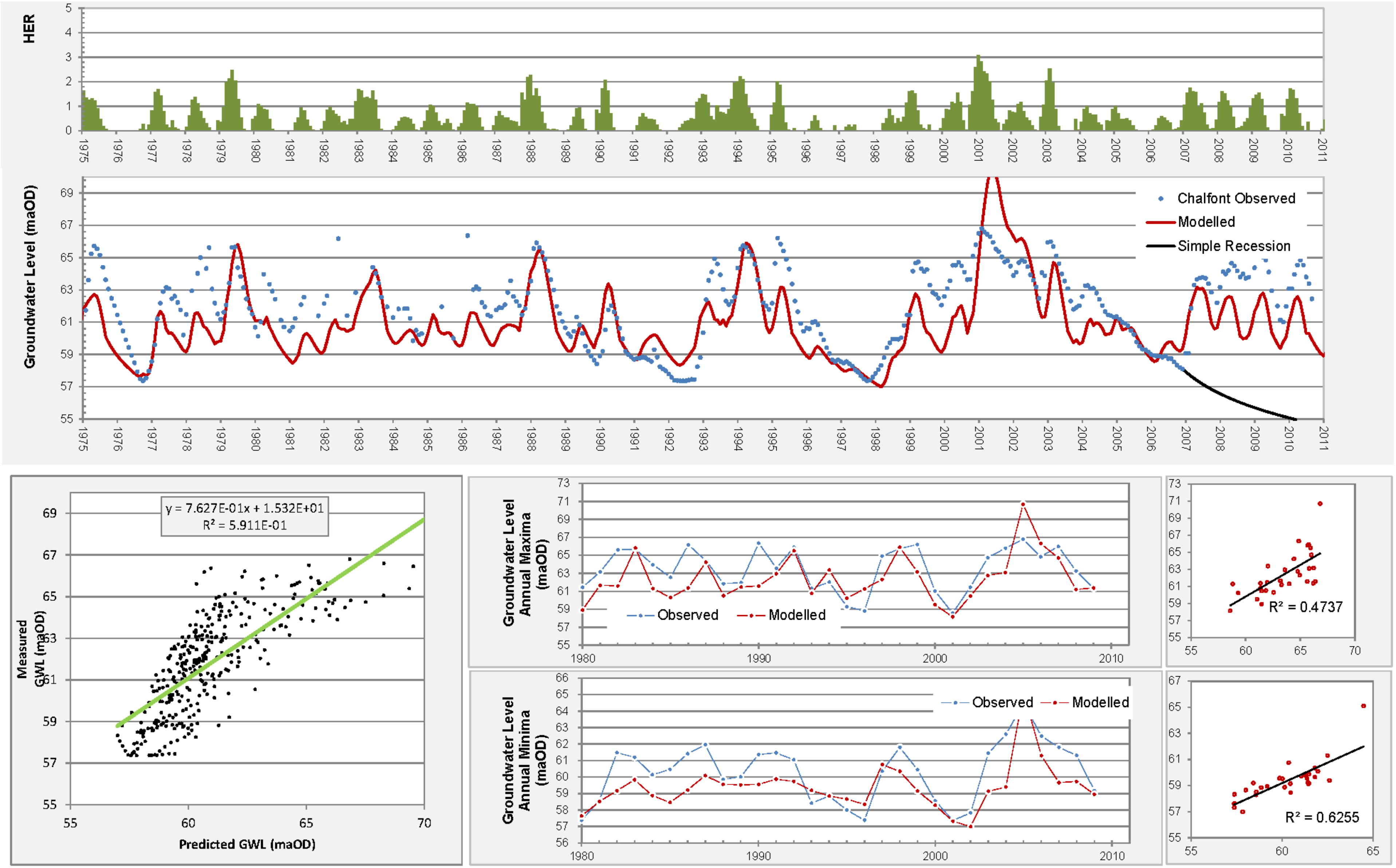
Affinity Water, June 2014. Level of Service Hindcasting – Assessment of the Frequency of Drought Restrictions. Technical Report 1.2. Water Resources Management Plan.

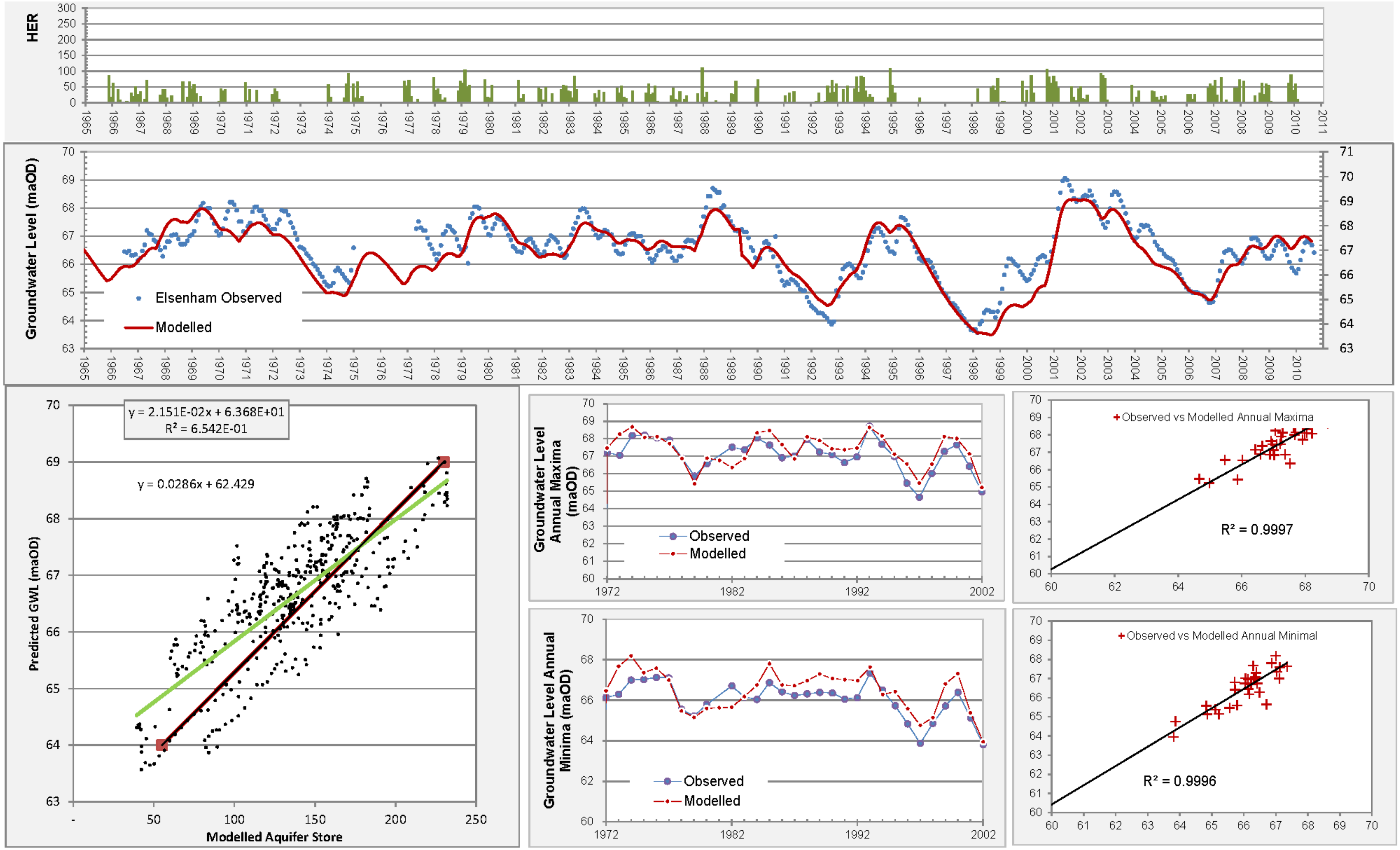
Environment Agency, December 2015. Understanding the performance of water supply systems during mild to extreme droughts.

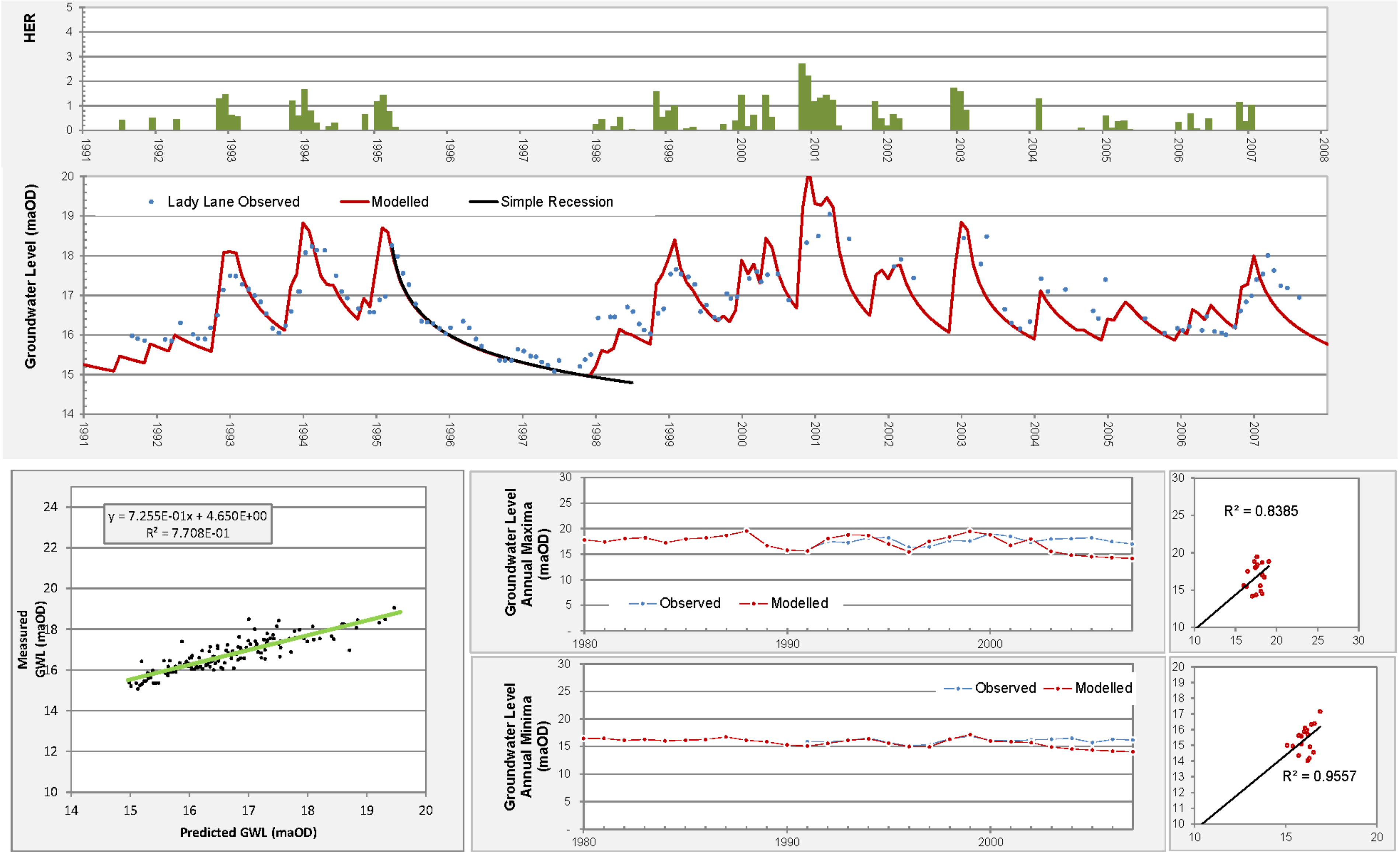
Environment Agency, June 2016. Drought Plan guideline extra information.

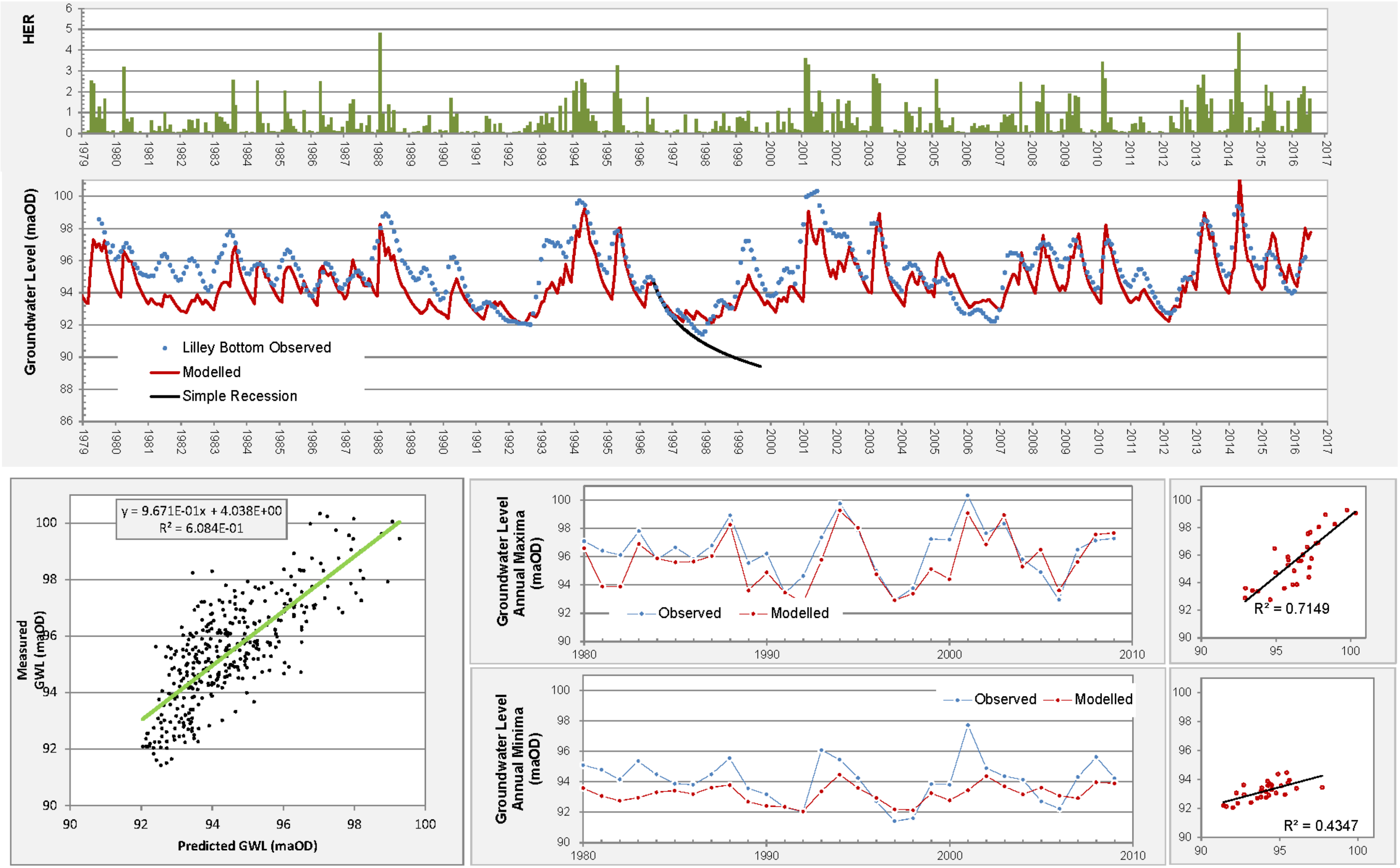
Appendix A. Calibration of lumped parameter groundwater level models

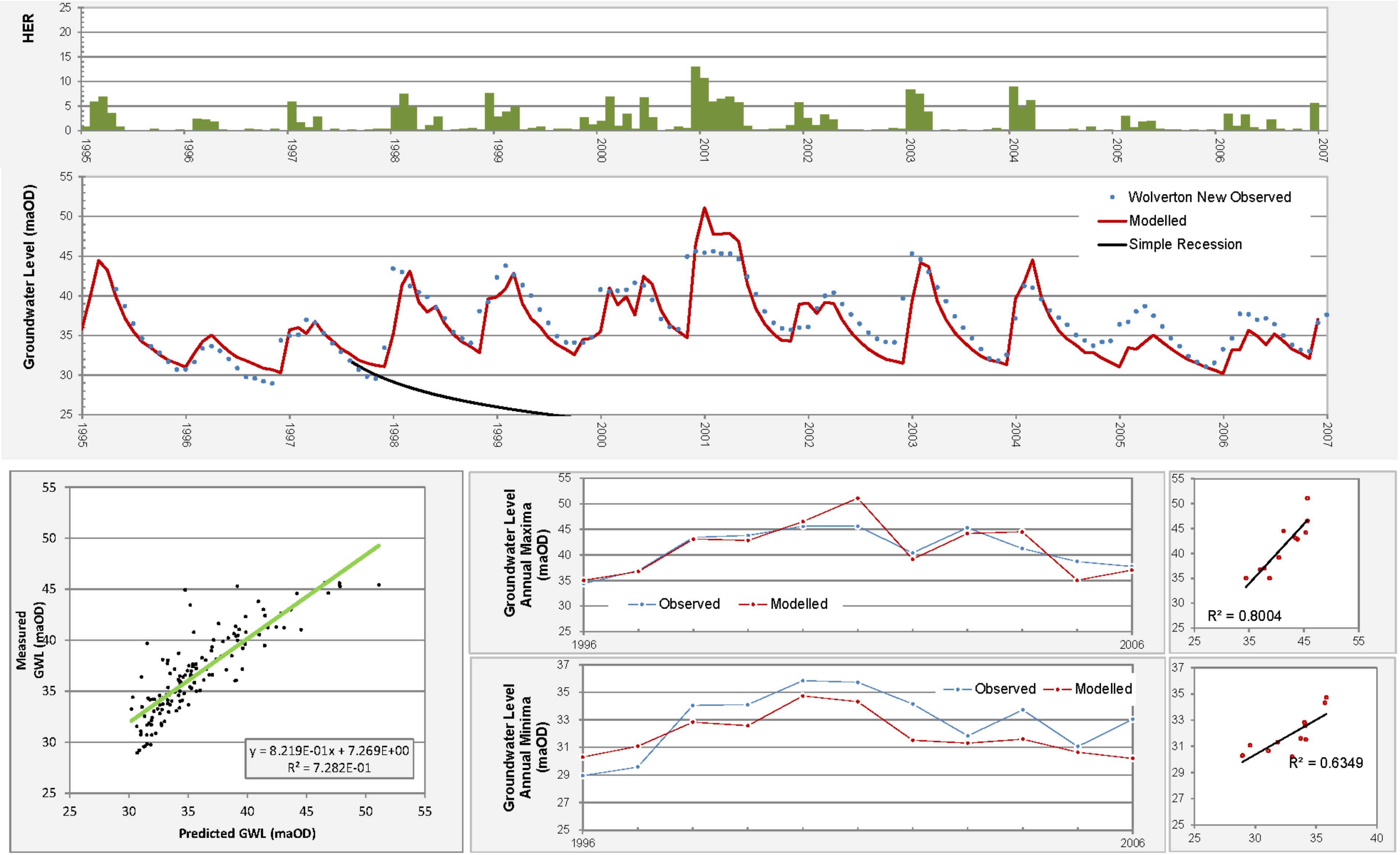
.


HER
Groundwater Level (maOD)
Chalfont Observed
Modelled
Simple Recession
y = 7.627E-01x + 1.532E+01
R² = 5.911E-01
Measured GWL (maOD)
Predicted GWL (maOD)
Groundwater Level Annual Maxima (maOD)
Observed
Modelled
R² = 0.4737
Groundwater Level Annual Minima (maOD)
Observed
Modelled
R² = 0.6255


HER
Groundwater Level (maOD)
Elsenham Observed
Modelled
y = 2.151E-02x + 6.368E+01
R² = 6.542E-01
y = 0.0286x + 62.429
Predicted GWL (maOD)
Modelled Aquifer Store
Groundwater Level Annual Maxima (maOD)
Observed
Modelled
Observed vs Modelled Annual Maxima
R² = 0.9997
Groundwater Level Annual Minima (maOD)
Observed
Modelled
Observed vs Modelled Annual Minimal
R² = 0.9996


HER
Groundwater Level (maOD)
Lady Lane Observed
Modelled
Simple Recession
y = 7.255E-01x + 4.650E+00
R² = 7.708E-01
Measured GWL (maOD)
Predicted GWL (maOD)
Groundwater Level Annual Maxima (maOD)
Observed
Modelled
R² = 0.8385
Groundwater Level Annual Minima (maOD)
R² = 0.9557


HER
Groundwater Level (maOD)
Lilley Bottom Observed
Modelled
Simple Recession
y = 9.671E-01x + 4.038E+00
R² = 6.084E-01
Measured GWL (maOD)
Predicted GWL (maOD)
Groundwater Level Annual Maxima (maOD)
Observed
Modelled
R² = 0.7149
Groundwater Level Annual Minima (maOD)
Observed
Modelled
R² = 0.4347


HER
Groundwater Level (maOD)
Wolverton New Observed
Modelled
Simple Recession
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Measured GWL (maOD)
Predicted GWL (maOD)
y = 8.219E-01x + 7.269E+00
R² = 7.282E-01
Groundwater Level Annual Maxima (maOD)
Observed
Modelled
R² = 0.8004
Groundwater Level Annual Minima (maOD)
Observed
Modelled
R² = 0.6349

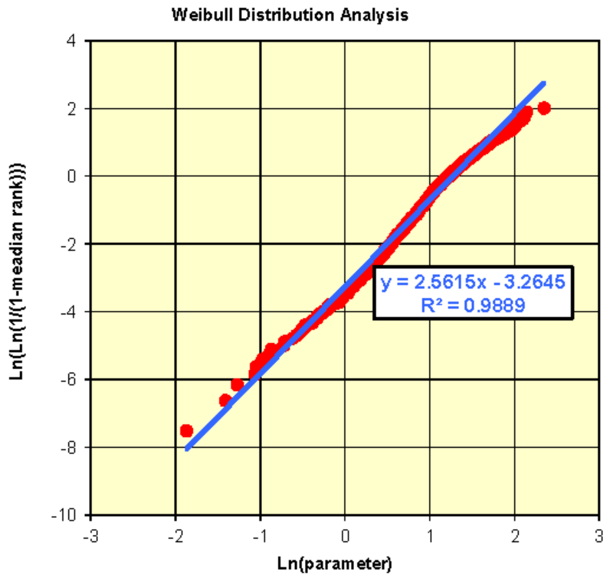
Appendix B.Frequency Analysis Plots

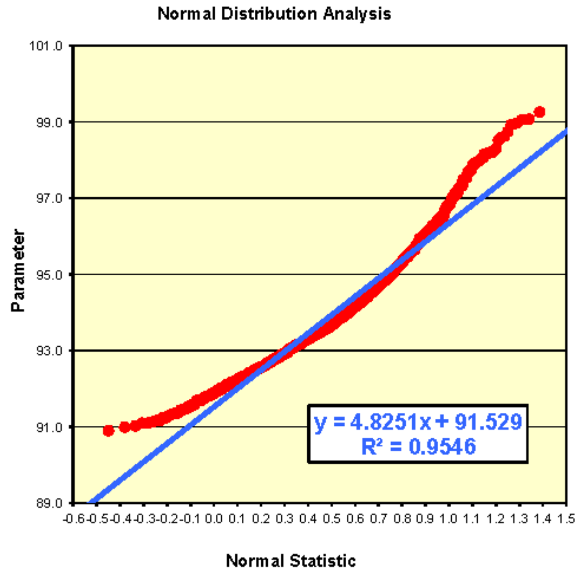
This appendix includes the full set of frequency analysis plots for Lilley Bottom observation borehole (all months and January to February) and example plots for the other key observation boreholes (all months).

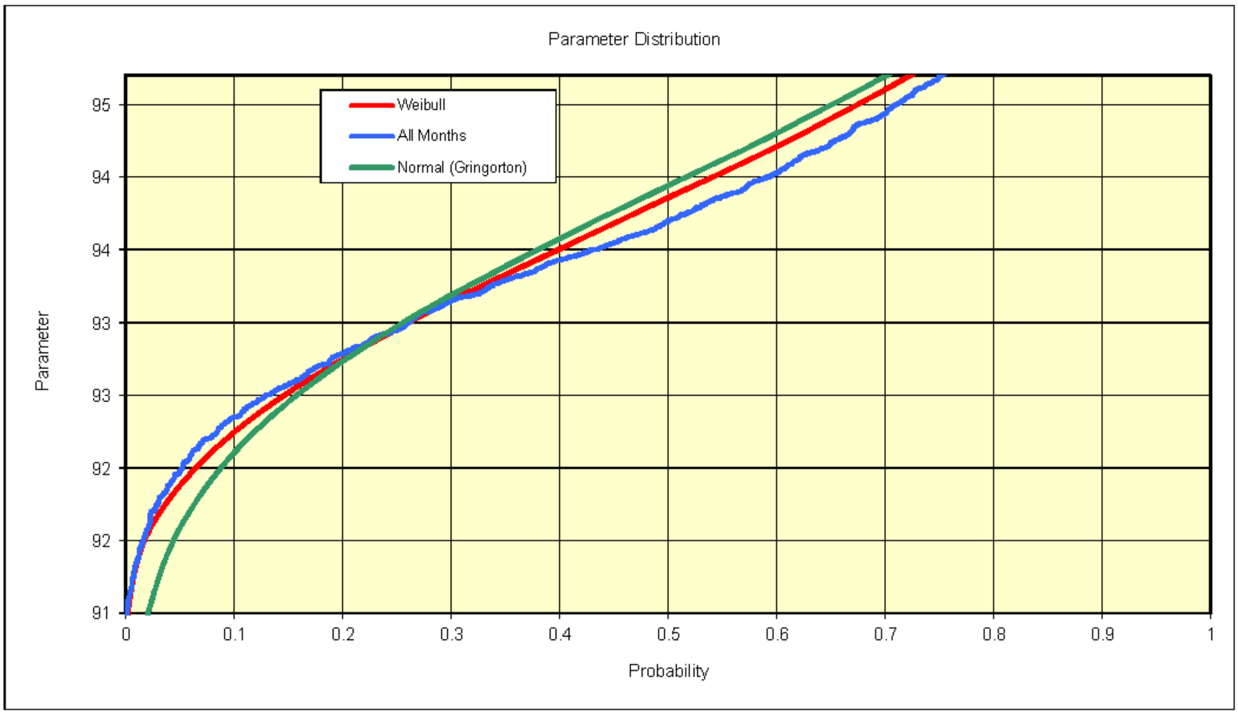
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.561	Mean	93.9	Param:	Minimum GWL
Intercept		-3.264	Standard Deviation	1.4	Units:	mAOD
Characteristic	α	3.577	Minimum	90.91	Class:	All Months
Shift	γ	90.76	Maximum	101.26		







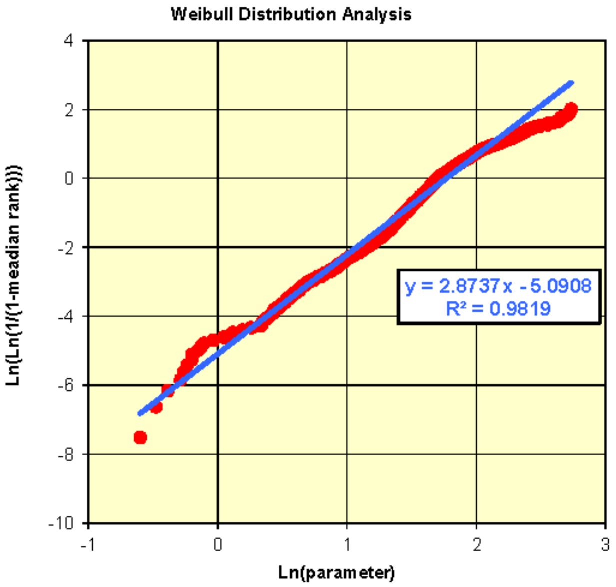
Results

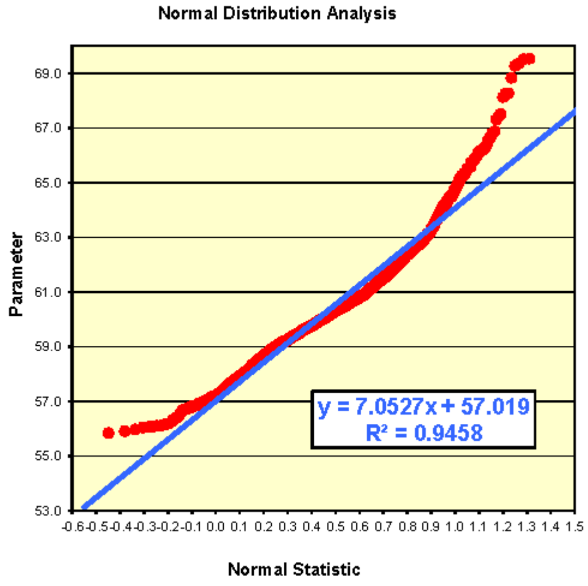
Probability	0.5	0.1	0.05	0.025	0.013	0.008
Return Period (year)	2	10	20	40	80	120
Weibull	93.86	92.24	91.88	91.61	91.40	91.31
Normal	93.94	92.10	91.58	91.13	90.72	90.50

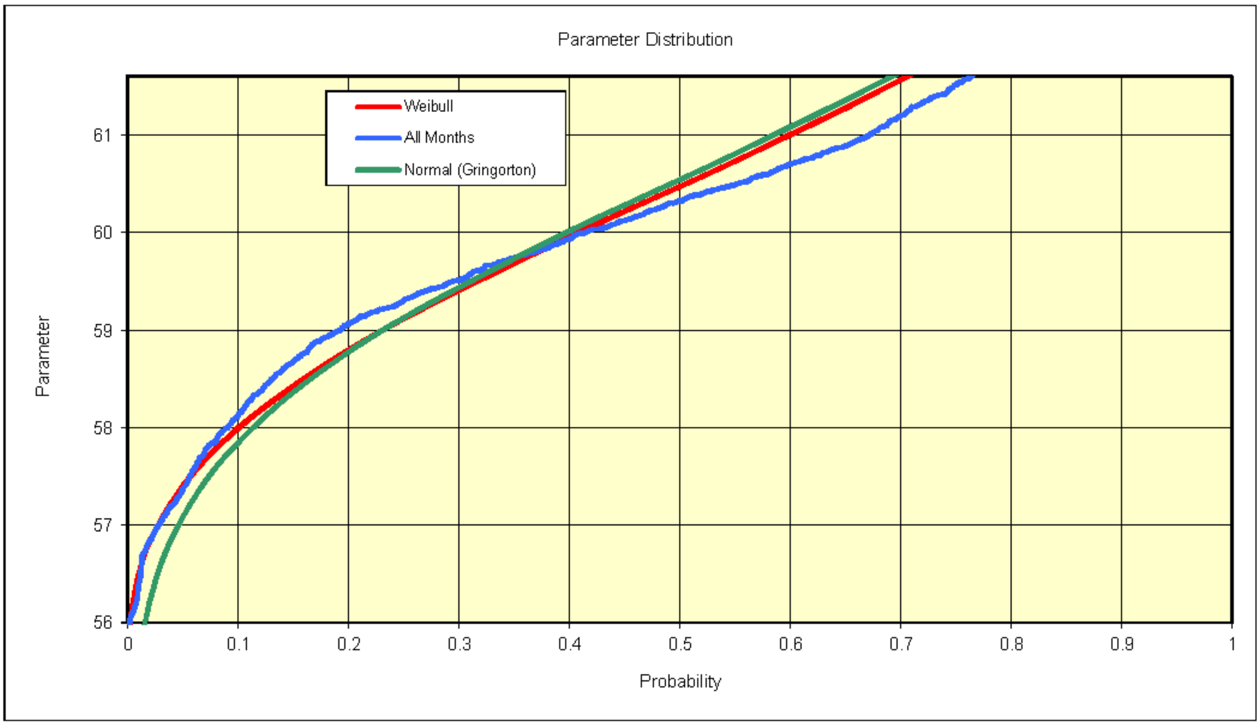
Frequency Analysis

Location: **Chalfont (Simmulated with LPM)**

Weibull Distribution Parameters			Normal Distribution Parameters			
Shape Parameter	β	2.881	Mean	60.5	Param:	Minimum GWL
Intercept		-5.101	Standard Deviation	2.1	Units:	mAOD
Characteristic	α	5.874	Minimum	55.85	Class:	All Months
Shift	γ	55.3	Maximum	70.70		







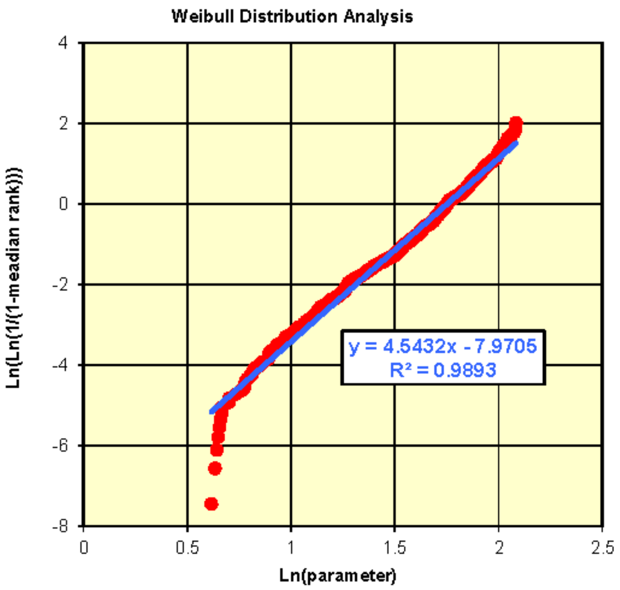
Results

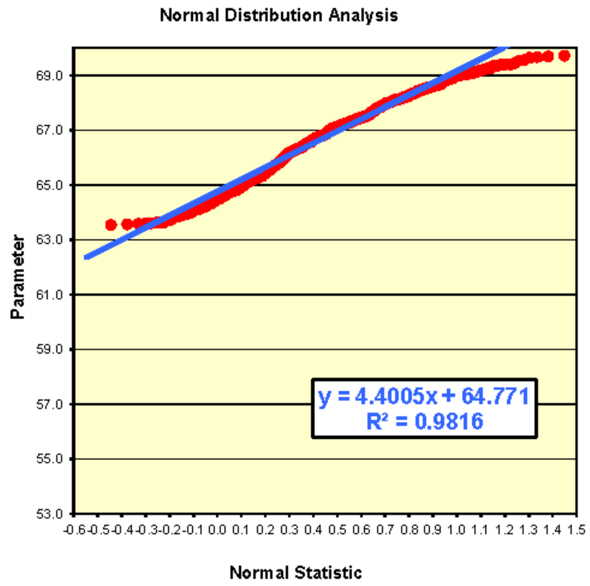
Probability	0.5	0.1	0.05	0.025	0.013	0.008
Return Period (year)	2	10	20	40	80	120
Weibull	60.47	57.99	57.40	56.94	56.59	56.42
Normal	60.55	57.84	57.08	56.41	55.82	55.50

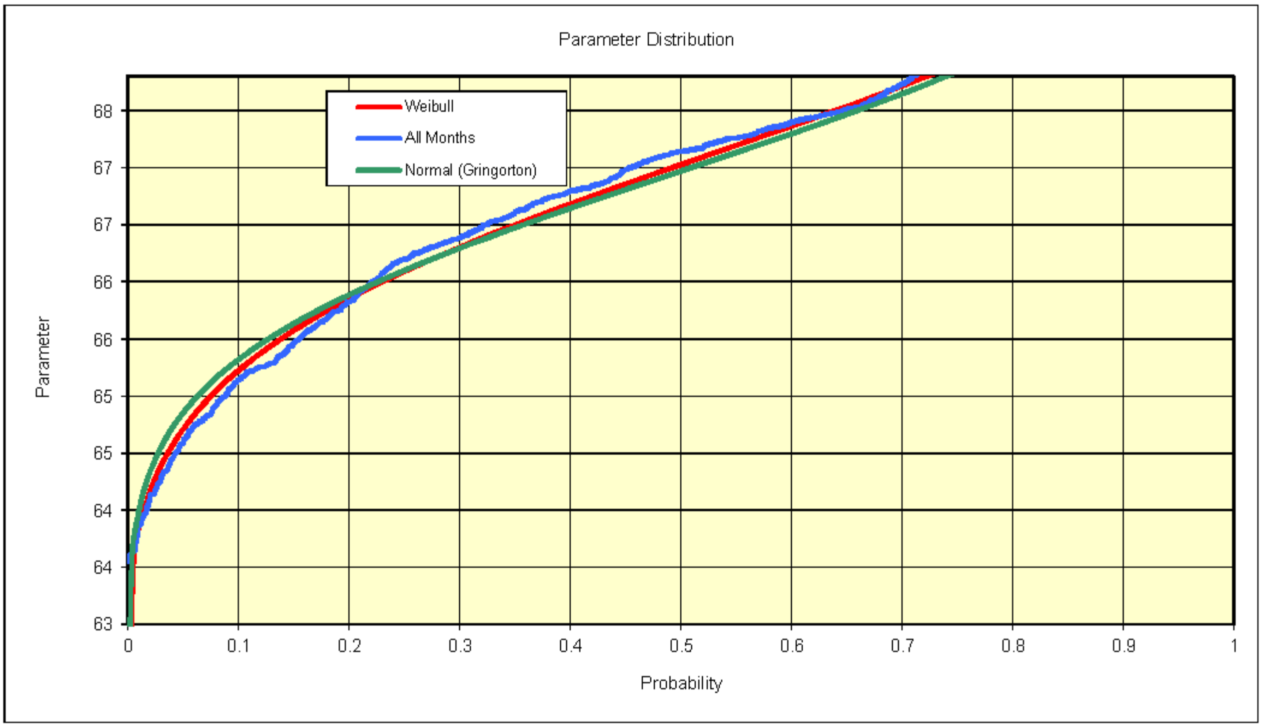
Frequency Analysis

Location: **Elsenham (Simulated)**

Weibull Distribution Parameters			Normal Distribution Parameters			
Shape Parameter	β	4.543	Mean	67.0	Param:	Minimum GWL
Intercept		-7.971	Standard Deviation	1.3	Units:	mAOD
Characteristic	α	5.78	Minimum	63.55	Class:	All Months
Shift	γ	61.7	Maximum	69.73		







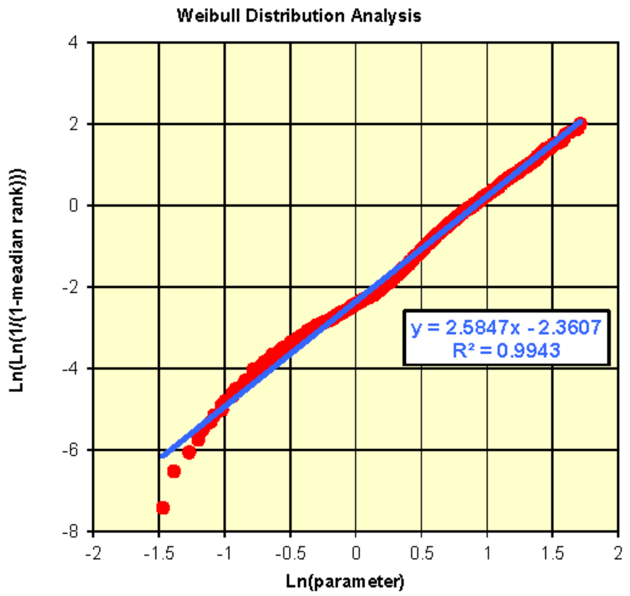
Results

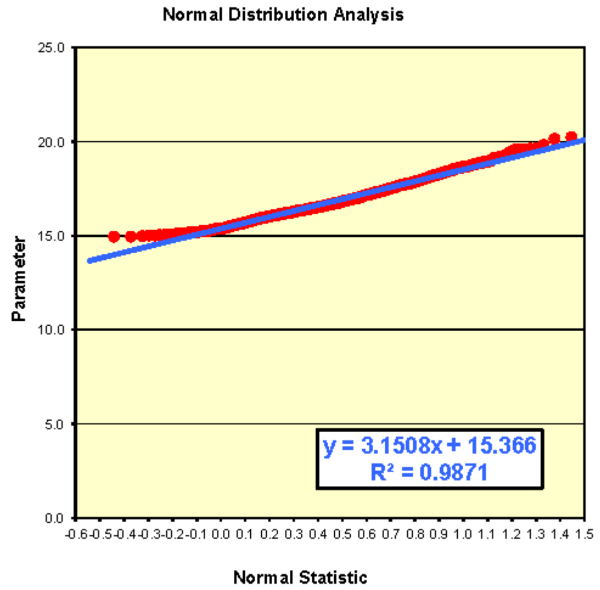
Probability	0.5	0.1	0.05	0.025	0.013	0.008
Return Period (year)	2	10	20	40	80	120
Weibull	67.03	65.22	64.70	64.27	63.90	63.71
Normal	66.97	65.32	64.85	64.44	64.08	63.88

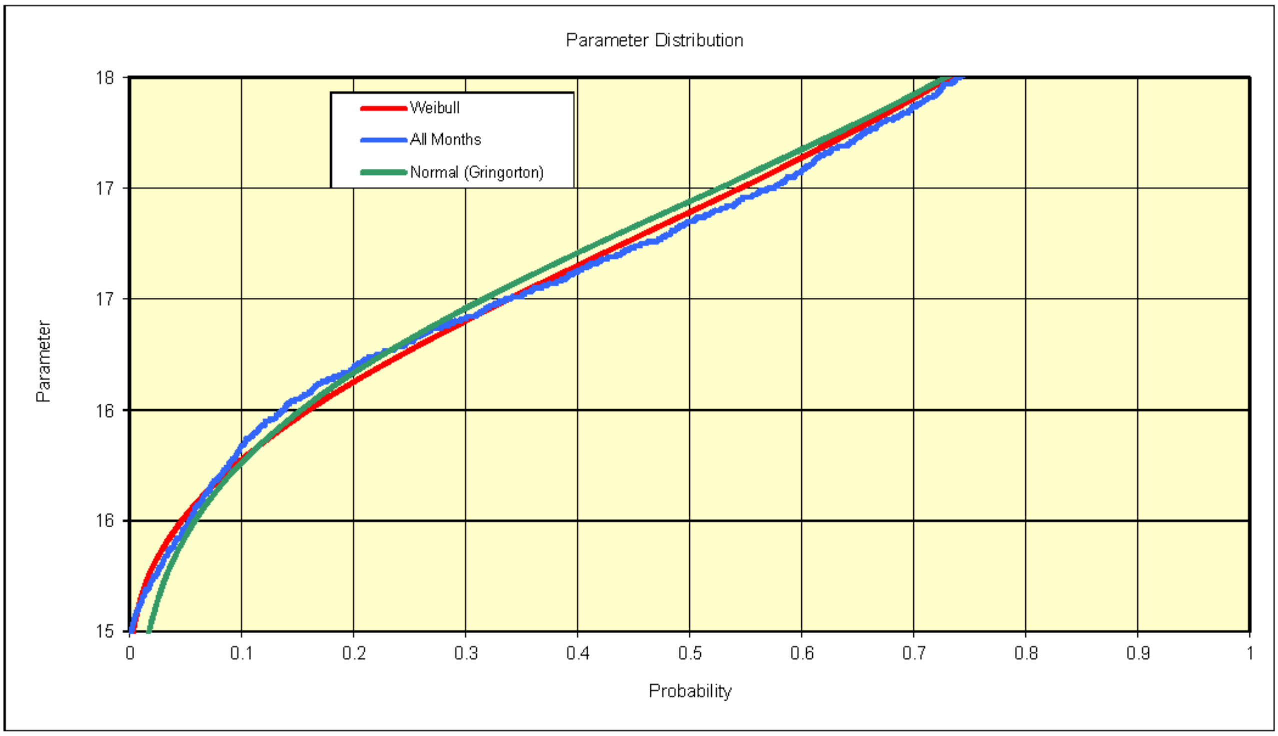
Frequency Analysis

Location: **Lady Lane (Simulated)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.585	Mean	16.9	Param:	Minimum GWL
Intercept		-2.361	Standard Deviation	0.9	Units:	mAOD
Characteristic	α	2.493	Minimum	14.96	Class:	All Months
Shift	γ	14.73	Maximum	20.26		







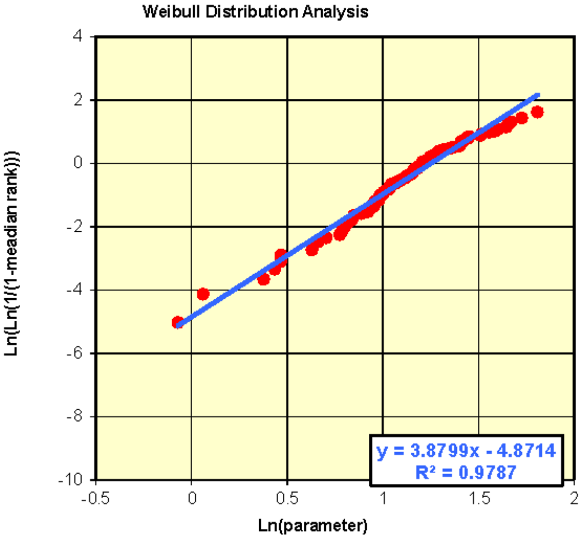
Results

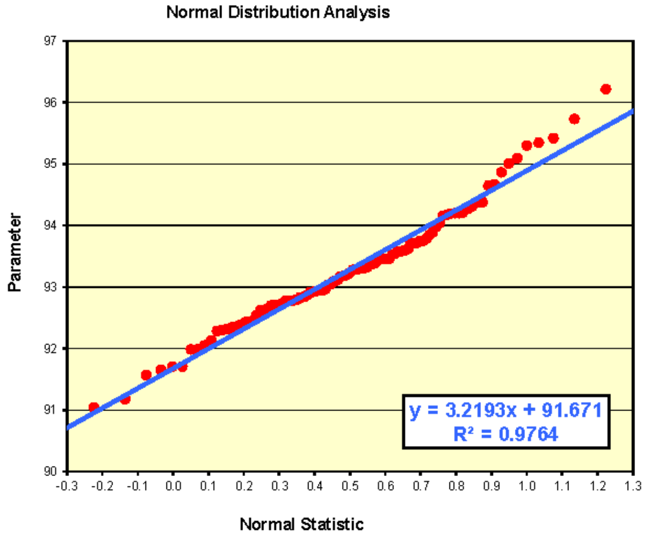
Probability	0.5	0.1	0.05	0.025	0.013	0.008
Return Period (year)	2	10	20	40	80	120
Weibull	16.89	15.77	15.52	15.33	15.19	15.12
Normal	16.94	15.76	15.43	15.13	14.88	14.73

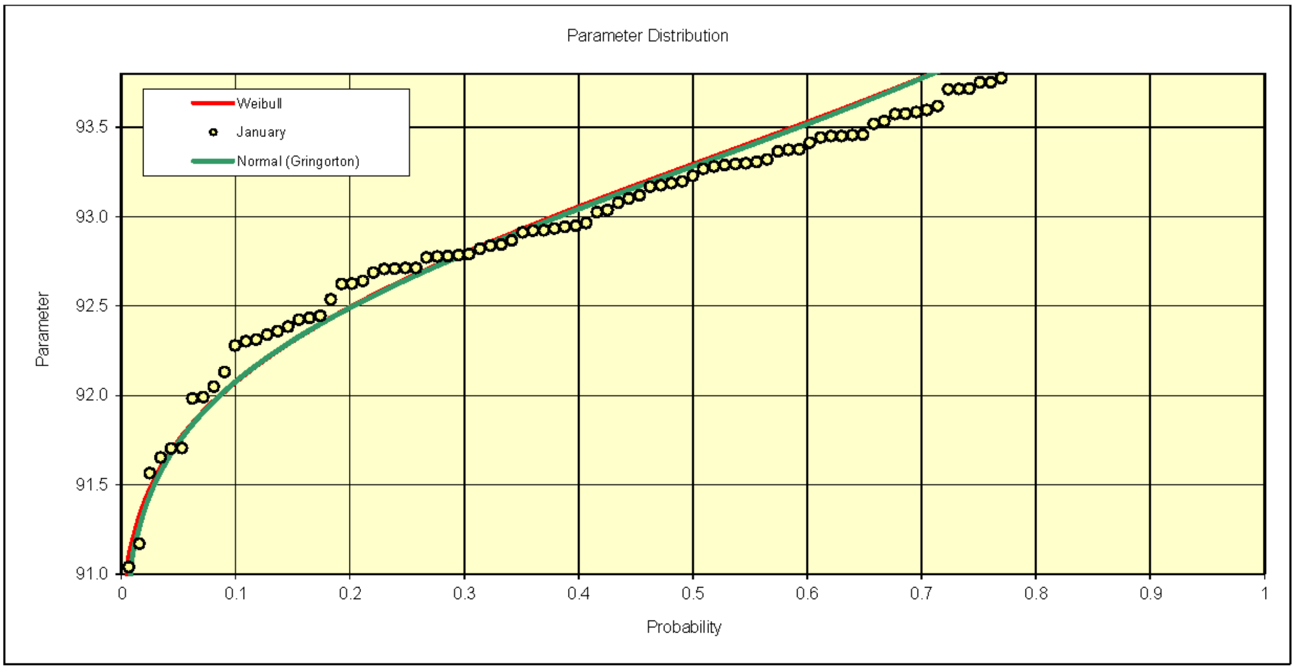
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	3.9169	Mean	93.281	Param:	**Minimum GWL**
Intercept		-4.907	Standard Deviation	0.939	Units:	**mAOD**
Characteristic	α	3.5002	Minimum	91.0	Class:	**January**
Shift	γ	90.105	Maximum	96.2		







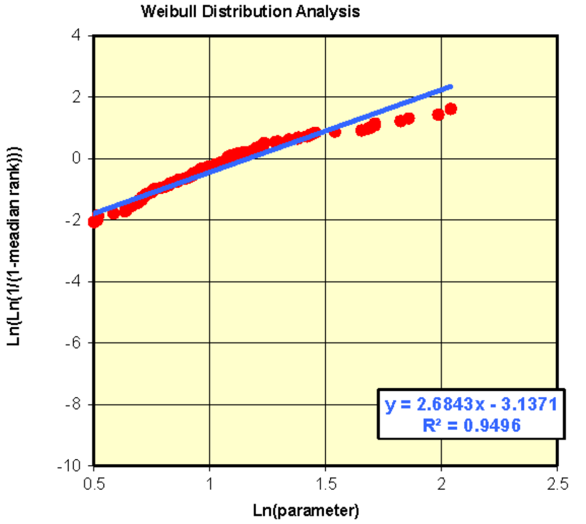
Results

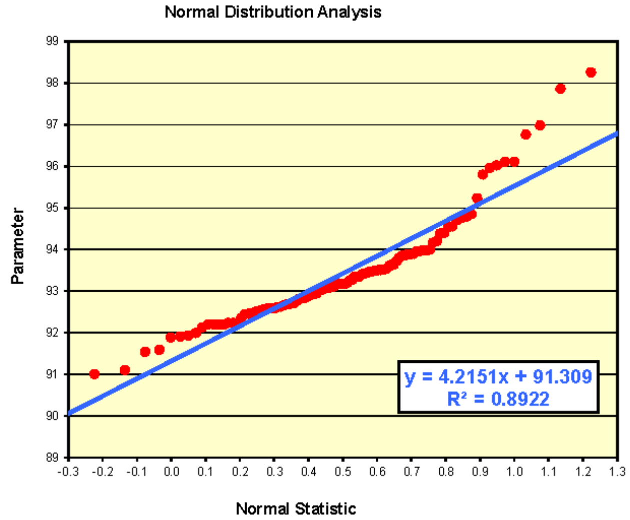
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.3	92.1	91.7	91.5	91.3	91.1
Normal	93.3	92.1	91.7	91.4	91.2	91.0

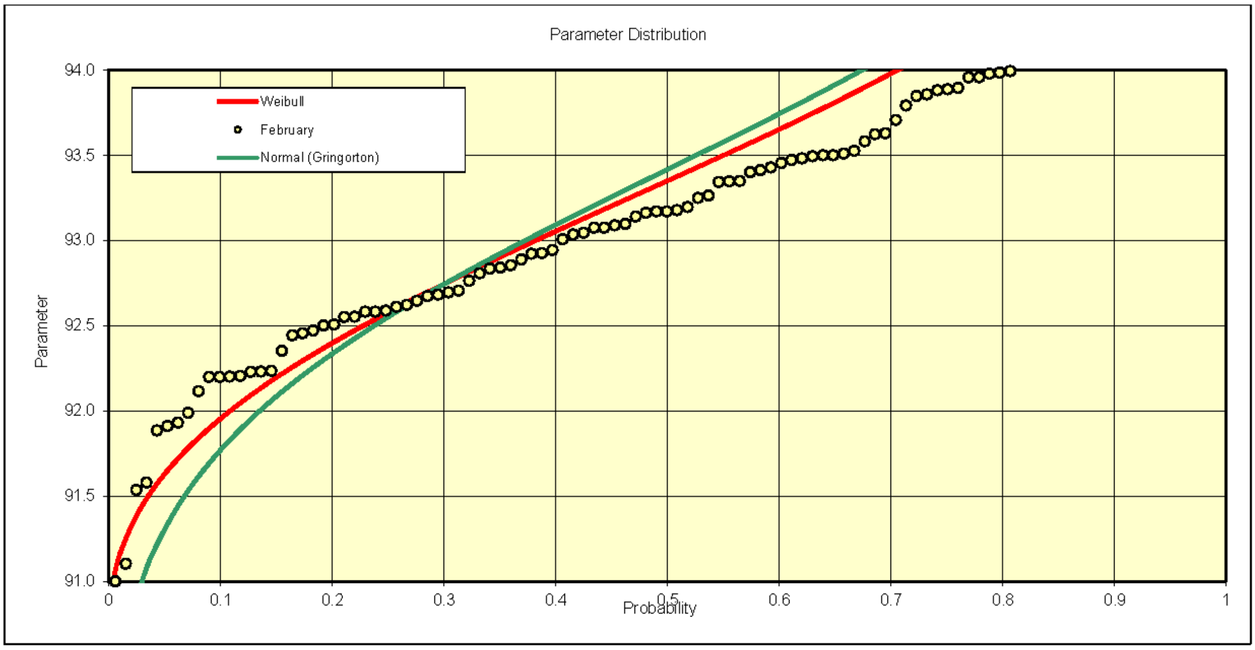
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.7231	Mean	93.4	Param:	Minimum GWL
Intercept		-3.167	Standard Deviation	1.3	Units:	mAOD
Characteristic	α	3.1995	Minimum	91.0	Class:	February
Shift	γ	90.553	Maximum	98.3		







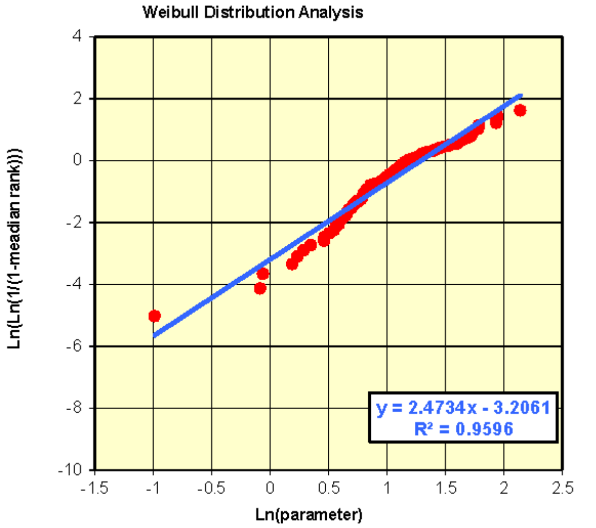
Results

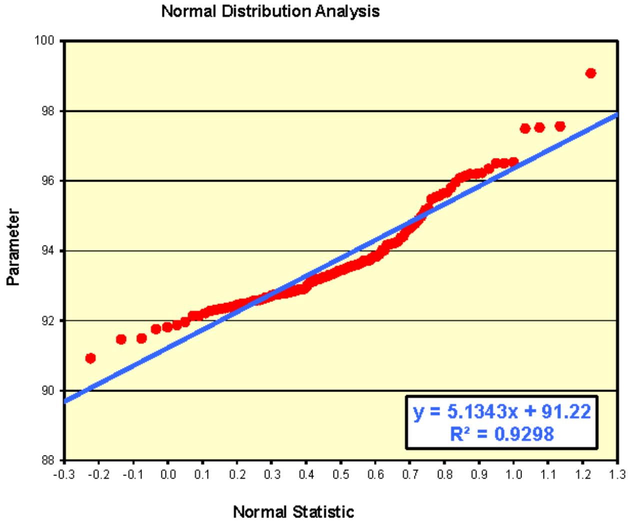
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.3	92.0	91.6	91.4	91.2	91.1
Normal	93.4	91.8	91.3	90.9	90.5	90.3

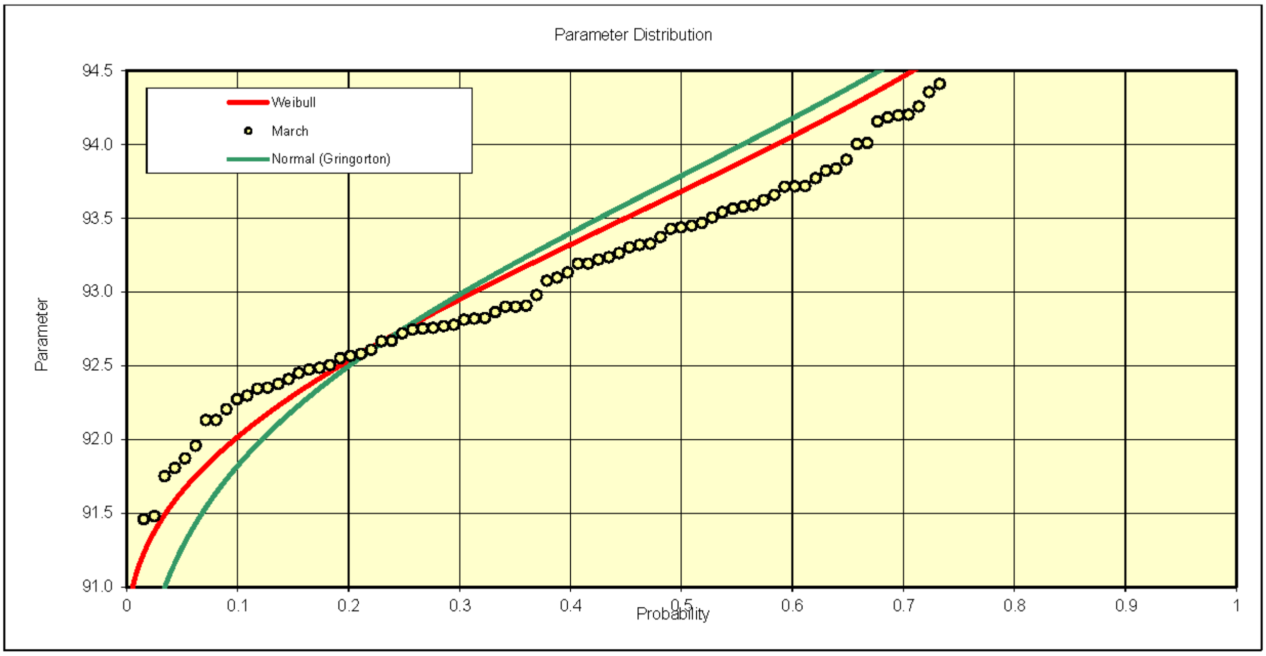
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.4946	Mean	93.8	Param:	Minimum GWL
Intercept		-3.224	Standard Deviation	1.5	Units:	mAOD
Characteristic	α	3.6414	Minimum	90.9	Class:	March
Shift	γ	90.538	Maximum	99.1		







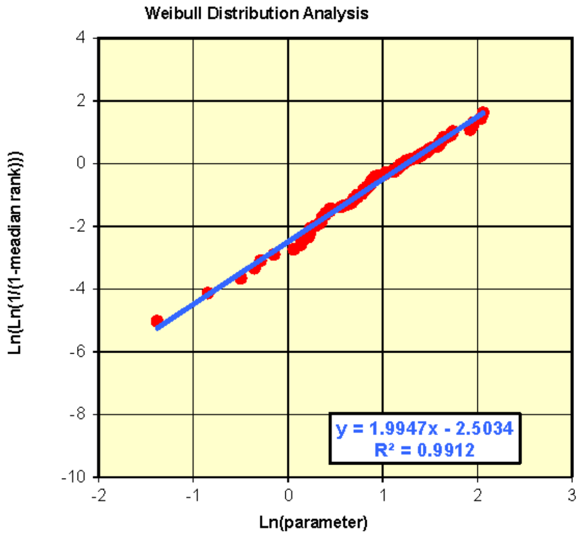
Results

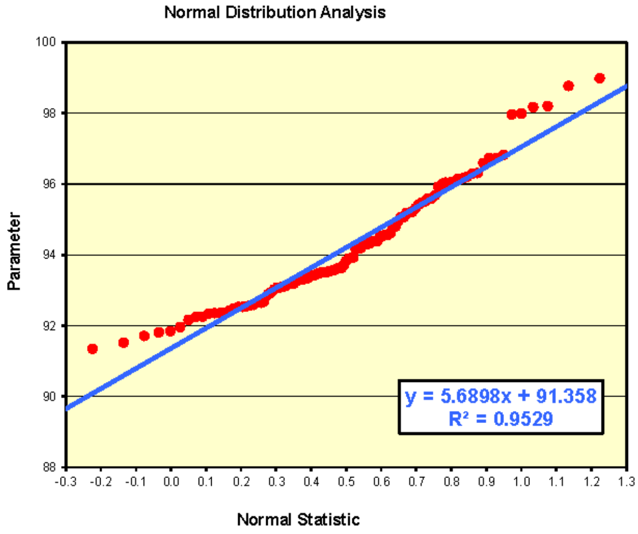
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.7	92.0	91.6	91.4	91.2	91.1
Normal	93.8	91.8	91.3	90.8	90.3	90.1

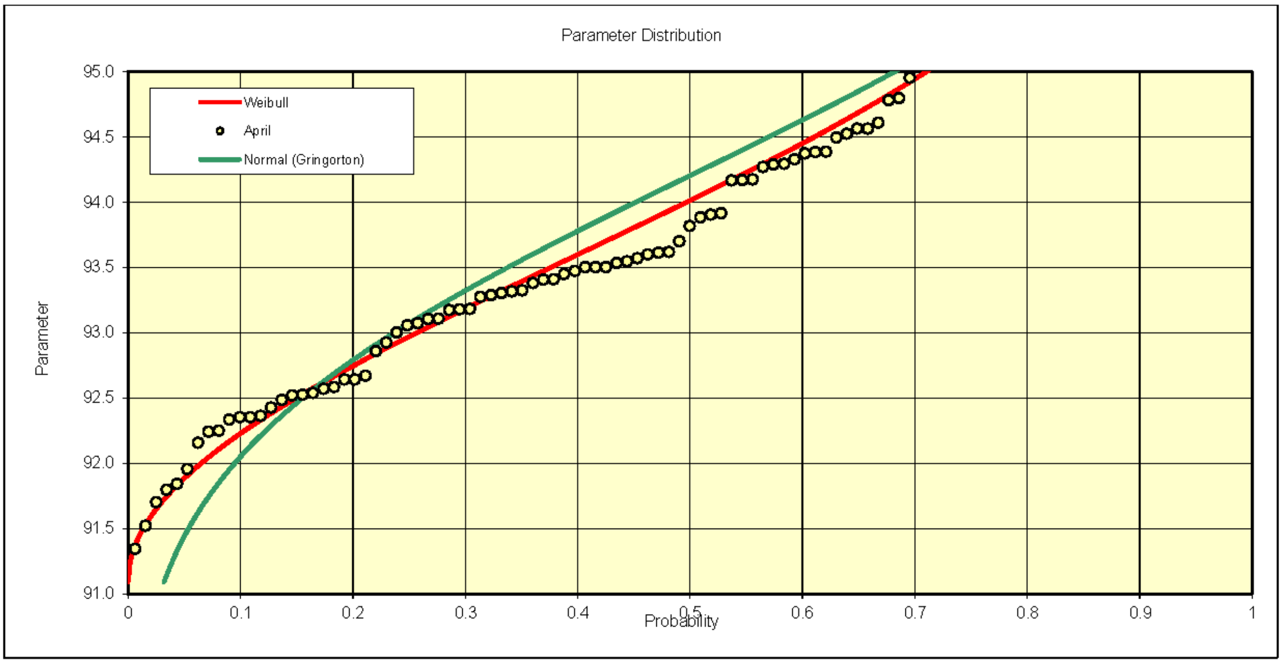
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	1.9947	Mean	94.2	Param:	**Minimum GWL**
Intercept		-2.503	Standard Deviation	1.7	Units:	**mAOD**
Characteristic	α	3.508	Minimum	91.3	Class:	**April**
Shift	γ	91.092	Maximum	99.0		







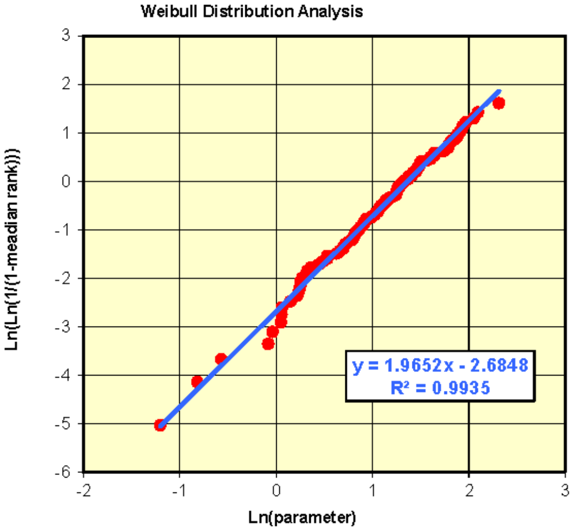
Results

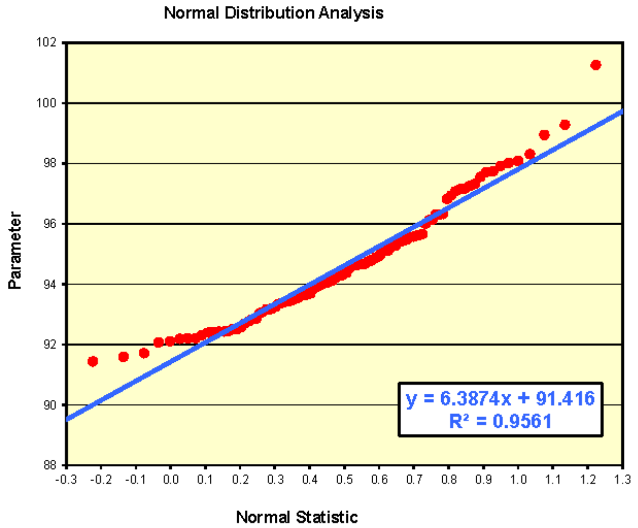
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.0	92.2	91.9	91.6	91.5	91.4
Normal	94.2	92.0	91.4	90.9	90.4	90.2

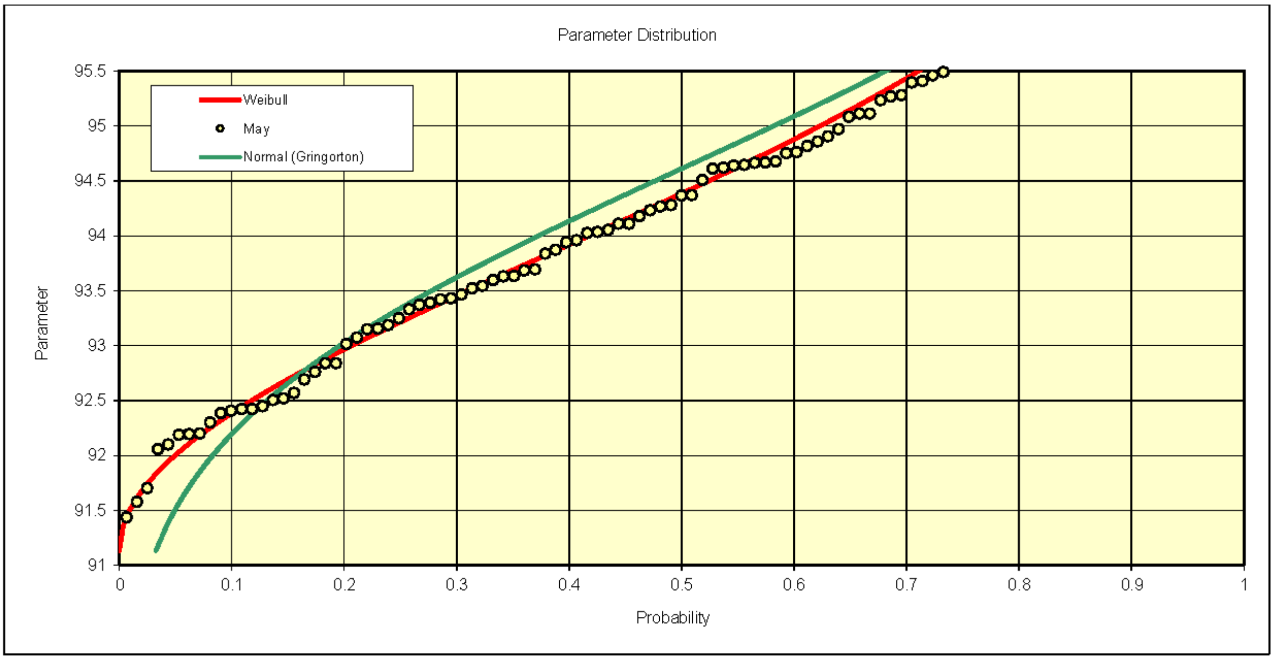
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	1.9728	Mean	94.6	Param:	Minimum GWL
Intercept		-2.691	Standard Deviation	1.9	Units:	mAOD
Characteristic	α	3.9111	Minimum	91.4	Class:	May
Shift	γ	91.136	Maximum	101.3		







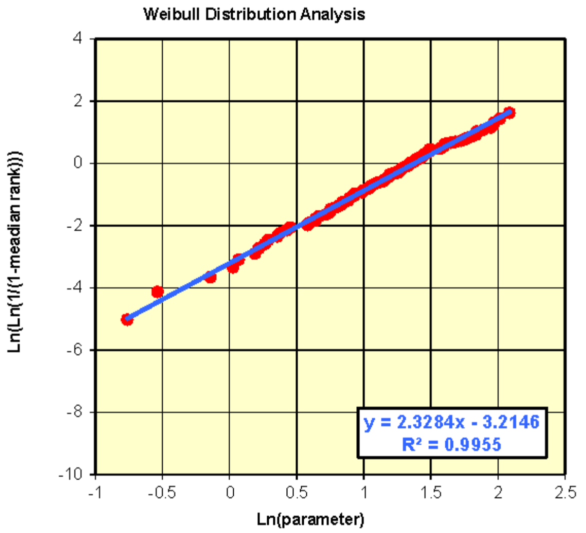
Results

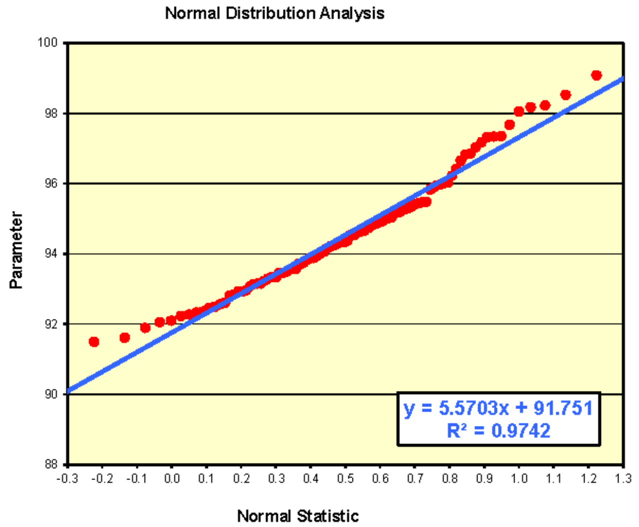
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.4	92.4	92.0	91.7	91.6	91.5
Normal	94.6	92.2	91.5	90.9	90.4	90.1

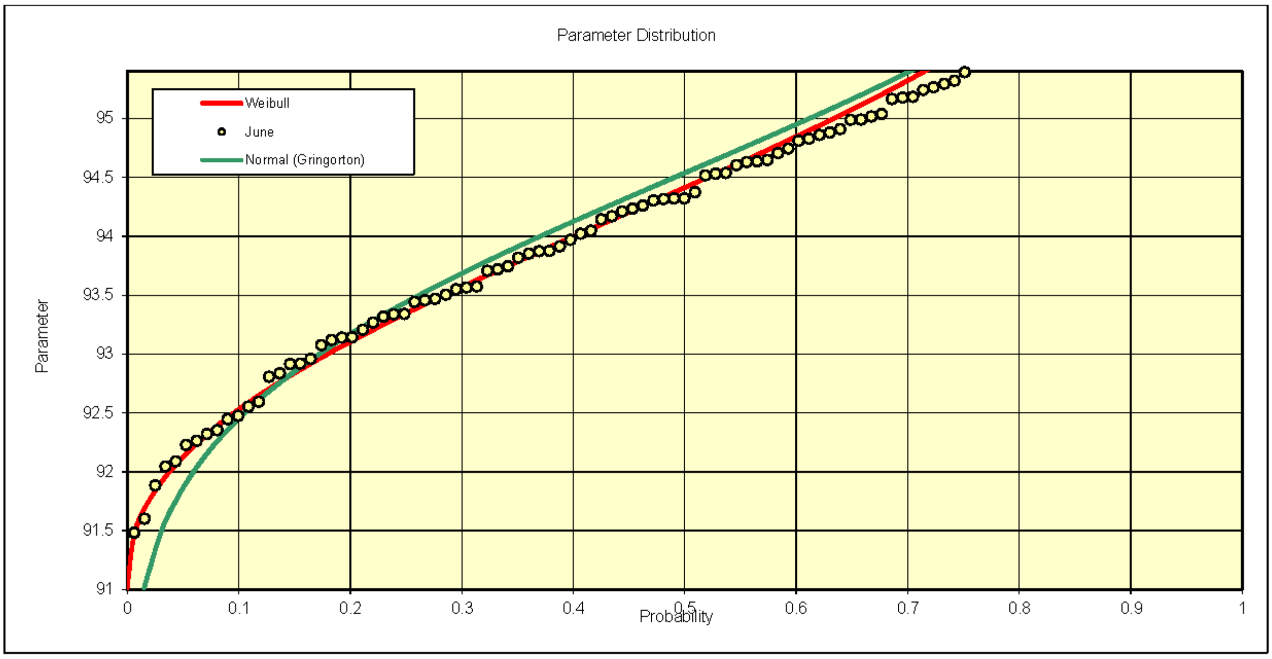
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.3294	Mean	94.5	Param:	Minimum GWL
Intercept		-3.215	Standard Deviation	1.6	Units:	mAOD
Characteristic	α	3.9763	Minimum	91.5	Class:	June
Shift	γ	91.015	Maximum	99.1		







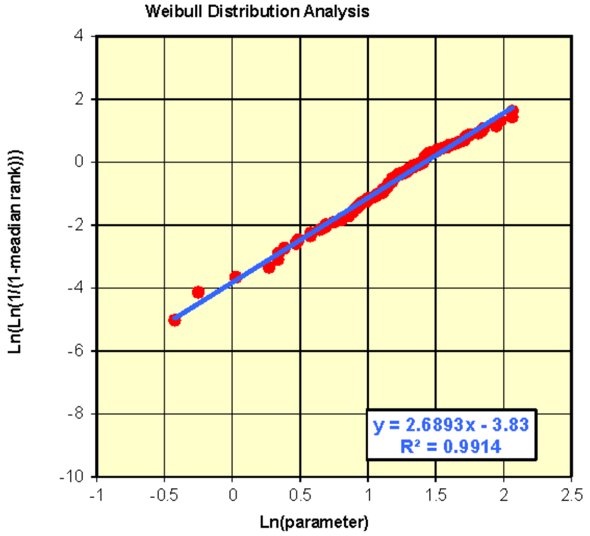
Results

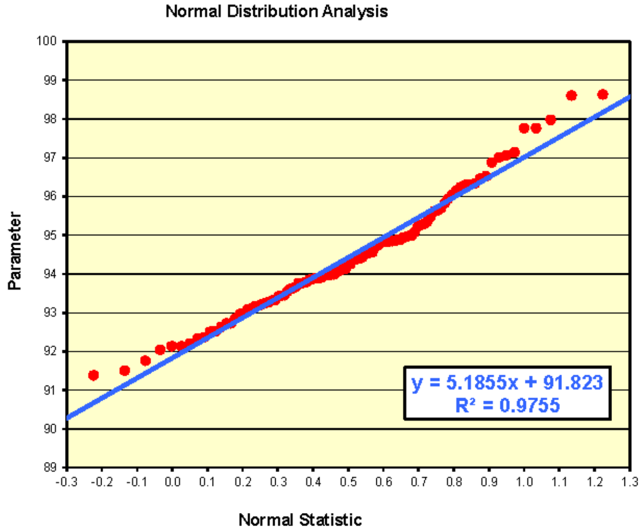
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.4	92.5	92.1	91.8	91.6	91.5
Normal	94.5	92.5	91.9	91.3	90.9	90.6

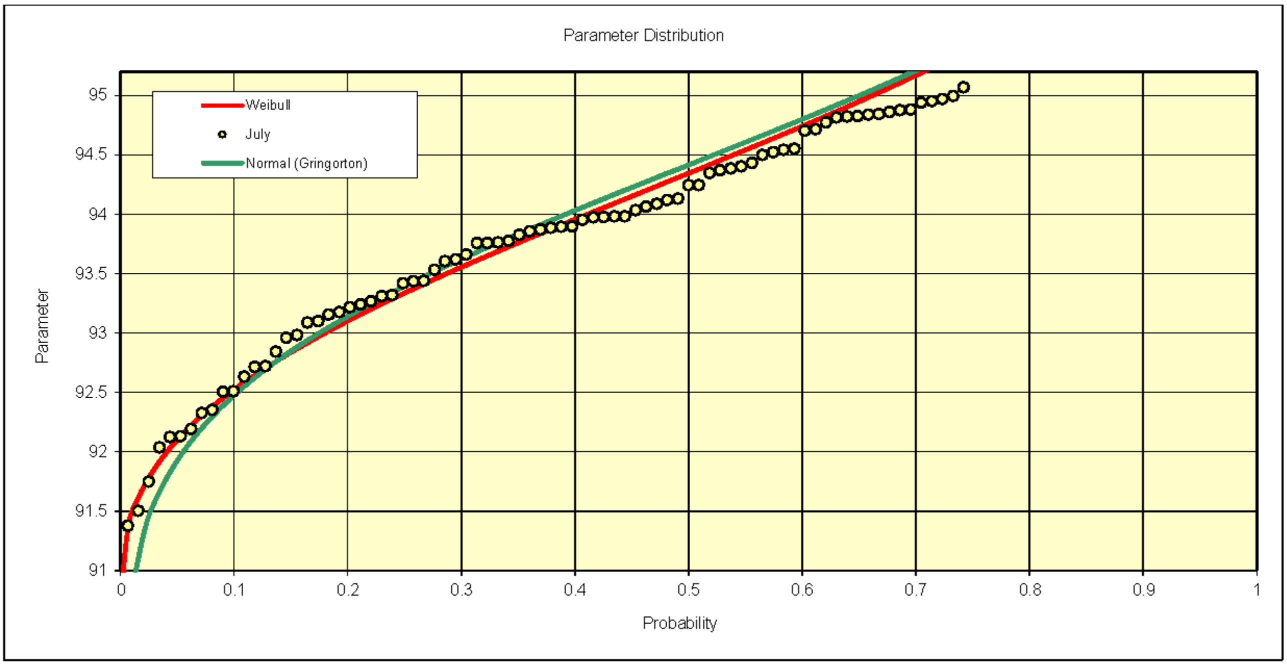
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	2.6938	Mean	94.4	Param:	**Minimum GWL**
Intercept		-3.834	Standard Deviation	1.5	Units:	**mAOD**
Characteristic	α	4.1513	Minimum	91.4	Class:	**July**
Shift	γ	90.722	Maximum	98.6		







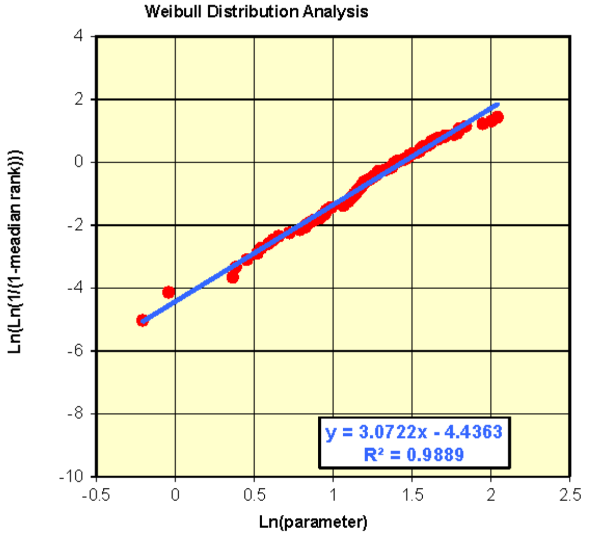
Results

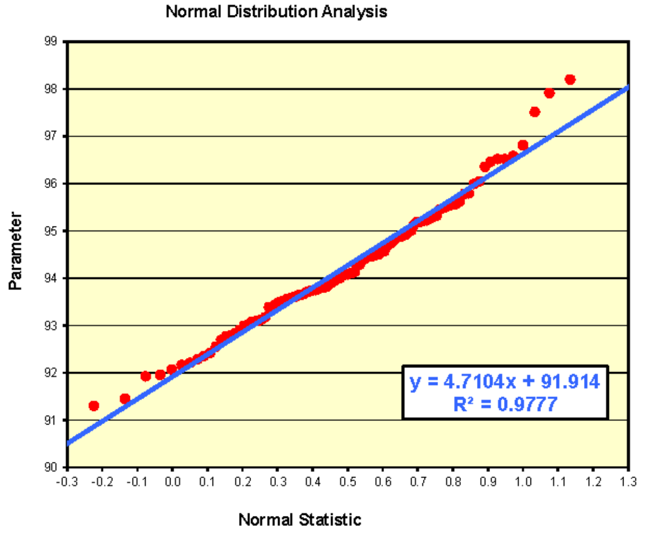
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.3	92.5	92.1	91.8	91.5	91.4
Normal	94.4	92.5	91.9	91.4	91.0	90.8

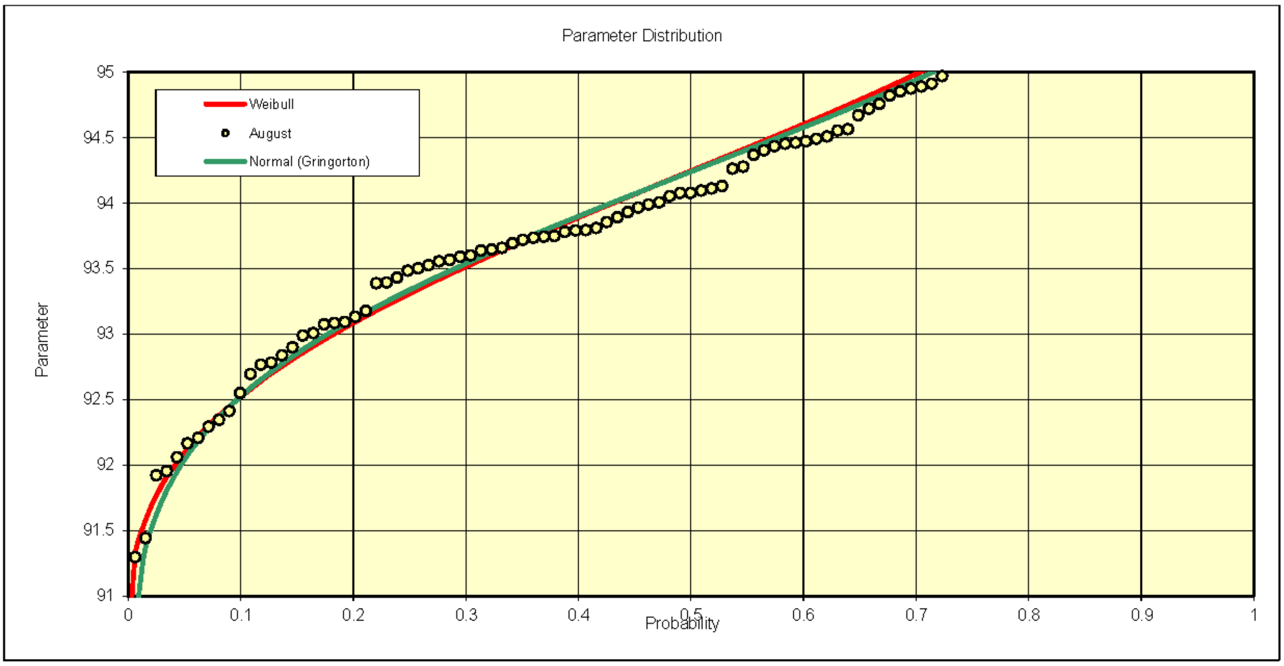
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	3.0722	Mean	94.2	Param:	**Minimum GWL**
Intercept		-4.436	Standard Deviation	1.3	Units:	**mAOD**
Characteristic	α	4.2376	Minimum	91.3	Class:	**August**
Shift	γ	90.482	Maximum	98.2		







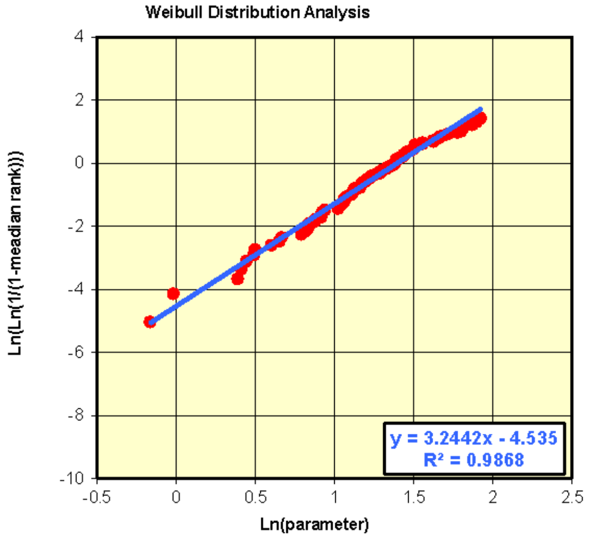
Results

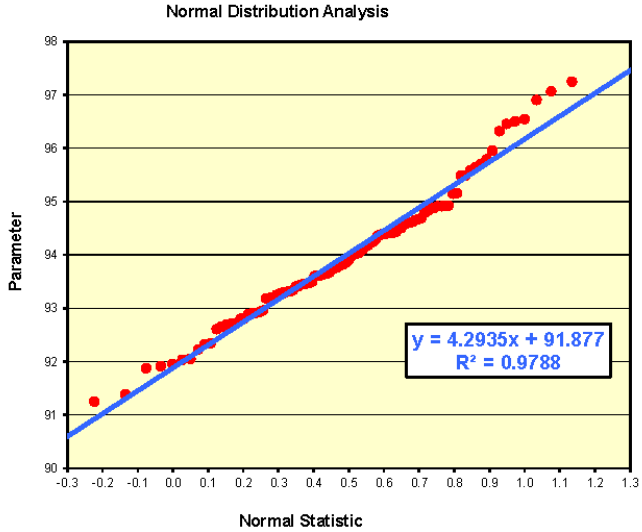
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.2	92.5	92.1	91.8	91.5	91.4
Normal	94.2	92.5	92.0	91.6	91.2	91.0

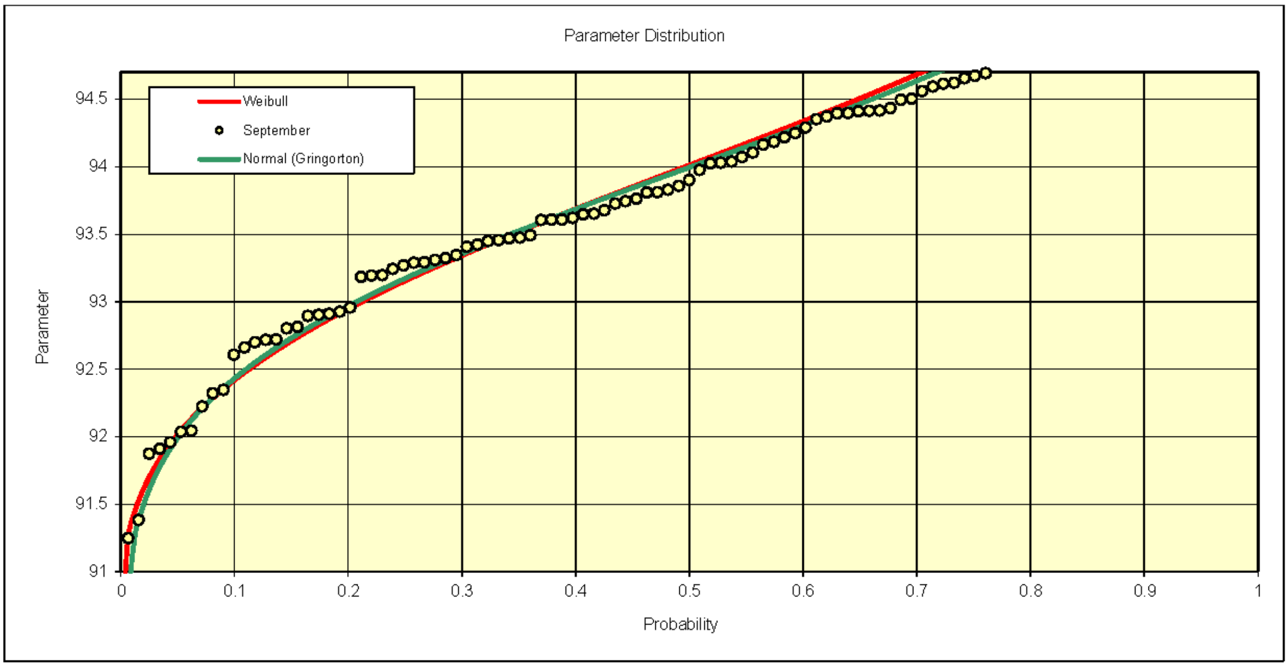
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			Normal Distribution Parameters			
Shape Parameter	β	3.2442	Mean	94.0	Param:	Minimum GWL
Intercept		-4.535	Standard Deviation	1.2	Units:	mAOD
Characteristic	α	4.0467	Minimum	91.2	Class:	September
Shift	γ	90.397	Maximum	97.3		







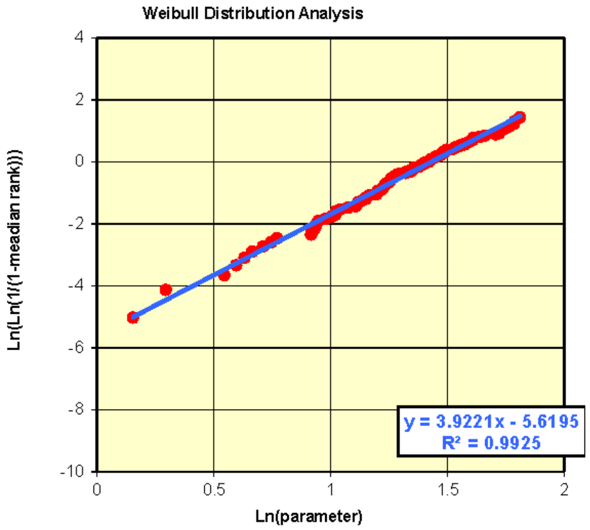
Results

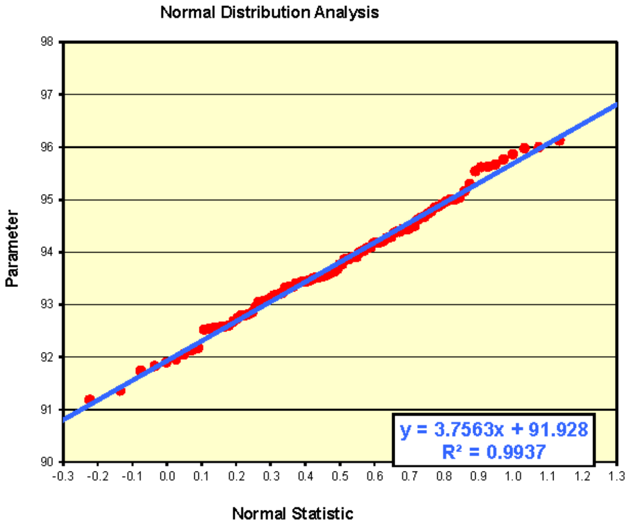
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	94.0	92.4	92.0	91.7	91.4	91.3
Normal	94.0	92.4	92.0	91.6	91.3	91.1

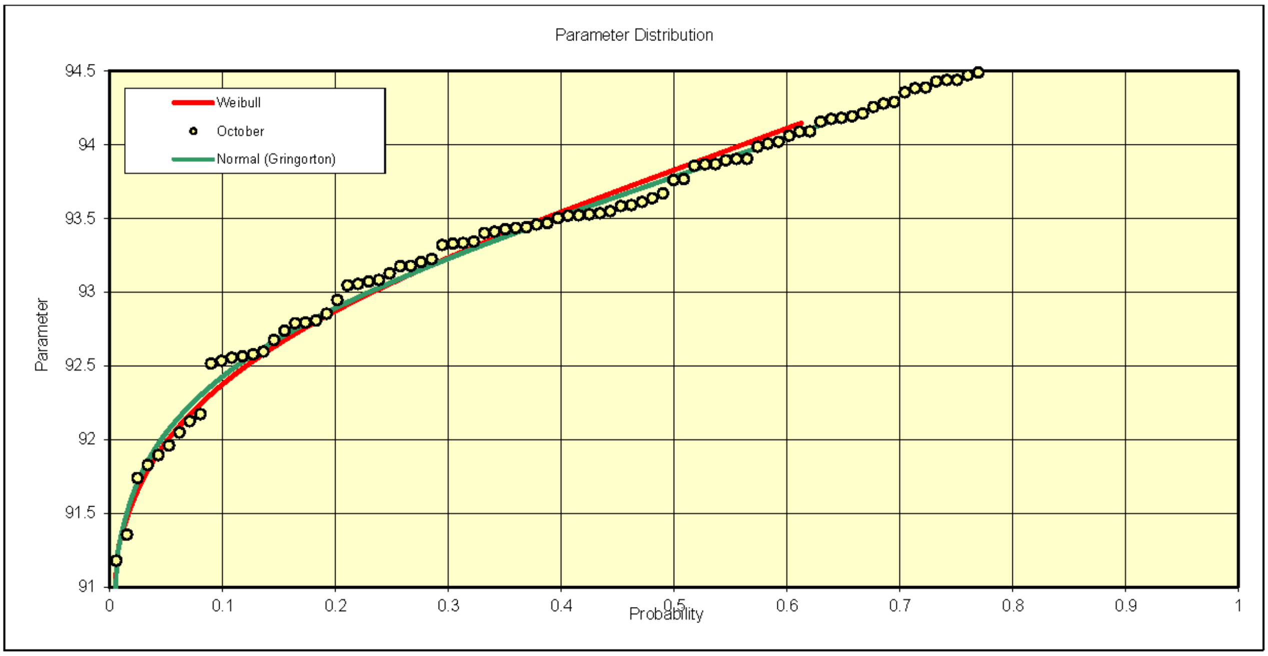
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	3.9221	Mean	93.8	Param:	**Minimum GWL**
Intercept		-5.619	Standard Deviation	1.1	Units:	**mAOD**
Characteristic	α	4.1903	Minimum	91.2	Class:	**October**
Shift	γ	90.011	Maximum	96.1		







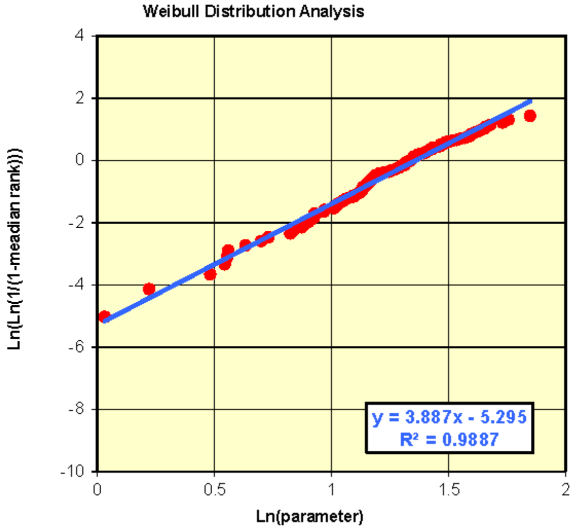
Results

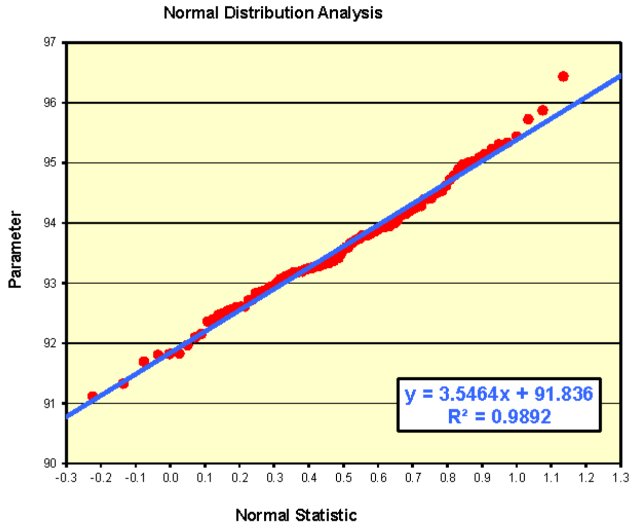
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.8	92.4	92.0	91.7	91.4	91.2
Normal	93.8	92.4	92.0	91.7	91.4	91.2

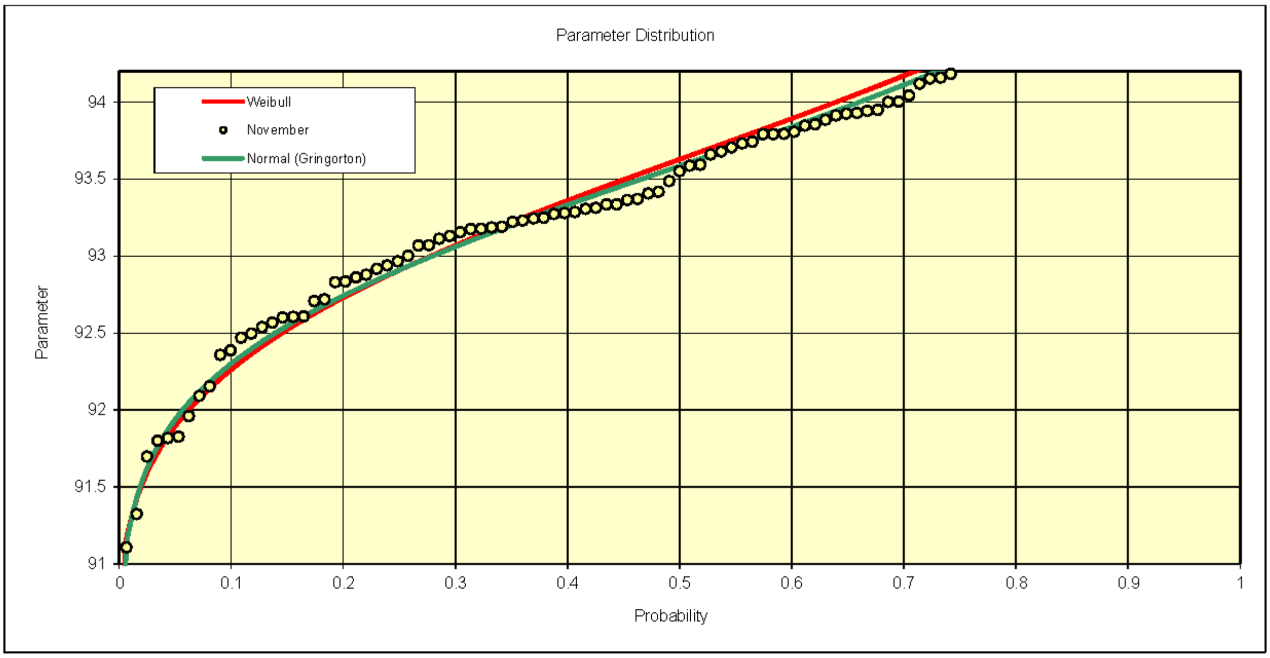
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	3.887	Mean	93.6	Param:	Minimum GWL
Intercept		-5.295	Standard Deviation	1.0	Units:	mAOD
Characteristic	α	3.905	Minimum	91.1	Class:	November
Shift	γ	90.074	Maximum	96.4		







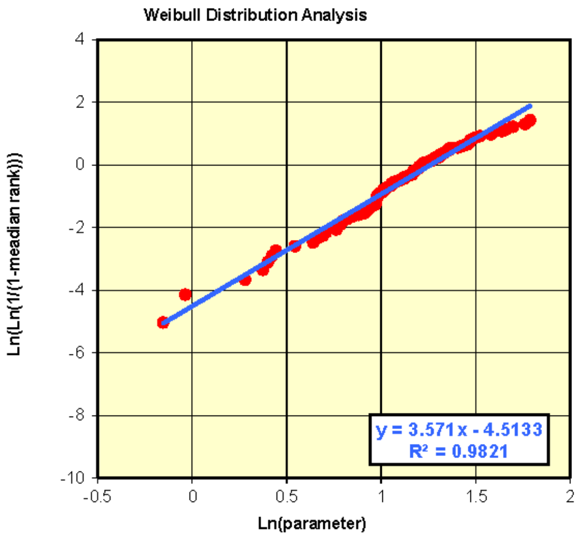
Results

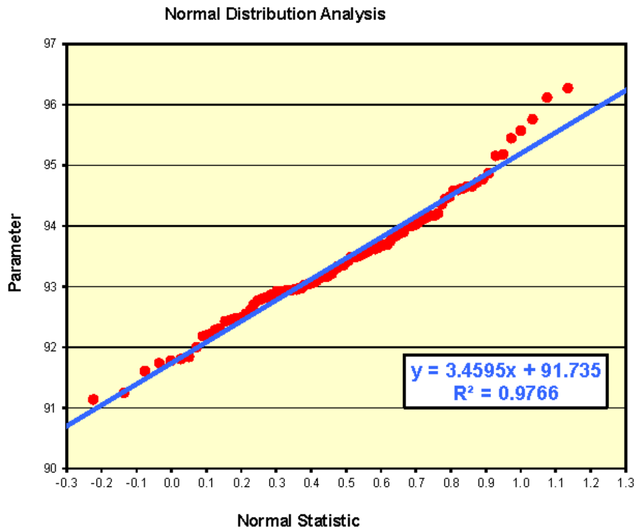
Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.6	92.3	91.9	91.6	91.3	91.2
Normal	93.6	92.3	91.9	91.6	91.3	91.2

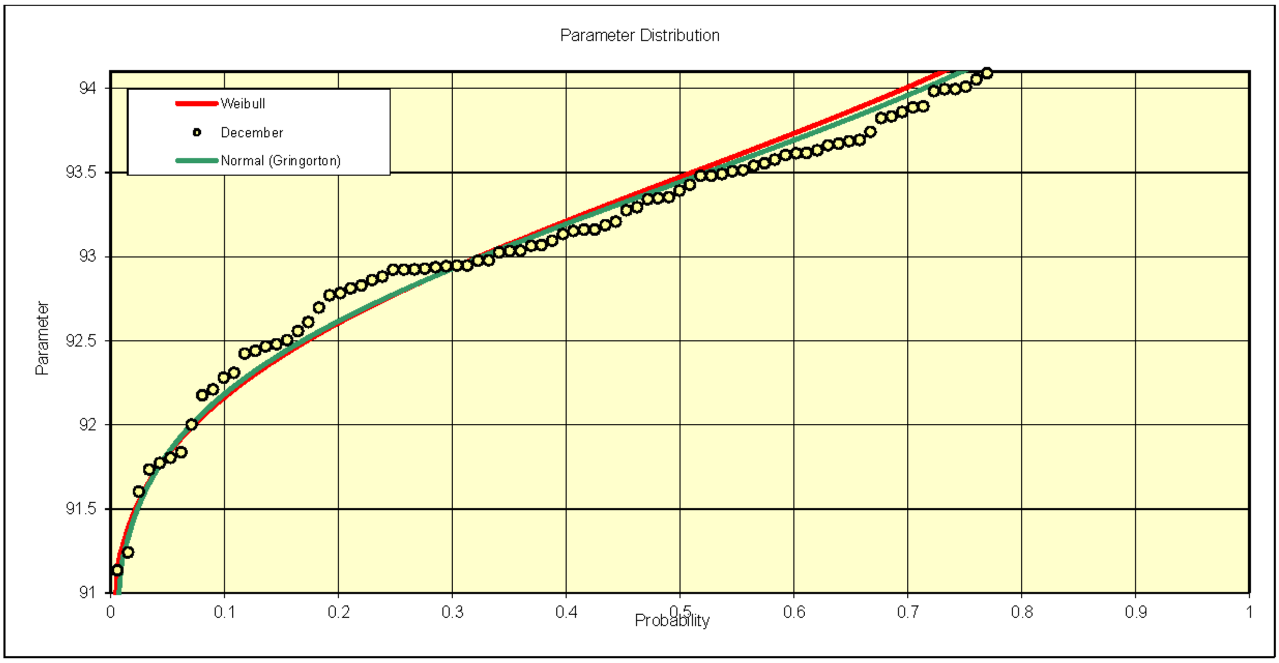
Frequency Analysis

Location: **Lilley Bottom (Modelled)**

Weibull Distribution Parameters			**Normal Distribution Parameters**			
Shape Parameter	β	3.571	Mean	93.4	Param:	Minimum GWL
Intercept		-4.513	Standard Deviation	1.0	Units:	mAOD
Characteristic	α	3.5392	Minimum	91.1	Class:	December
Shift	γ	90.277	Maximum	96.3		

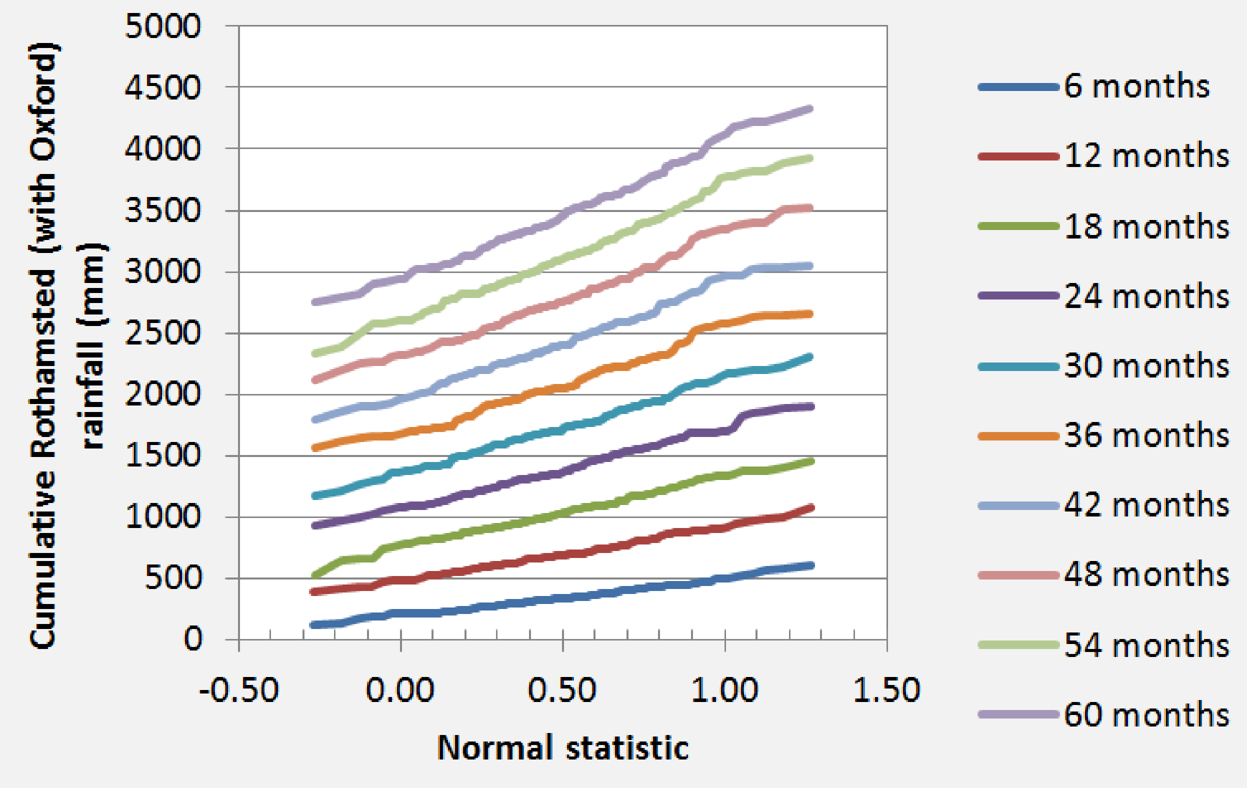


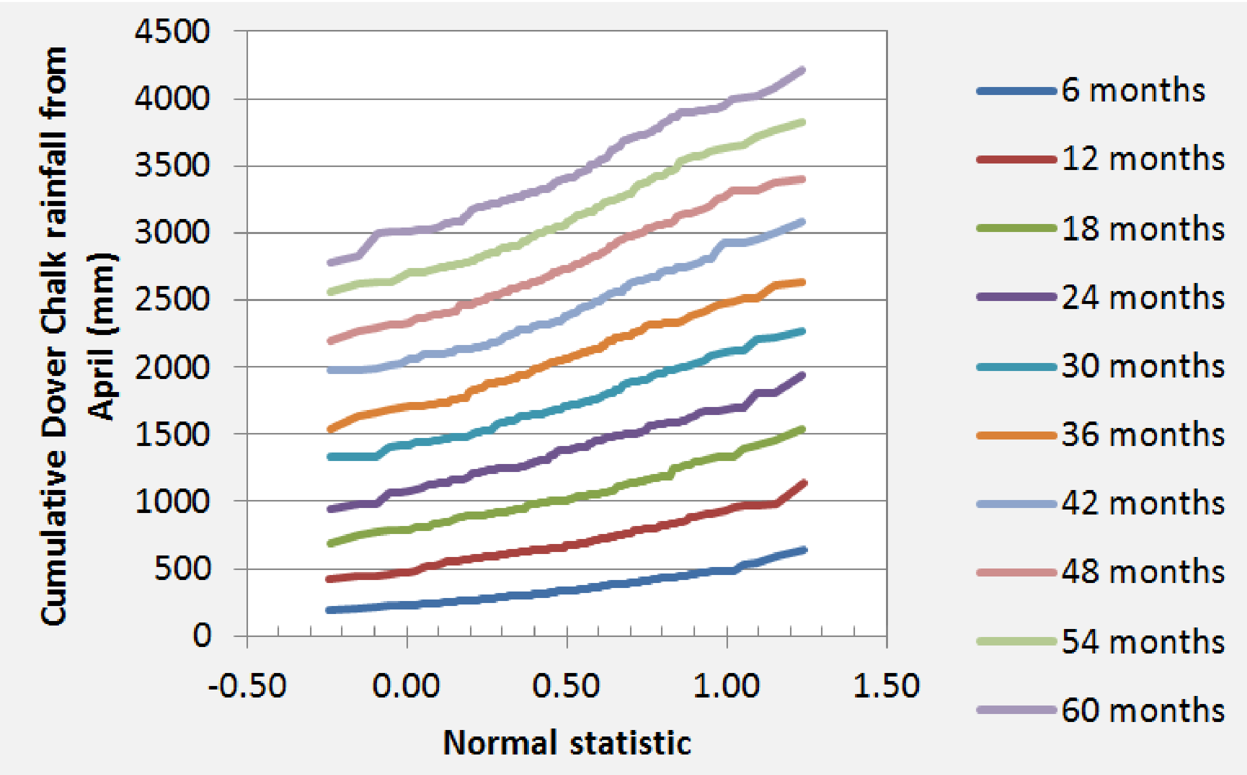




Results

Probability	0.5	0.1	0.05	0.025	0.0125	0.0083
Return Period (year)	2	10	20	40	80	120
Weibull	93.5	92.2	91.8	91.5	91.3	91.2
Normal	93.4	92.2	91.8	91.5	91.2	91.1


Cumulative Rothamsted (with Oxford) rainfall (mm)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-0.50
0.00
0.50
1.00
1.50
Normal statistic
6 months
12 months
18 months
24 months
30 months
36 months
42 months
48 months
54 months
60 months


Cumulative Dover Chalk rainfall from April (mm)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-0.50
0.00
0.50
1.00
1.50
Normal statistic
6 months
12 months
18 months
24 months
30 months
36 months
42 months
48 months
54 months
60 months

Appendix C.Synthetic Climate Data

C.1 Rothamsted (with Oxford)

C.1.1 Baseline Conditions

Rainfall and PET during Baseline Conditions

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	62.94	47.30	46.63	48.43	51.99	54.11	58.28	61.99	56.11	71.80	68.80	65.11
PET (mm)	17.91	19.85	27.91	40.73	56.84	73.13	83.24	81.25	68.49	49.37	30.21	20.57

C.1.2 Summer Profile

Rainfall during Drought Conditions in the Summer Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	60.05	44.02	42.30	42.65	44.77	45.83	49.61	53.71	48.89	66.02	64.47	61.83
20%	57.16	40.75	37.97	36.87	37.55	37.55	40.94	45.43	41.66	60.24	60.13	58.55
30%	54.27	37.47	33.63	31.10	30.32	29.27	32.27	37.14	34.44	54.46	55.80	55.28
40%	51.38	34.19	29.30	25.32	23.10	20.99	23.60	28.86	27.22	48.68	51.46	52.00
50%	48.49	30.92	24.96	19.54	15.87	12.71	14.93	20.58	19.99	42.90	47.13	48.72
60%	45.60	27.64	20.63	13.76	8.65	4.42	6.26	12.30	12.77	37.13	42.79	45.44
70%	42.71	24.36	16.29	7.98	1.43	0.00	0.00	4.02	5.54	31.35	38.46	42.17
80%	39.82	21.09	11.96	2.20	0.00	0.00	0.00	0.00	0.00	25.57	34.13	38.89

Evapotranspiration during Drought Conditions in the Summer Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	21.49	23.82	33.49	48.87	68.20	87.76	99.88	97.50	82.19	59.24	36.26	24.68

C.1.3 Winter Profile

Rainfall during Drought Conditions in the Winter Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	54.27	39.02	39.41	42.65	47.66	50.84	55.39	58.71	51.78	66.02	61.58	56.82
20%	45.60	30.74	32.19	36.87	43.32	47.56	52.50	55.44	47.44	60.24	54.35	48.54
30%	36.93	22.45	24.96	31.10	38.99	44.28	49.61	52.16	43.11	54.46	47.13	40.26
40%	28.27	14.17	17.74	25.32	34.66	41.01	46.72	48.88	38.77	48.68	39.90	31.98
50%	19.60	5.89	10.51	19.54	30.32	37.73	43.83	45.61	34.44	42.90	32.68	23.70
60%	10.93	0.00	3.29	13.76	25.99	34.45	40.94	42.33	30.11	37.13	25.46	15.42
70%	2.26	0.00	0.00	7.98	21.65	31.18	38.05	39.05	25.77	31.35	18.23	7.13
80%	0.00	0.00	0.00	2.20	17.32	27.90	35.16	35.78	21.44	25.57	11.01	0.00

Evapotranspiration during Drought Conditions in the Winter Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	17.91	19.85	27.91	40.73	56.84	73.13	83.24	81.25	68.49	49.37	30.21	20.57

C.1.4 April and October Profile

Rainfall during Drought Conditions in the April and October Profiles

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	57.16	41.52	40.85	42.65	46.21	48.33	52.50	56.21	50.33	66.02	63.02	59.33
20%	51.38	35.74	35.08	36.87	40.43	42.55	46.72	50.43	44.55	60.24	57.24	53.55
30%	45.60	29.96	29.30	31.10	34.66	36.78	40.94	44.65	38.77	54.46	51.46	47.77
40%	39.82	24.18	23.52	25.32	28.88	31.00	35.16	38.87	33.00	48.68	45.68	41.99
50%	34.04	18.40	17.74	19.54	23.10	25.22	29.38	33.09	27.22	42.90	39.90	36.21
60%	28.27	12.62	11.96	13.76	17.32	19.44	23.60	27.31	21.44	37.13	34.13	30.43
70%	22.49	6.85	6.18	7.98	11.54	13.66	17.82	21.53	15.66	31.35	28.35	24.65
80%	16.71	1.07	0.40	2.20	5.76	7.88	12.04	15.76	9.88	25.57	22.57	18.87

Evapotranspiration during Drought Conditions in the April and October Profiles

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	17.91	19.85	27.91	40.73	56.84	73.13	83.24	81.25	68.49	49.37	30.21	20.57

C.2 Dover

C.2.1 Baseline Conditions

Rainfall and PET during Baseline Conditions

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	60.50	46.43	45.60	43.69	44.09	45.84	52.84	56.44	60.16	84.21	80.08	69.77
PET (mm)	14.02	20.92	34.54	47.15	68.67	71.82	79.16	72.85	51.98	37.21	19.40	13.85

C.2.2 Summer Profile

Rainfall during Drought Conditions in the Summer Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	57.63	43.17	41.29	37.95	36.91	37.60	44.22	48.20	52.97	78.47	75.77	66.52
20%	54.75	39.91	36.98	32.20	29.72	29.36	35.60	39.96	45.79	72.72	71.46	63.26
30%	51.88	36.66	32.67	26.45	22.54	21.13	26.98	31.73	38.60	66.97	67.15	60.00
40%	49.01	33.40	28.35	20.71	15.36	12.89	18.36	23.49	31.42	61.22	62.84	56.74
50%	46.13	30.14	24.04	14.96	8.17	4.66	9.74	15.26	24.24	55.48	58.53	53.48
60%	43.26	26.88	19.73	9.21	0.99	0	1.12	7.02	17.05	49.73	54.22	50.22
70%	40.38	23.62	15.42	3.46	0	0	0	0	9.87	43.98	49.91	46.96
80%	37.51	20.36	11.11	0	0	0	0	0	2.69	38.24	45.60	43.71

Evapotranspiration during Drought Conditions in the Summer Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	16.82	25.10	41.45	56.58	82.40	86.19	94.99	87.42	62.38	44.65	23.28	16.62

C.2.3 Winter Profile

Rainfall during Drought Conditions in the Winter Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	51.88	38.20	38.41	37.95	39.78	42.58	49.97	53.18	55.85	78.47	72.90	61.54
20%	43.26	29.96	31.23	32.20	35.47	39.32	47.09	49.92	51.54	72.72	65.71	53.30
30%	34.64	21.72	24.04	26.45	31.16	36.06	44.22	46.66	47.22	66.97	58.53	45.07
40%	26.02	13.49	16.86	20.71	26.85	32.80	41.35	43.40	42.91	61.22	51.35	36.83
50%	17.40	5.25	9.68	14.96	22.54	29.54	38.47	40.14	38.60	55.48	44.16	28.60
60%	8.78	0	2.49	9.21	18.23	26.28	35.60	36.89	34.29	49.73	36.98	20.36
70%	0.16	0	0	3.46	13.92	23.03	32.73	33.63	29.98	43.98	29.79	12.12
80%	0	0	0	0	9.61	19.77	29.85	30.37	25.67	38.24	22.61	3.89

Evapotranspiration during Drought Conditions in the Winter Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	14.02	20.92	34.54	47.15	68.67	71.82	79.16	72.85	51.98	37.21	19.40	13.85

C.2.4 April and October Profile

Rainfall during Drought Conditions in the April and October Profiles

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	54.75	40.68	39.85	37.95	38.34	40.09	47.09	50.69	54.41	78.47	74.33	64.03
20%	49.01	34.94	34.10	32.20	32.60	34.34	41.35	44.94	48.66	72.72	68.59	58.28
30%	43.26	29.19	28.35	26.45	26.85	28.59	35.60	39.19	42.91	66.97	62.84	52.53
40%	37.51	23.44	22.61	20.71	21.10	22.85	29.85	33.45	37.17	61.22	57.09	46.79
50%	31.76	17.70	16.86	14.96	15.36	17.10	24.11	27.70	31.42	55.48	51.35	41.04
60%	26.02	11.95	11.11	9.21	9.61	11.35	18.36	21.95	25.67	49.73	45.60	35.29
70%	20.27	6.20	5.37	3.46	3.86	5.61	12.61	16.21	19.93	43.98	39.85	29.54
80%	14.52	0.45	0.00	0.00	0.00	0.00	6.86	10.46	14.18	38.24	34.10	23.80

Evapotranspiration during Drought Conditions in the April and October Profiles

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	14.02	20.92	34.54	47.15	68.67	71.82	79.16	72.85	51.98	37.21	19.40	13.85

Appendix D. ADO and PDO Values

WRZ1 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
CHES	5.22	5.22	5.02	4.77	4.52	4.27	6.00	6.00	5.50	5.23	4.95	4.68
HUGH	-	-	-	-	-	-	-		-	-	-	-
HUNT	-	-	-	-	-	-	-	-	-	-	-	-
BATC	16.00	16.00	16.00	16.00	16.00	16.00	19.00	19.00	19.00	16.00	16.00	16.00
CHOR	8.20	8.20	8.20	7.79	7.38	6.97	9.09	9.09	9.09	8.64	8.18	7.73
MILE	13.30	12.30	10.30	9.79	9.27	8.76	13.30	12.30	10.30	9.79	9.27	8.76
NORO	14.50	14.50	14.50	14.50	14.50	14.50	17.00	17.00	17.00	14.50	14.50	14.50
SPRW	4.50	4.50	4.50	4.50	4.50	4.50	16.00	16.00	16.00	10.00	10.00	10.00
STOC	-	-	-	-	-	-	-	-	-	-	-	-
WESY	15.50	15.50	15.50	15.50	15.50	15.50	20.46	20.46	20.46	15.50	15.50	15.50
BERK	4.63	4.63	4.63	4.40	4.17	3.94	6.00	6.00	6.00	5.70	5.40	5.10
CHAR	1.78	1.78	1.48	1.41	1.33	1.26	1.78	1.78	1.48	1.41	1.33	1.26
HUNT	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
LITT	0.37	0.32	0.27	0.26	0.24	0.23	0.40	0.35	0.30	0.29	0.27	0.26
MARL	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34
PICC	5.72	5.72	5.72	5.43	5.15	4.86	10.72	10.72	10.72	10.18	9.65	9.11
AMER	4.00	4.00	4.00	4.00	4.00	4.00	9.00	9.00	9.00	8.55	8.10	7.65
CHAL	4.00	4.00	4.00	3.80	3.60	3.40	4.50	4.50	4.50	4.28	4.05	3.83
GREM	1.00	1.00	1.00	0.95	0.90	0.85	5.68	5.68	5.68	5.40	5.11	4.83
GERR	6.33	6.33	4.83	4.59	4.35	4.11	6.33	6.33	4.83	4.59	4.35	4.11
BULS	3.30	3.30	3.30	3.14	2.97	2.81	3.41	3.41	3.41	3.24	3.07	2.90

WRZ2 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
SHEN	0.84	0.64	0.44	0.40	0.35	0.26	1.47	1.02	0.77	0.69	0.62	0.46
BERR	11.52	11.52	11.02	10.47	9.92	9.37	15.00	15.00	13.00	12.35	11.70	11.05
BRIC	14.00	14.00	14.00	13.30	12.60	11.90	15.00	15.00	15.00	14.25	13.50	12.75
BUSY	9.00	9.00	8.00	7.60	7.20	6.80	9.00	9.00	8.00	7.60	7.20	6.80
BUSA	4.00	3.00	2.00	1.90	1.80	1.70	4.00	3.00	2.00	1.90	1.80	1.70
EAST	29.00	29.00	29.00	27.55	26.10	24.65	35.00	35.00	35.00	33.25	31.50	29.75
NETH	28.00	28.00	25.00	23.75	22.50	21.25	30.00	30.00	25.00	23.75	22.50	21.25
NORT	-	-	-	-	-	-	-	-	-	-	-	-
POOR	-	-	-	-	-	-	-	-	-	-	-	-
RUIS	-	-	-	-	-	-	-	-	-	-	-	-
TOLP	8.00	7.50	6.50	6.18	5.85	5.53	8.00	7.50	6.50	6.18	5.85	5.53
WALL	15.00	14.00	13.00	12.35	11.70	11.05	15.00	14.00	13.00	12.35	11.70	11.05
EASH	2.18	2.18	2.18	2.18	2.18	2.18	6.55	6.55	6.55	6.55	6.55	6.55
WHEA	7.50	7.50	7.50	7.50	7.50	7.50	9.00	9.00	9.00	7.50	7.50	7.50
BOWB	-	-	-	-	-	-	-	-	-	-	-	-
FRIA	2.21	2.21	2.21	2.21	2.21	2.21	12.00	12.00	12.00	11.40	10.80	10.20
HOLY	8.20	8.20	8.20	7.79	7.38	6.97	9.09	9.09	9.09	8.64	8.18	7.73
MUDL	10.03	10.03	10.03	9.53	9.03	8.53	11.37	11.37	11.37	10.80	10.23	9.66
REDB	1.37	1.37	1.32	1.25	1.19	1.12	1.75	1.75	1.55	1.47	1.40	1.32
SHAK	1.14	1.14	1.14	1.08	1.03	0.97	1.92	1.92	1.92	1.82	1.73	1.63
STON	2.05	2.00	1.90	1.81	1.71	1.62	3.00	2.50	2.00	1.90	1.80	1.70
THEG	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50	20.50
WATF	-	-	-	-	-	-	-	-	-	-	-	-

WRZ3 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
AST1	1.60	1.60	1.60	1.44	1.28	0.96	1.60	1.60	1.60	1.44	1.28	0.96
STEV	2.00	2.00	2.00	1.80	1.60	1.20	2.50	2.50	2.50	2.25	2.00	1.50
CHIP	2.60	2.60	2.60	2.34	2.08	1.56	2.60	2.60	2.60	2.34	2.08	1.56
CODI	0.65	0.55	0.40	0.38	0.36	0.34	0.65	0.55	0.40	0.38	0.36	0.34
EAGL	1.00	1.00	1.00	0.90	0.80	0.60	1.00	1.00	1.00	0.90	0.80	0.60
HARS	1.36	1.36	1.36	1.29	1.22	1.16	1.36	1.36	1.36	1.29	1.22	1.16
KINW	1.25	1.25	1.25	1.19	1.13	1.06	1.25	1.25	1.25	1.19	1.13	1.06
LOND	1.10	1.00	0.90	0.81	0.72	0.54	1.10	1.00	0.90	0.81	0.72	0.54
MOLE	1.82	1.82	1.32	1.25	1.19	1.12	1.82	1.82	1.32	1.25	1.19	1.12
MUSH	4.32	4.32	4.22	4.01	3.80	3.59	4.99	4.99	4.89	4.65	4.40	4.16
NORM	7.40	6.90	6.40	5.76	5.12	3.84	7.40	6.90	6.40	5.76	5.12	3.84
OFFS	-	-	-	-	-	-	-	-	-	-	-	-
OUGH	4.10	4.00	3.90	3.71	3.51	3.32	5.22	5.00	4.80	4.56	4.32	4.08
PERI	4.19	4.19	3.99	3.79	3.59	3.39	4.19	4.19	3.99	3.79	3.59	3.39
PORT	1.84	1.64	1.44	1.30	1.15	0.86	1.84	1.64	1.44	1.30	1.15	0.86
RUNL C	6.30	6.20	6.00	5.40	4.80	3.60	6.30	6.20	6.00	5.40	4.80	3.60
RUNL G	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71	2.71
SCHO	-	-	-	-	-	-	-	-	-	-	-	-
SLIP	-	-	-	-	-	-	-	-	-	-	-	-
TEMP	4.49	4.49	4.49	4.27	4.04	3.82	4.49	4.49	4.49	4.27	4.04	3.82
THEH	3.41	3.41	3.41	3.24	3.07	2.90	3.80	3.80	3.80	3.61	3.42	3.23
WADE	5.50	5.50	5.50	5.23	4.95	4.68	5.50	5.50	5.50	5.23	4.95	4.68
WATE	1.09	1.09	1.09	1.04	0.98	0.93	1.20	1.20	1.20	1.14	1.08	1.02

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
WELL	1.15	1.15	1.15	1.04	0.92	0.69	1.15	1.15	1.15	1.04	0.92	0.69
WYMO	1.14	1.14	1.14	1.08	1.03	0.97	1.53	1.53	1.53	1.45	1.38	1.30
CRES group	28.49	28.49	28.49	27.07	25.64	24.22	29.05	29.05	29.05	27.60	26.15	24.69
ALBE												
DIGS	7.88	7.88	7.38	7.01	6.64	6.27	7.88	7.88	7.38	7.01	6.64	6.27
FULL	-	-	-	-	-	-	-	-	-	-	-	-
ROES	7.52	7.52	7.02	6.32	5.62	4.21	7.52	7.52	7.02	6.32	5.62	4.21
TYTT	8.53	8.53	8.03	7.23	6.42	4.82	8.53	8.53	8.03	7.23	6.42	4.82
HATF	-	-	-	-	-	-	-	-	-	-	-	-
NOMA	7.50	7.50	7.50	7.13	6.75	6.38	7.50	7.50	7.50	7.13	6.75	6.38
ESSE	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
KENS	6.82	6.82	6.82	6.48	6.14	5.80	7.45	7.45	7.45	7.08	6.71	6.33
WATT	2.40	2.40	2.40	2.28	2.16	2.04	2.40	2.40	2.40	2.28	2.16	2.04
WHIH	2.00	2.00	2.00	2.00	2.00	2.00	10.00	10.00	10.00	9.50	9.00	8.50
BALD	1.00	0.90	0.80	0.72	0.64	0.48	3.40	3.10	2.80	2.52	2.24	1.68
BOWR	4.50	4.30	4.10	3.69	3.28	2.46	4.50	4.30	4.10	3.69	3.28	2.46
FULR	4.50	4.30	4.10	3.69	3.28	2.46	4.50	4.30	4.10	3.69	3.28	2.46

WRZ4 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
IVER	225.00	225.00	225.00	225.00	225.00	225.00	225.00	225.00	225.00	225.00	225.00	225.00
BLAF	16.00	16.00	16.00	16.00	16.00	16.00	20.00	20.00	20.00	20.00	20.00	20.00
ICKE	-	-	-	-	-	-	-	-	-	-	-	-

WRZ5 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
HADH	1.20	1.10	1.00	0.90	0.80	0.60	1.20	1.10	1.00	0.90	0.80	0.60
THUN	9.09	9.09	9.09	8.64	8.18	7.73	9.09	9.09	9.09	8.64	8.18	7.73
NORS	6.70	6.50	6.40	6.08	5.76	5.44	6.70	6.50	6.40	6.08	5.76	5.44
STAN Nr 2	0.28	0.28	0.28	0.25	0.22	0.17	2.16	2.16	2.16	1.94	1.73	1.30
CAUS	4.55	4.55	3.55	3.37	3.20	3.02	4.55	4.55	3.55	3.37	3.20	3.02
SPRF	-	-	-	-	-	-	-	-	-	-	-	-
UTTL	6.00	6.00	6.00	5.70	5.40	5.10	6.00	6.00	6.00	5.70	5.40	5.10

WRZ6 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
CHER Groundwater	26.00	24.00	21.00	18.90	16.80	12.60	35.00	30.00	22.00	19.80	17.60	13.20
CLAN	0.20	0.10	-	-	-	-	0.20	0.10	-	-	-	-
EGHA Surface Water	120.06	120.06	120.06	120.06	120.06	120.06	142.00	142.00	142.00	142.00	142.00	142.00
CHER Surface Water	25.36	25.36	25.36	25.36	25.36	25.36	40.00	40.00	40.00	40.00	40.00	40.00
WALT Surface Water	30.08	30.08	30.08	30.08	30.08	30.08	45.00	45.00	45.00	45.00	45.00	45.00

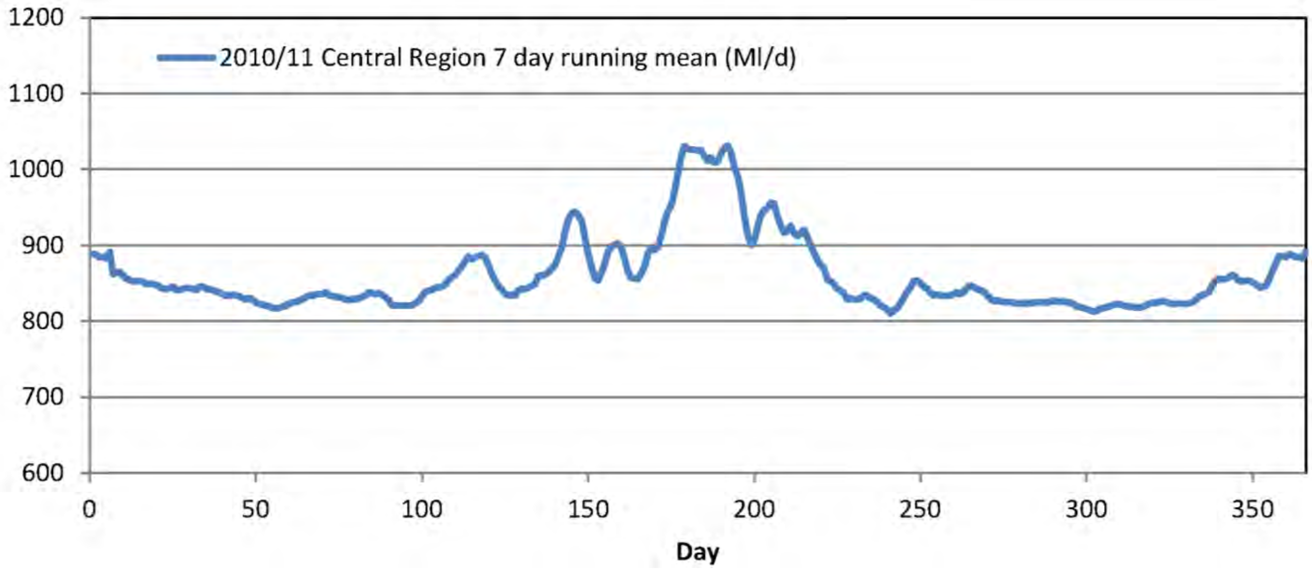
WRZ7 ADO and PDO at given groundwater level return periods

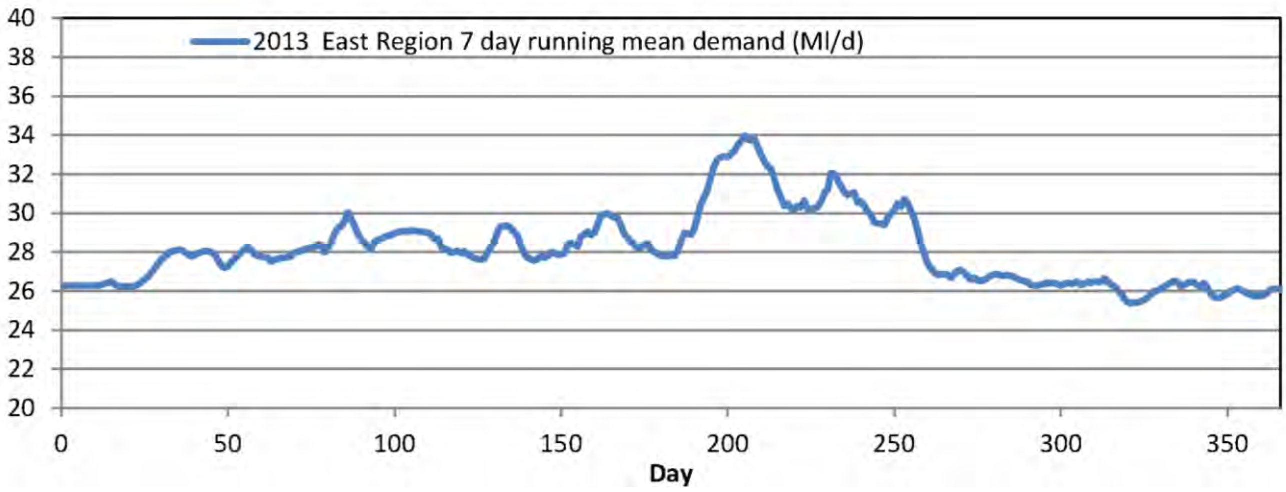
Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
BROM	2.28	2.28	2.28	2.17	2.05	1.94	2.69	2.69	2.69	2.56	2.42	2.29
CONN	4.10	4.00	3.50	3.33	3.15	2.98	7.00	5.00	3.50	3.33	3.15	2.98
STMG	5.21	5.21	4.21	4.00	3.79	3.58	4.38	4.38	3.38	3.21	3.04	2.87
LIGH	1.50	1.50	1.50	1.43	1.35	1.28	1.50	1.50	1.50	1.43	1.35	1.28
KING	3.17	3.17	3.17	3.01	2.85	2.69	3.70	3.70	3.70	3.52	3.33	3.15
PRIM	3.00	3.00	3.00	2.85	2.70	2.55	3.12	3.12	3.12	2.96	2.81	2.65
HOLM	1.30	1.30	1.30	1.24	1.17	1.11	1.18	1.18	1.18	1.12	1.06	1.00
DOVP	2.40	2.20	2.00	1.80	1.60	1.20	2.40	2.20	2.00	1.80	1.60	1.20
BUCM	4.00	4.00	4.00	3.80	3.60	3.40	4.00	4.00	4.00	3.80	3.60	3.40
COWL	3.48	3.48	3.48	3.31	3.13	2.96	3.48	3.48	3.48	3.31	3.13	2.96
DENG	4.65	4.40	3.90	3.51	3.12	2.34	5.58	5.23	4.73	4.26	3.78	2.84
OTTI	0.85	0.75	0.65	0.59	0.52	0.39	2.82	2.50	1.50	1.35	1.20	0.90
SKEE	0.15	0.10	-	-	-	-	0.23	0.20	-	-	-	-
WORL	1.50	1.30	0.80	0.72	0.64	0.48	2.64	2.14	1.64	1.48	1.31	0.98
LYEO	3.36	3.36	3.36	3.19	3.02	2.86	3.36	3.36	3.36	3.19	3.02	2.86
DREL	2.26	2.16	1.96	1.76	1.57	1.18	3.55	3.05	2.05	1.85	1.64	1.23
LOWS	-	-	-	-	-	-	-	-	-	-	-	-
DENTON	1.89	1.89	1.89	1.80	1.70	1.61	2.10	2.10	2.10	2.00	1.89	1.79
TAPN	4.80	4.60	4.10	3.90	3.69	3.49	4.80	4.60	4.10	3.90	3.69	3.49
RAKN	2.40	2.40	2.40	2.28	2.16	2.04	2.40	2.40	2.40	2.28	2.16	2.04

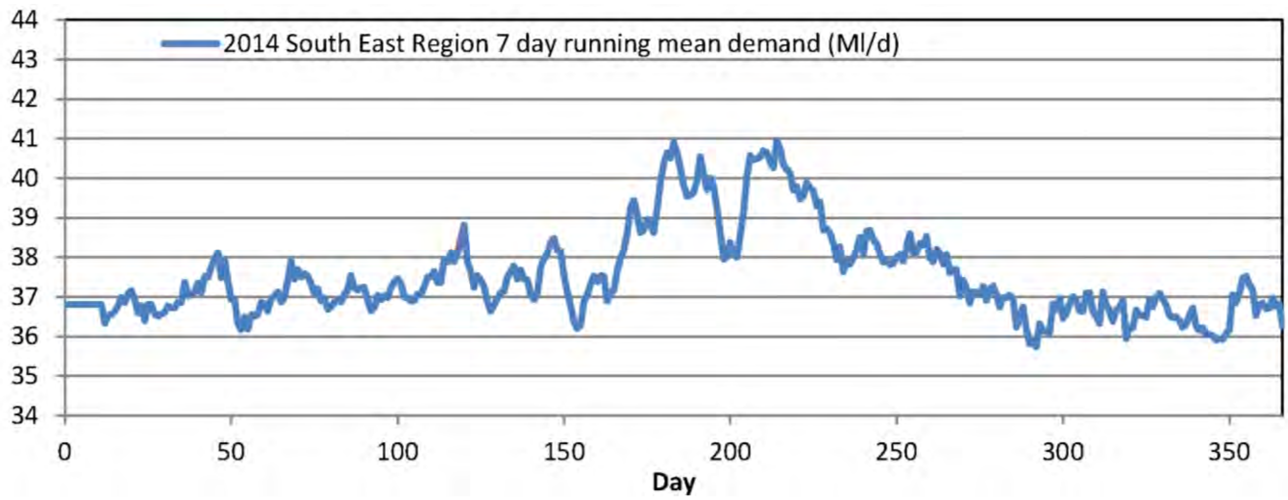
WRZ8 ADO and PDO at given groundwater level return periods

Source Name	ADO / Return Period						PDO/ Return Period					
	10	20	50	100	200	500	10	20	50	100	200	500
ESTB	2.00	2.00	2.00	1.90	1.80	1.70	2.00	2.00	2.00	2.85	2.70	2.55
ARDL	8.10	8.10	8.10	8.10	8.10	8.10	10.80	10.80	10.80	10.80	10.80	10.80
DEDH	6.29	6.29	6.29	5.98	5.66	5.35	8.19	8.19	8.19	7.78	7.37	6.96
STRD	4.39	4.39	4.39	4.17	3.95	3.73	6.19	6.19	6.19	5.88	5.57	5.26
HIGM	5.09	5.09	5.09	4.84	4.58	4.33	7.29	7.29	7.29	6.93	6.56	6.20
STOK	8.09	8.09	8.09	7.69	7.28	6.88	11.69	11.69	11.69	11.11	10.52	9.94
LAWF	-	-	-	-	-	-	-	-	-	-	-	-
SHEL	3.09	3.09	3.09	2.94	2.78	2.63	3.59	3.59	3.59	3.41	3.23	3.05
LATT	1.50	1.50	1.50	1.43	1.35	1.28	2.00	2.00	2.00	1.90	1.80	1.70

Appendix E.Demand profiles

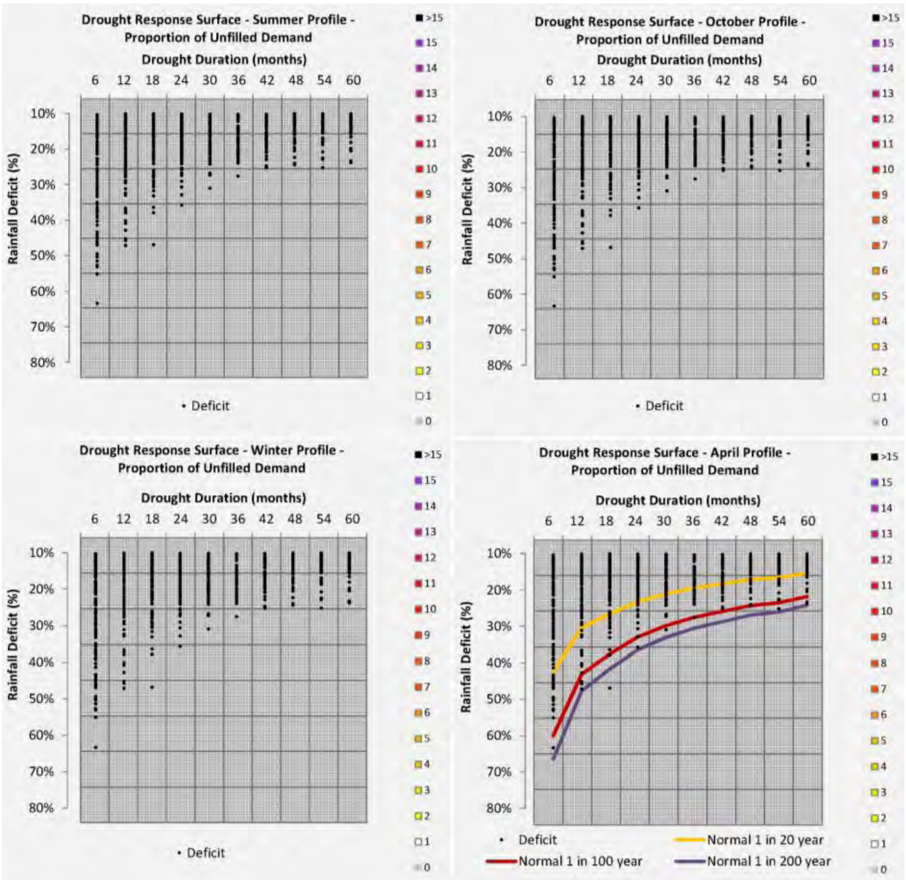




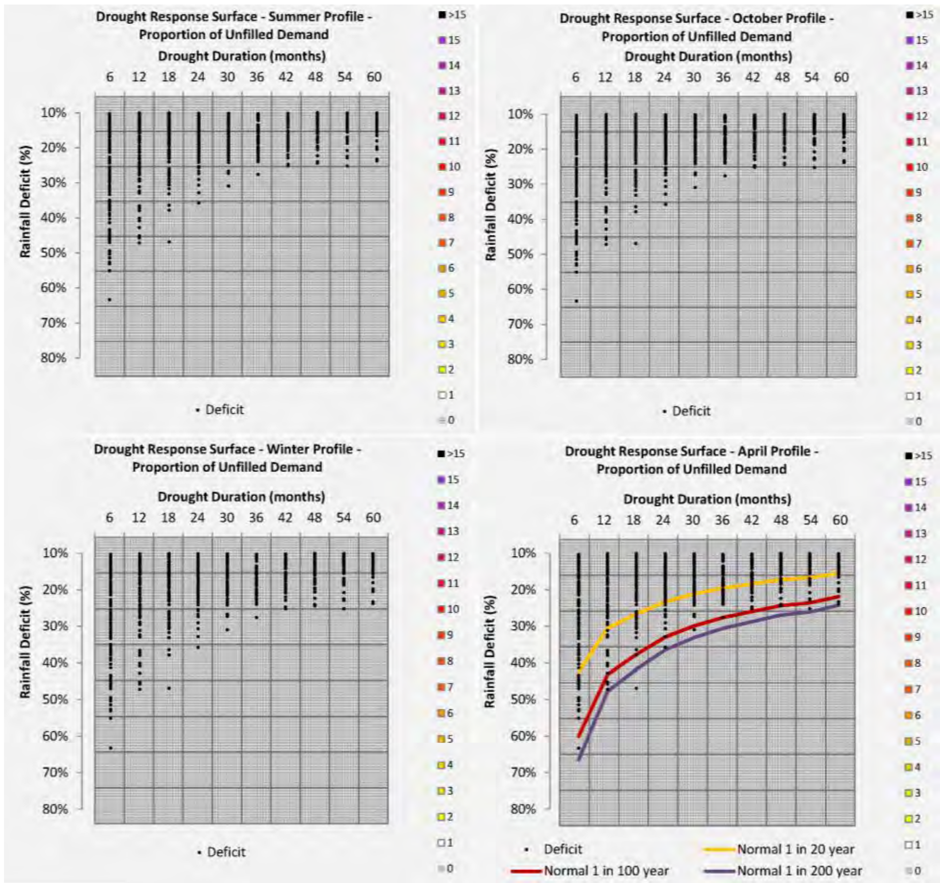


Appendix F.Initial WRZ Model Results (No transfers or drought management actions)

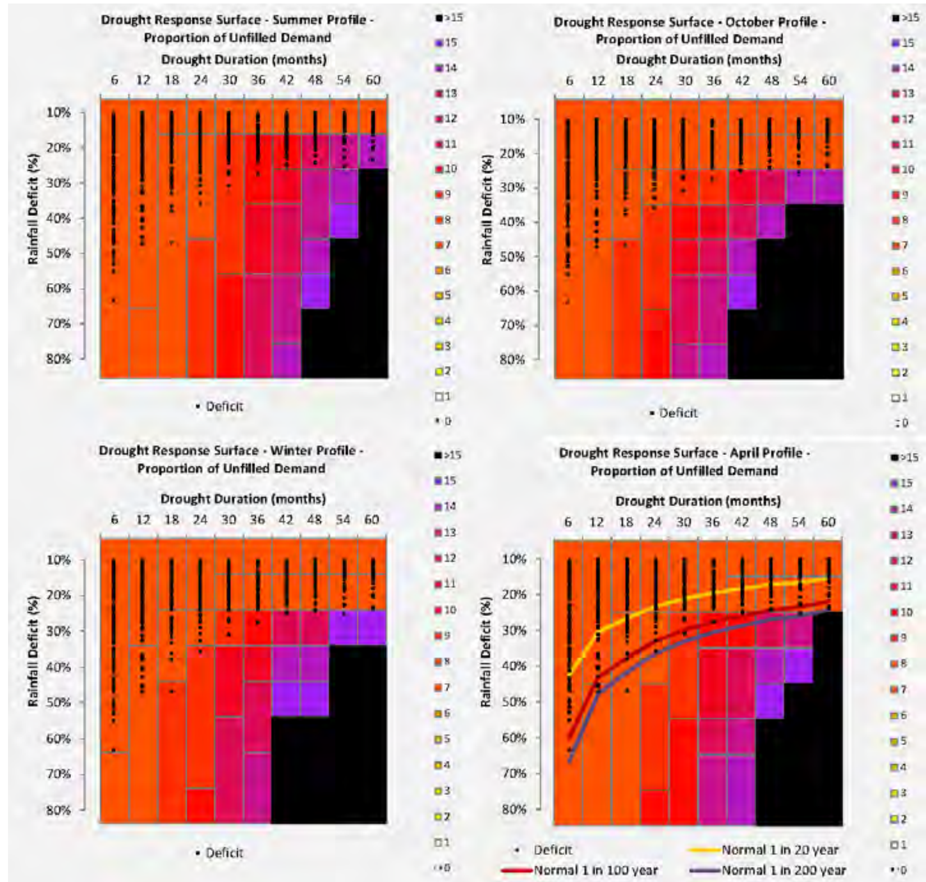
This appendix presents the results of the WRZ models run with no transfers between WRZs or imports from neighbouring water companies. The models had no drought management actions enabled.



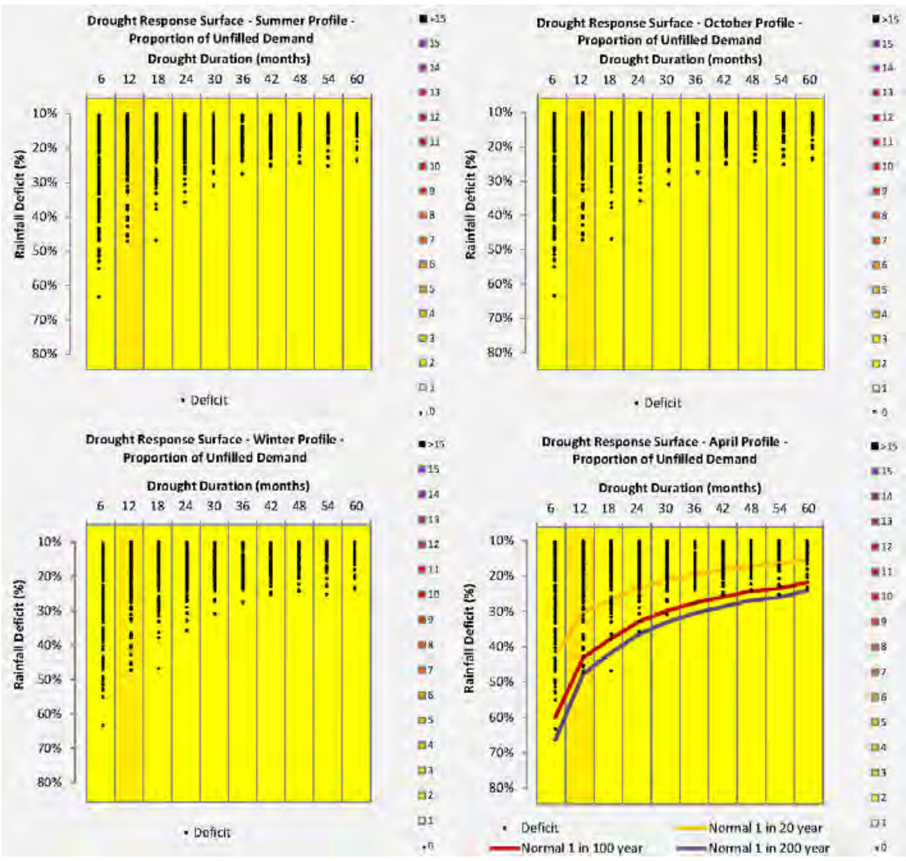
WRZ1 (Misbourne) unfulfilled demand (without transfers or drought management actions)



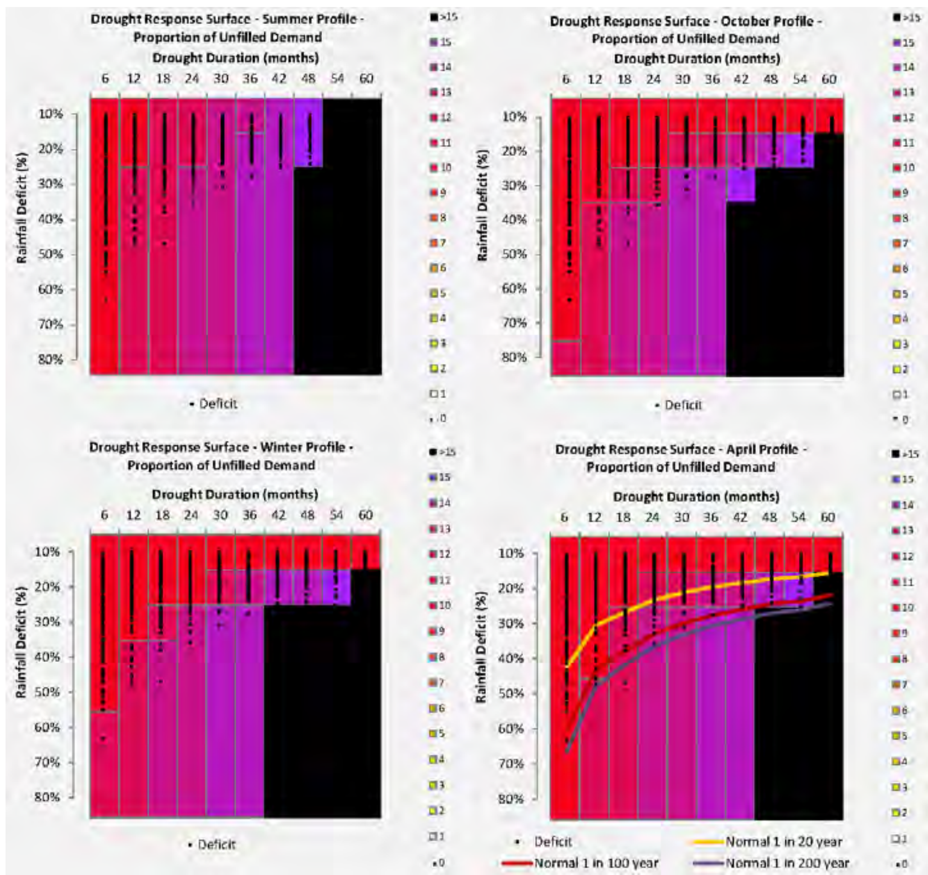
WRZ2 (Colne) unfulfilled demand (without transfers or drought management actions)



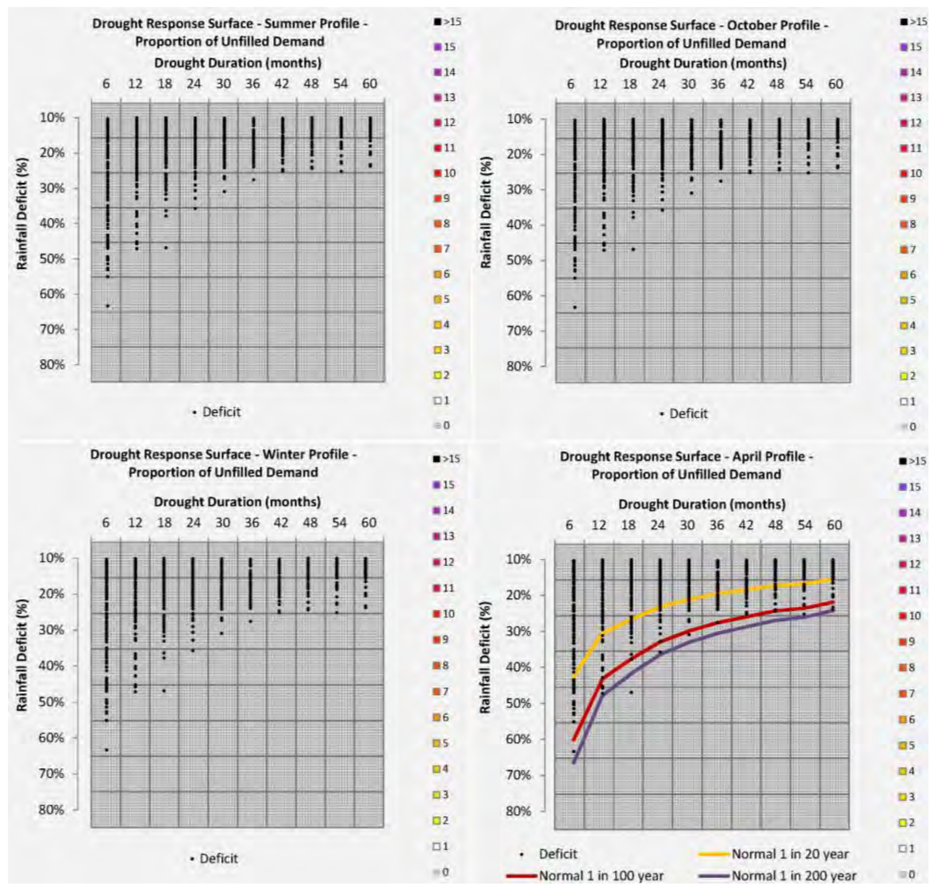
WRZ3 (Lee) unfulfilled demand (without transfers or drought management actions)



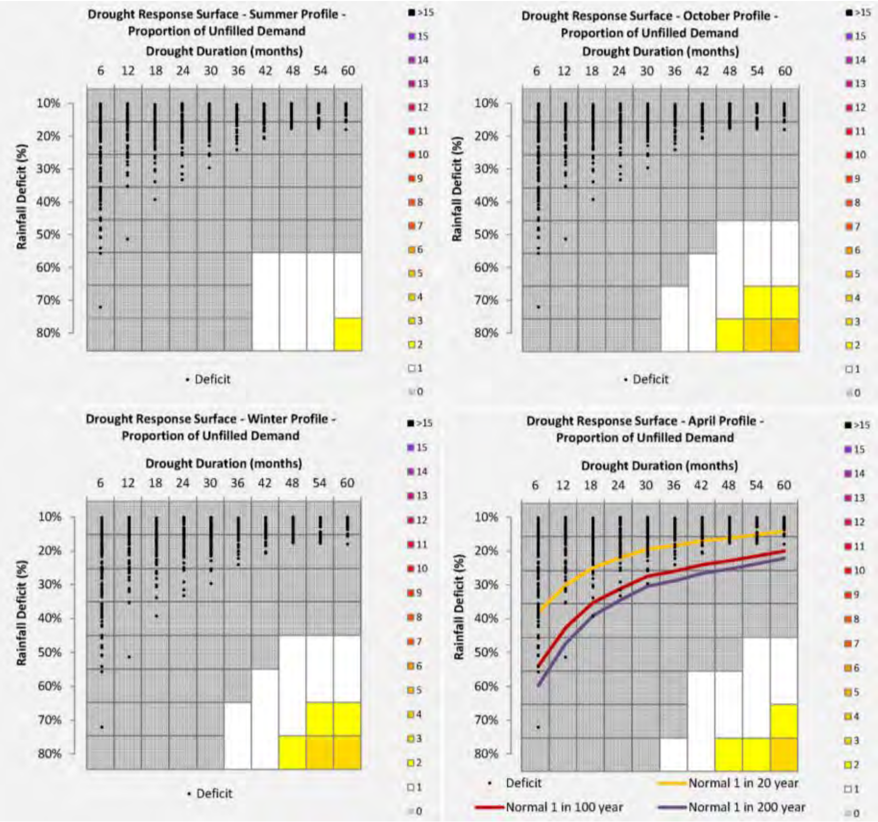
WRZ4 (Pin) unfulfilled demand (without transfers or drought management actions)



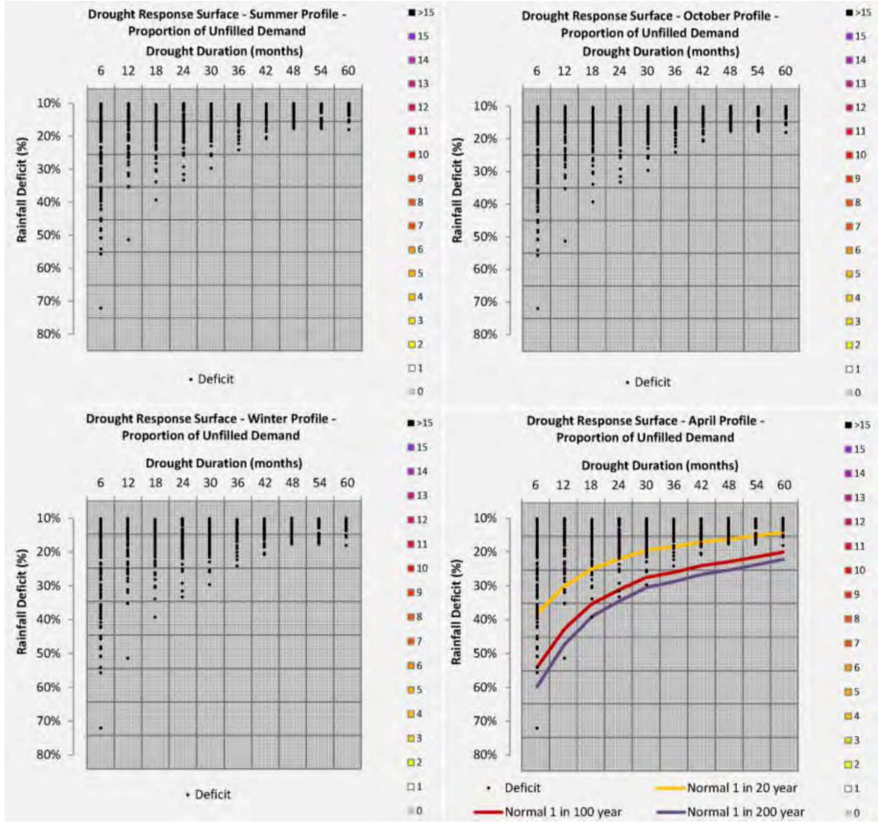
WRZ5 (Stort) unfulfilled demand (without transfers or drought management actions)



WRZ6 unfulfilled demand (without transfers or drought management actions)



WRZ7 (Dour) unfulfilled demand (without transfers or drought management actions)



WRZ8 unfulfilled demand (without transfers or drought management actions)

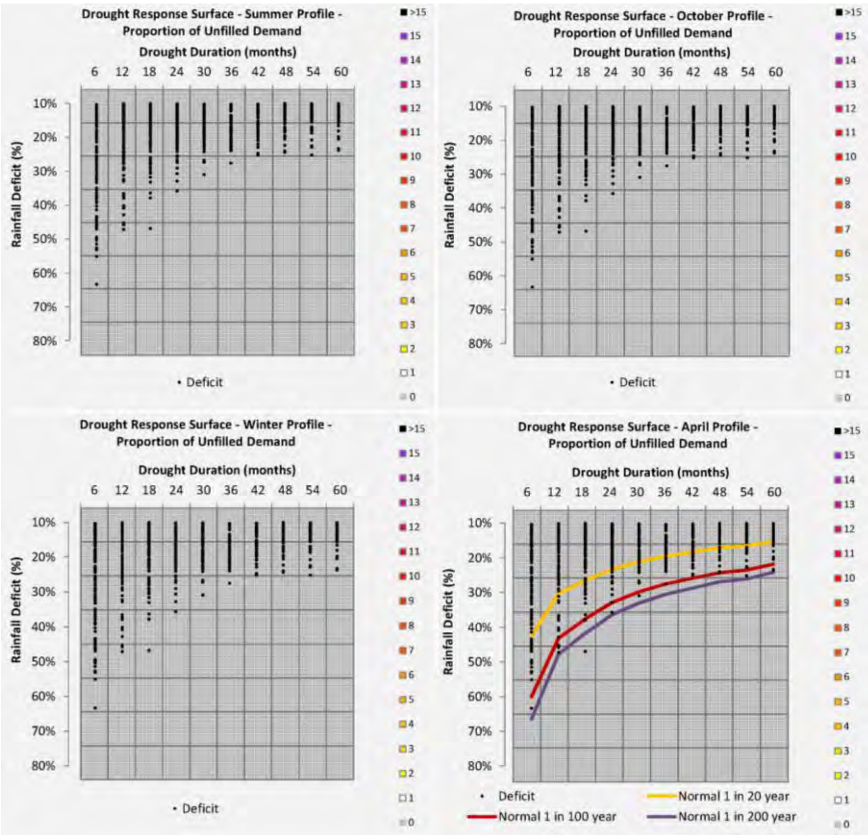
Appendix G. Transfers (scenario with no drought management actions)

Assumed water transfers between WRZs and from neighbouring water companies under a scenario where drought management activities are never applied

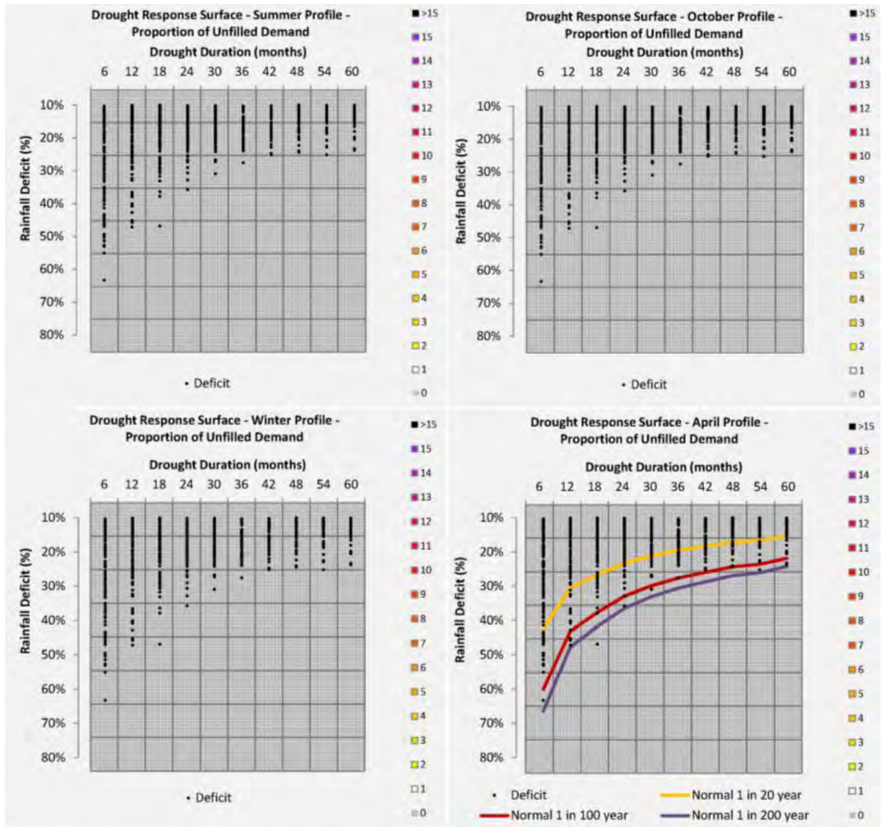
WRZ Model	Imports					Exports				
	Total Import (Ml/d)	Maximum Capacity (Ml/d)	Used %	From	Name	Total Export (Ml/d)	Maximum Capacity (Ml/d)	Used %	To	Name
WRZ1	-	20.40	0%	WRZ3	FRIA South	**21.63**	35.00	0%	WRZ3	FRIA North
		2.10	0%	WRZ2	GRVP		44.00	0%	WRZ2	GRVP to HERC
		16.80	0%	WRZ4	SPRW Bst to HERC		3.69	0%	WRZ2	Tylersfield PSV-
		9.58	0%	WRZ4	HERB		24.12	0%	WRZ4	SPRW valve to HARE
		11.80	0%	WRZ4	Flow from HARE at BATC		9.84	0%	WRZ4	BLAF valve to HARE
		-	-	-	-		**30.90**	**70%**	**WRZ4**	**BATC HL to HARE**
WRZ2	-	7.70	0%	WRZ4	ROLW to BUSY	-	7.56	0%	WRZ4	ROWL to ARKL
		70.00	0%	WRZ4	ICKE Booster		57.50	0%	WRZ4	ARKL flow in from ICKE
		44.00	0%	WRZ1	GRVP to HERC		147.00	0%	WRZ4	PRV Umbrella
		3.69	0%	WRZ1	Tylersfield PSV-		2.10	0%	WRZ1	GRVP to Watford
WRZ3	**90.47**	35.00	0%	WRZ1	FRIA North	**35.04**	20.40	0%	WRZ1	FRIA Wash South
		30.40	0%	WRZ4	NORM North		**7.20**	**70%**	**WRZ5**	**Northern Link**
		109	**83%**	**Anglian Water**	**Grafham (Anglian Water)**		**50.00**	**60%**	**WRZ5**	**27" BULL to SACO**
WRZ4	**31.63**	19.24	0%	WRZ3	BROO to ARKL	-	30.40	0%	WRZ3	NORM North
		7.56	0%	WRZ2	ROWL to ARKL		7.70	0%	WRZ2	ROWL to BUSY
		57.50	0%	WRZ2	ARKL flow in from ICKE		70.00	0%	WRZ2	ICKE Booster
		147.00	0%	WRZ2	PRV Umbrella		16.80	0%	WRZ1	SPRW Bst to HERC

WRZ Model	Imports: Total Import (Ml/d)	Imports: Maximum Capacity (Ml/d)	Imports: Used %	Imports: From	Imports: Name	Exports: Total Export (Ml/d)	Exports: Maximum Capacity (Ml/d)	Exports: Used %	Exports: To	Exports: Name
		24.12	0%	WRZ1	SPRW valve to HARE		9.58	0%	WRZ1	BLAF Booster (HERB)
		9.84	0%	WRZ1	BLAF valve to HARE		11.80	0%	WRZ1	Flow from HARE at BATC
		30.90	**70%**	**WRZ1**	**BATC HL to HARE**		20.00	0%	WRZ6	HARE to EGHA Colnbrook V
		10.00	**100%**	**WRZ6**	**EGHA to HARE Colnbrook V**		1.00	0%	WRZ6	Rickmansworth Forward
		0.82	0%	WRZ6	LAMM		6.00	0%	WRZ6	HARE valve to ALLR
		10.10	0%	Thames Water	STNP		-	-	-	-
		10.81	0%	Thames Water	FORT		-	-	-	-
		1.00	0%	Thames Water	HAML		-	-	-	-
WRZ5	**36.04**	**7.20**	**70%**	**WRZ3**	**Northern Link**	-	-	-	-	-
		50.00	**60%**	**WRZ3**	**27" BULL to SACO**		-	-	-	-
		1.00	**100%**	**Cambridge Water**	**Cambridge**		-	-	-	-
WRZ6	-	20.00	0%	WRZ4	HARE to EGHA Colnbrook V	**47.00**	**10.00**	**100%**	**WRZ4**	**EGHA to HARE Colnbrook V**
		1.00	0%	WRZ4	Rickmansworth Forward		0.82	0%	WRZ4	LAMM
		6.00	0%	WRZ4	HARE valve to ALLR		**37.00**	**100%**	**South East Water**	**South East Water Export**
		1.00	0%	Thames Water	LADY to PARB		-	-	-	-
		13.43	0%	Thames Water	KEMP		-	-	-	-

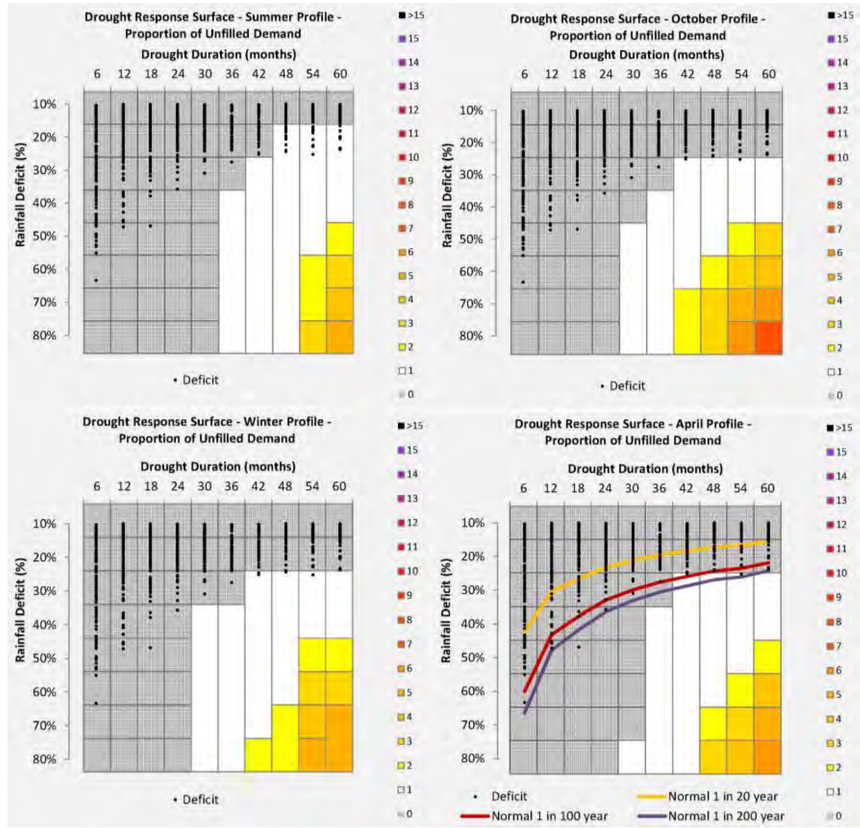
Appendix H. Results (with transfers and without drought management actions)



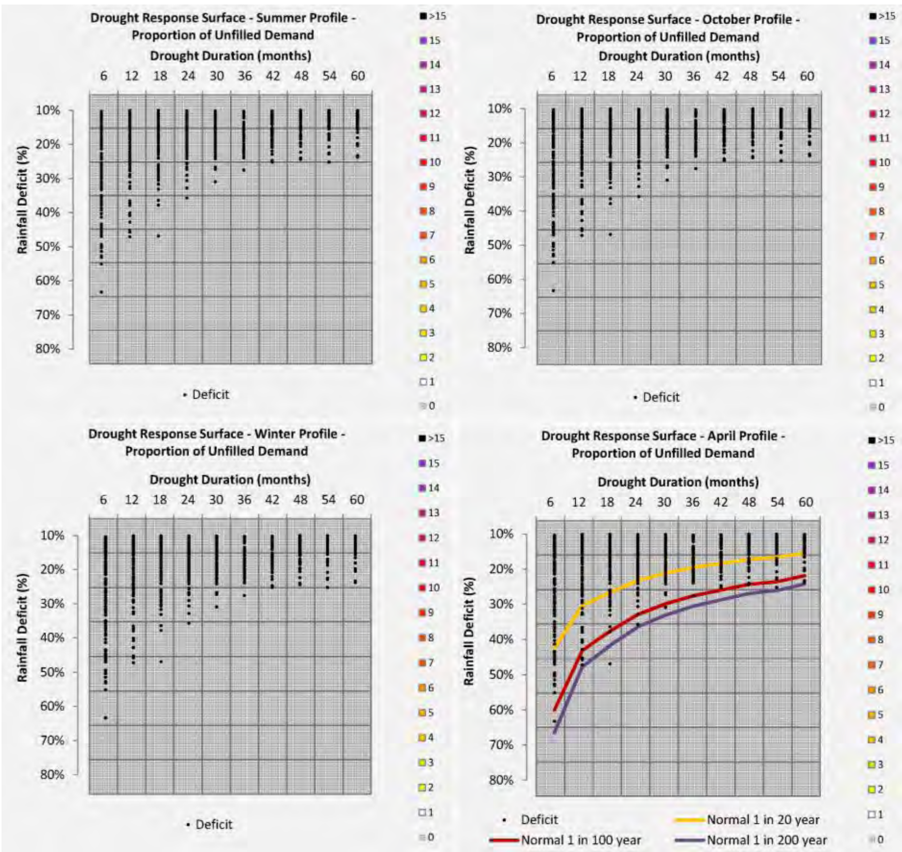
WRZ1 (Misbourne) unfulfilled demand (with transfers, without drought management actions)



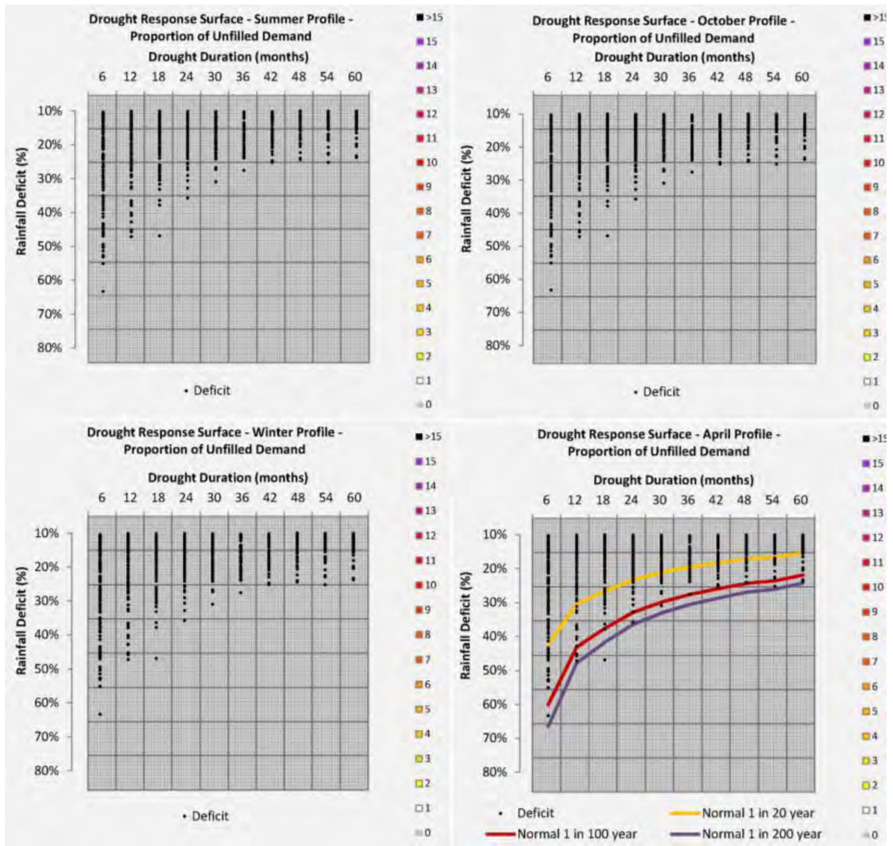
WRZ2 (Colne) unfulfilled demand (with transfers, without drought management actions)



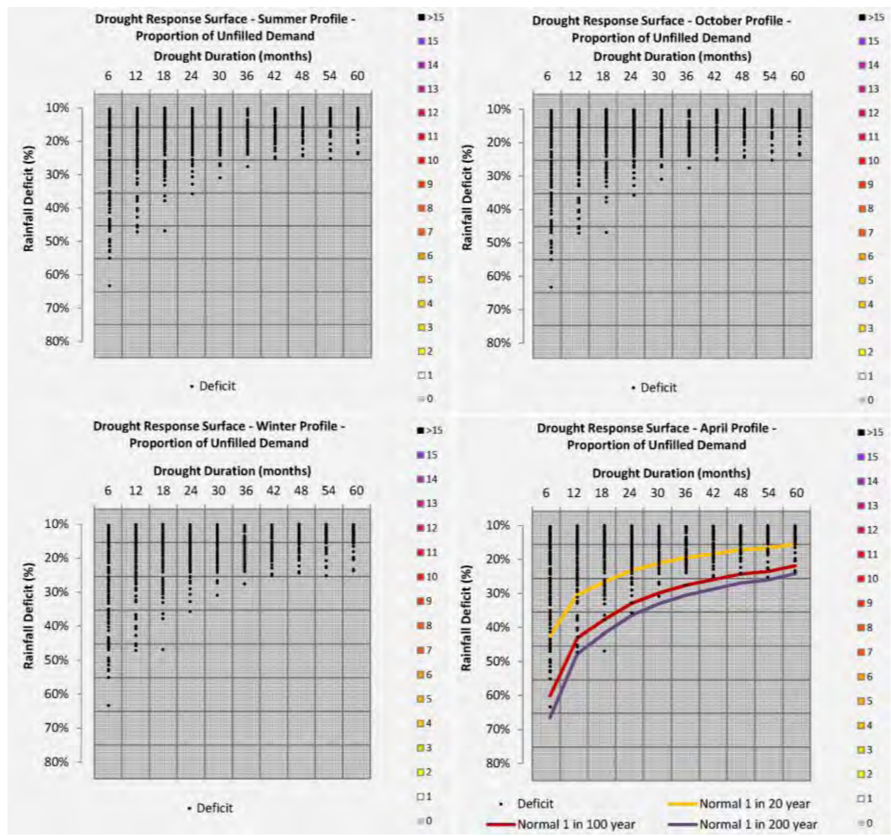
WRZ3 (Lee) unfulfilled demand (with transfers, without drought management actions)



WRZ4 (Pin) unfulfilled demand (with transfers, without drought management actions)



WRZ5 (Stort) unfulfilled demand (with transfers, without drought management actions)



WRZ6 unfulfilled demand (with transfers, without drought management actions)

Appendix I.Transfers (scenario with drought management actions)

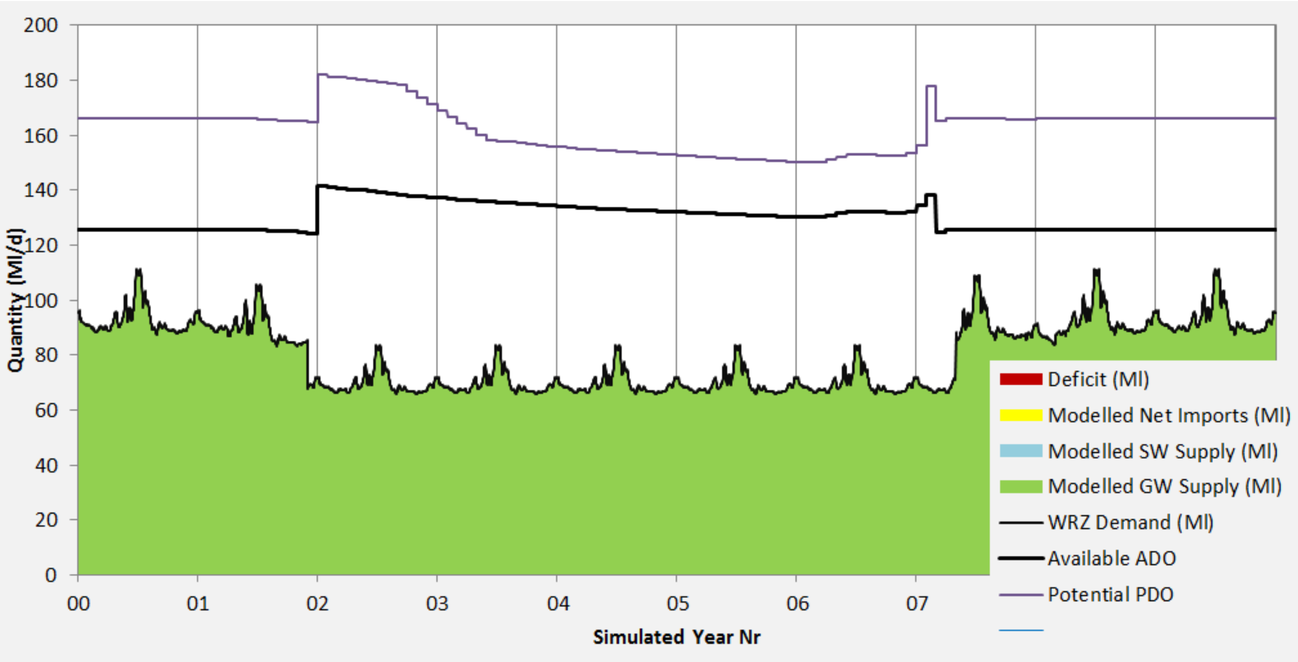
Assumed water transfers between WRZs and from neighbouring water companies under a scenario where drought management activities are in place

	Import					Export				
	Total Import (Ml/d)	**MaxCap (Ml/d)**	**Used %**	**From**	**Name**	**Total Export (Ml/d)**	**MaxCap (Ml/d)**	**Used %**	**To**	**Name**
WRZ1	-	20.40	0%	WRZ3	FRIA South	**26.88**	**35.00**	**15%**	**WRZ3**	**FRIA North**
		2.10	0%	WRZ2	GRVP to Watford		44.00	0%	WRZ2	GRVP to HERC
		16.80	0%	WRZ4	SPRW Bst to HERC		3.69	0%	WRZ2	Tylersfield PSV-
		9.58	0%	WRZ4	BLAF Booster (HERC)		24.12	0%	WRZ4	SPRW valve to HARE
		11.80	0%	WRZ4	Flow from HARE at BATC		9.84	0%	WRZ4	BLAF valve to HARE
		-	-	-	-		**30.90**	**70%**	**WRZ4**	**BATC HL to HARE**
WRZ2	-	7.70	0%	WRZ4	ROWL to BUSY	**22.05**	7.56	0%	WRZ4	ROWL to ARKL
		70.00	0%	WRZ4	ICKE Booster		57.50	0%	WRZ4	ARKL flow in from ICKE
		44.00	0%	WRZ1	GRVP to HERC		**147.00**	**15%**	**WRZ4**	**PRV Umbrella**
		3.69	0%	WRZ1	Tylersfield PSV-		2.10	0%	WRZ1	GRVP to Watford
WRZ3	**53.43**	**35.00**	**15%**	**WRZ1**	**FRIA North**	**25.04**	20.40	0%	WRZ1	FRIA South
		30.40	**33%**	**WRZ4**	**NORM North**		**7.20**	**70%**	**WRZ5**	**Northern Link**
		109.00	**35%**	**Anglian W.**	**Grafham (Anglian Water)**		**50.00**	**40%**	**WRZ5**	**27" BULL to SACO**
WRZ4	**43.68**	19.24	0%	WRZ3	BROO to ARKL	**10.03**	**30.40**	**33%**	**WRZ3**	**NORM North**
		7.56	0%	WRZ2	ROWL to ARKL		7.70	0%	WRZ2	ROWL to BUSY
		57.50	0%	WRZ2	ARKL flow in from ICKE		70.00	0%	WRZ2	ICKE Booster
		147.00	**15%**	**WRZ2**	**PRV Umbrella**		16.80	0%	WRZ1	SPRW Bst to HERC
		24.12	0%	WRZ1	SPRW valve to HARE		9.58	0%	WRZ1	BLAF Booster (HERC)
		9.84	0%	WRZ1	BLAF valve to HARE		11.80	0%	WRZ1	Flow from HARE at BATC
		30.90	**70%**	**WRZ1**	**BATC HL to HARE**		20.00	0%	WRZ6	HARE to EGHA Colnbrook V

	Import					Export				
	Total Import (Ml/d)	MaxCap (Ml/d)	Used %	From	Name	Total Export (Ml/d)	MaxCap (Ml/d)	Used %	To	Name
		10.00	0%	WRZ6	EGHA to HARE Colnbrook V		1.00	0%	WRZ6	Rickmansworth Forward
		0.82	0%	WRZ6	LAMM		6.00	0%	WRZ6	HARE valve to ALLR
		10.10	0%	Thames W.	STNP		-	-	-	-
		10.81	0%	Thames W.	FORT		-	-	-	-
		1.00	0%	Thames W.	HAML		-	-	-	-
WRZ5	**26.04**	**7.20**	**70%**	**WRZ3**	**Northern Link**	-	-	-	-	-
		50.00	**40%**	**WRZ3**	**27" BULL to SACO**		-	-	-	-
		1.00	**100%**	**Cambridge W.**	**Cambridge**		-	-	-	-
WRZ6	-	20.00	0%	WRZ4	HARE to EGHA Colnbrook V	**37.00**	10.00	0%	WRZ4	EGHA to HARE Colnbrook V
		1.00	0%	WRZ4	Rickmansworth Forward		0.82	0%	WRZ4	LAMM
		6.00	0%	WRZ4	HARE valve to ALLR		**37.00**	**100%**	**SEW**	**South East Water Export**
		1.00	0%	Thames	LADY to PARB		-	-	-	-
		13.43	0%	Thames	KEMP		-	-	-	-

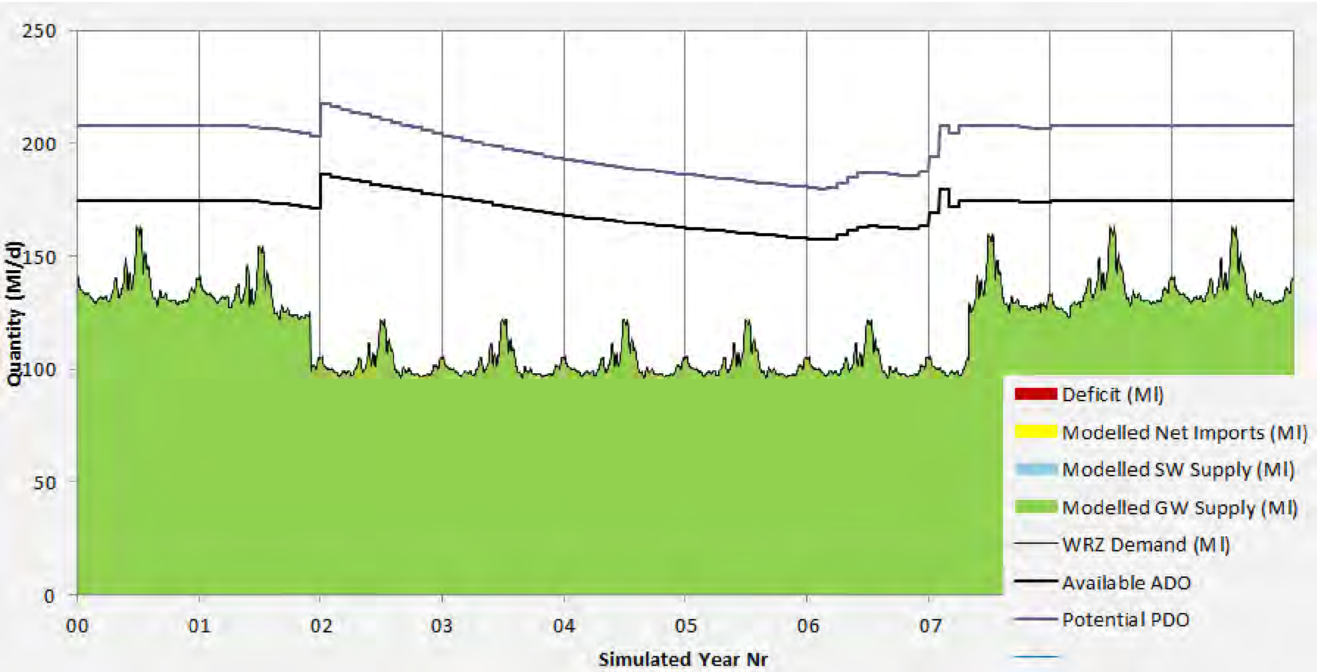
Appendix J. Example utilisation of resources in the worst drought scenario tested

J.1 WRZ1



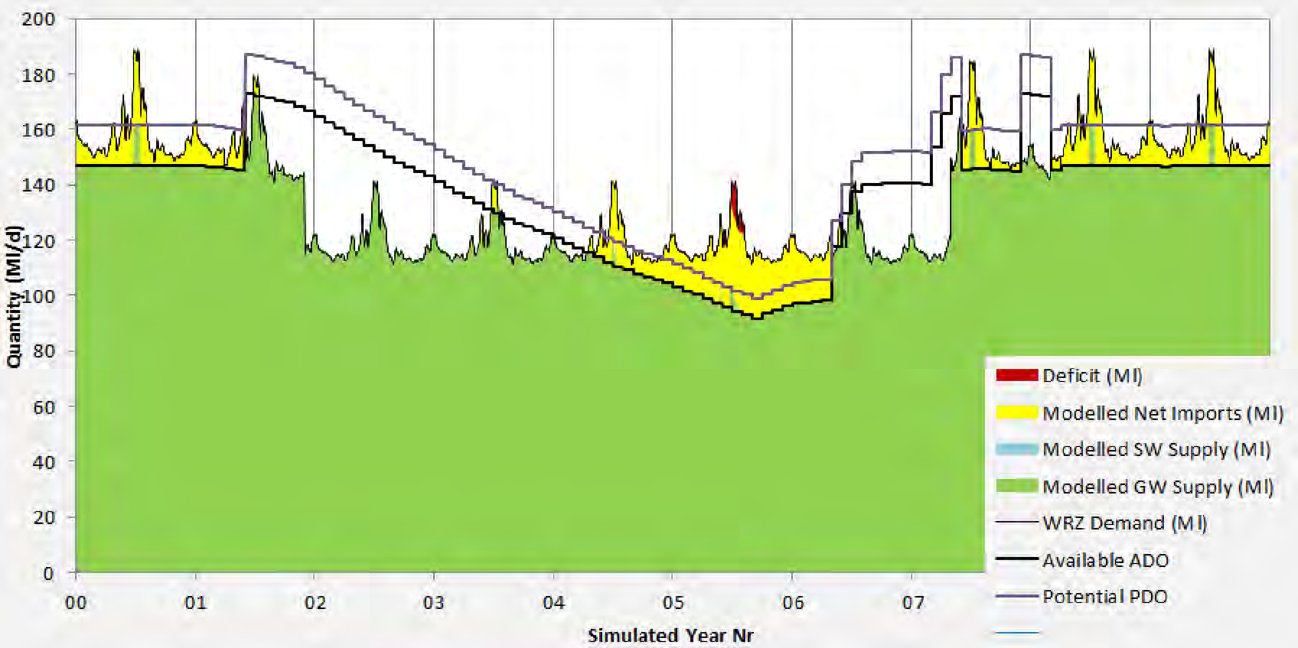
WRZ1 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.2 WRZ2



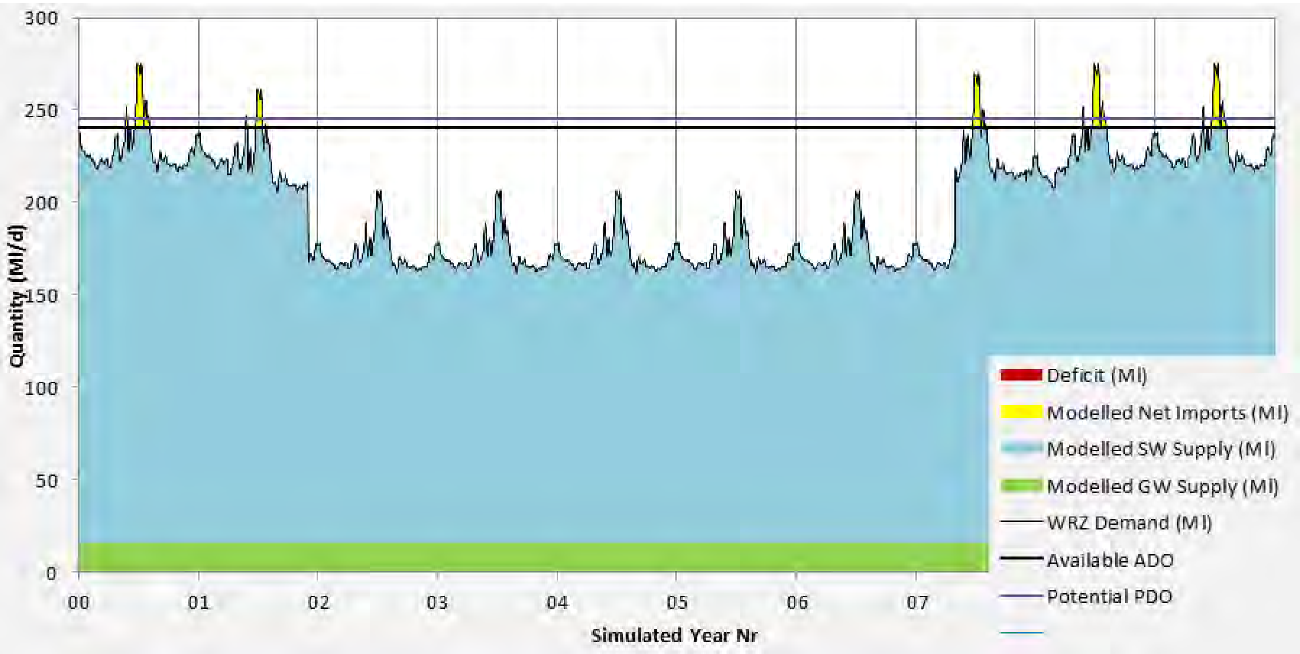
WRZ2 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.3 WRZ3



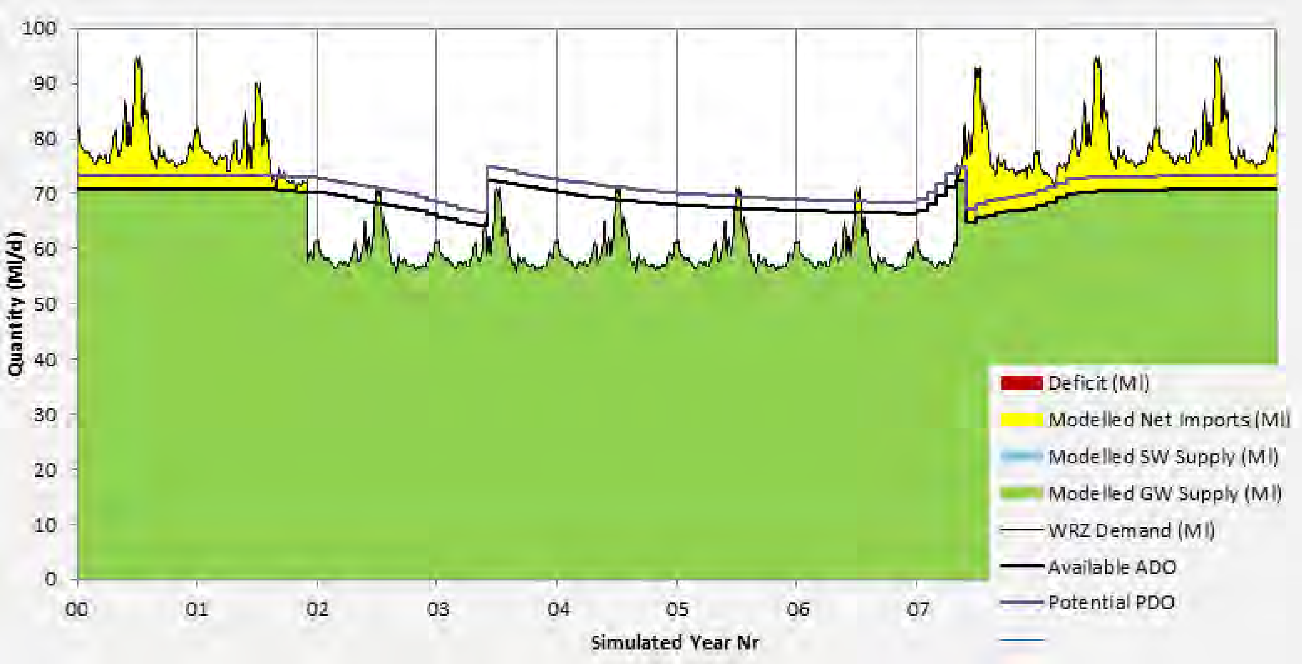
WRZ3 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.4 WRZ4



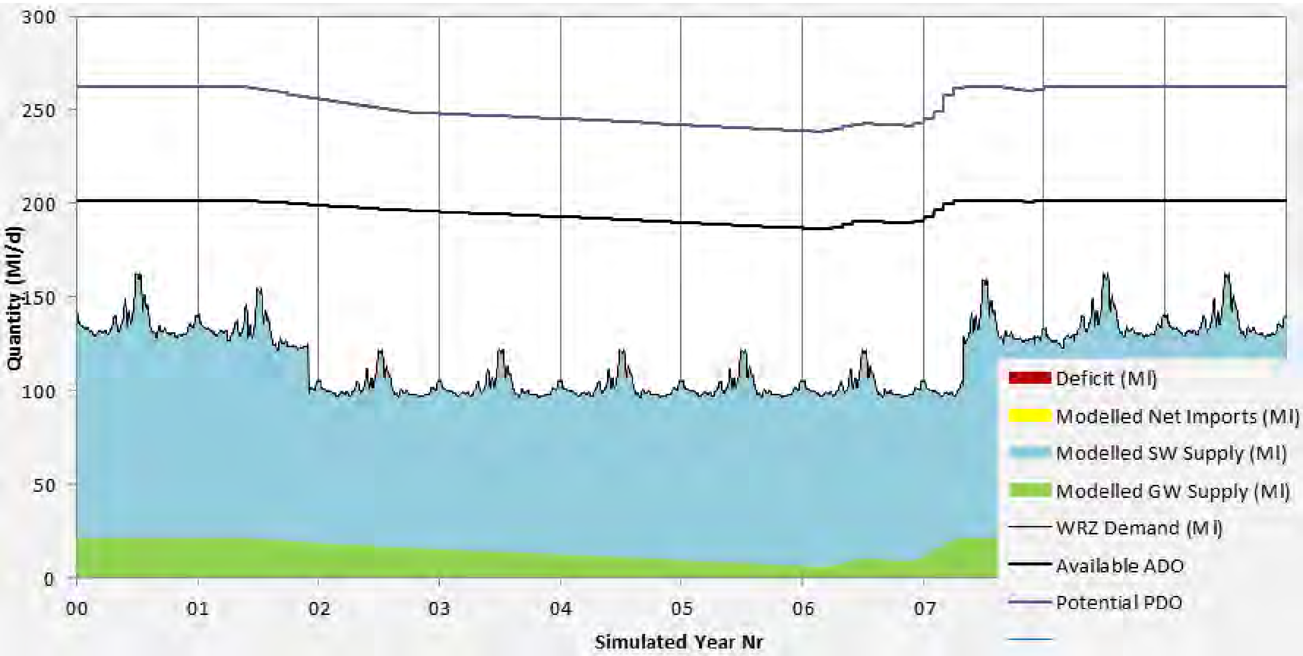
WRZ4 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.5 WRZ5



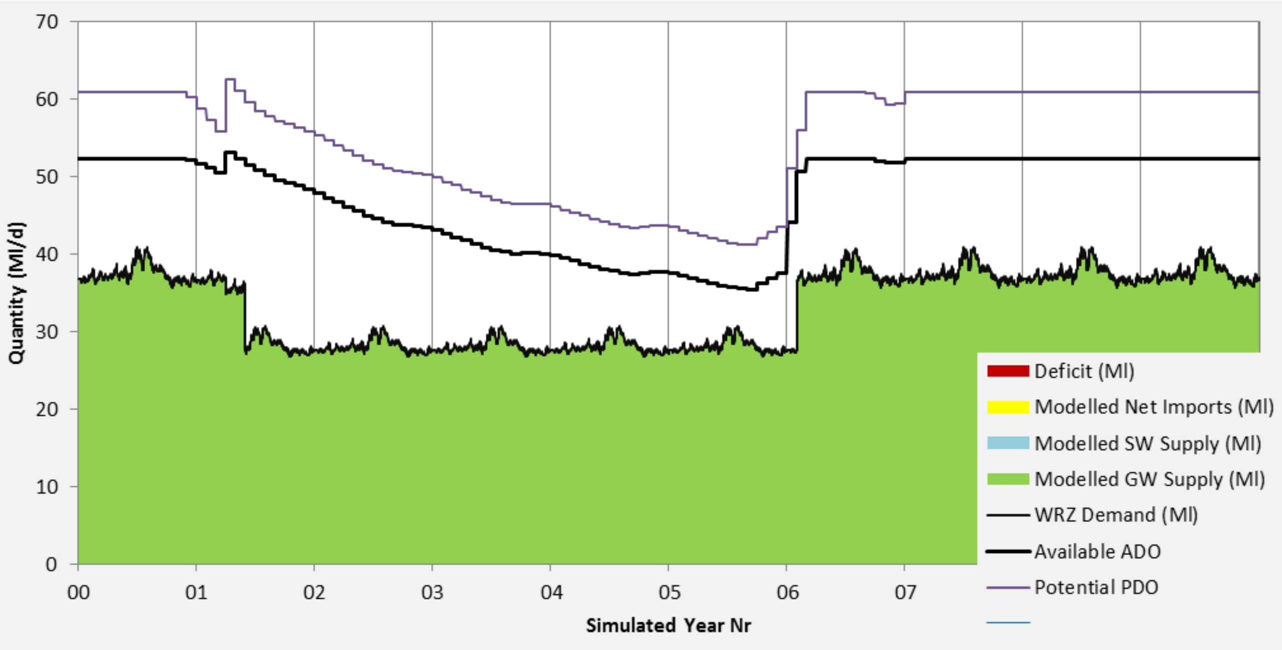
WRZ5 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.6 WRZ6



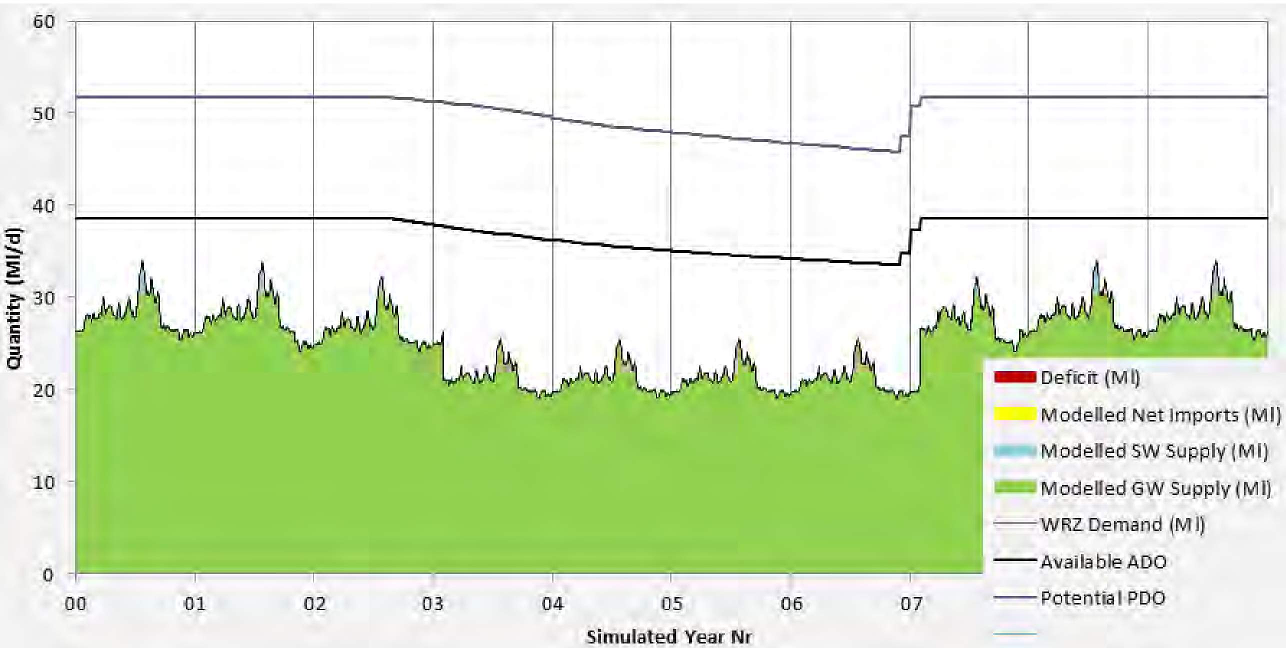
WRZ6 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.7 WRZ7



WRZ7 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

J.8 WRZ8



WRZ8 Example utilisation (October Profile, 60 month drought, 80% rainfall deficit. Transfers and drought activities switched on)

About AECOM

AECOM (NYSE: ACM) is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental, energy, water and government. With approximately 100,000 employees around the world, AECOM is a leader in all of the key markets that it serves. AECOM provides a blend of global reach, local knowledge, innovation, and collaborative technical excellence in delivering solutions that enhance and sustain the world's built, natural, and social environments. A Fortune 500 company, AECOM serves clients in more than 100 countries and has annual revenue in excess of $6 billion.

More information on AECOM and its services can be found at www.aecom.com.

Scott House
Alençon Link
Basingstoke
Hampshire
RG21 7PP
United Kingdom
+44 1256 310200