Appendix N. Drought Response Surfaces

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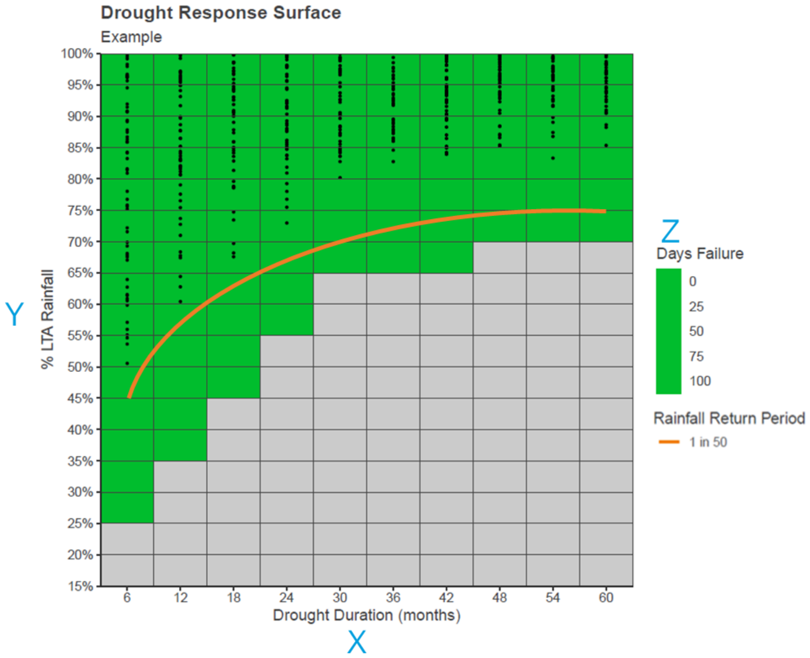
Drought Response Surfaces

We have included an assessment of the risk of potential shortfall in water resources in severe droughts using Drought Response Surfaces (DRS).

We have undertaken this assessment for each of our Water Resource Zones (WRZs). We have utilised an appropriate method for each WRZ, dependant on the size and relative drought vulnerability of the WRZ and considering the best available data for each zone. It should be noted that there is a significant level of uncertainty associated with this type of assessment. As part of our Water Resource Management Plan (WRMP) 24 updates, we have built upon and improved our drought vulnerability assessments using new models and datasets that have become available since WRMP19 was produced. The drought response surfaces presented in this document reflect some of these new approaches while following the UKWIR guidance.

Interpreting Drought Response surfaces

Figure 1: Example Drought Response Surface

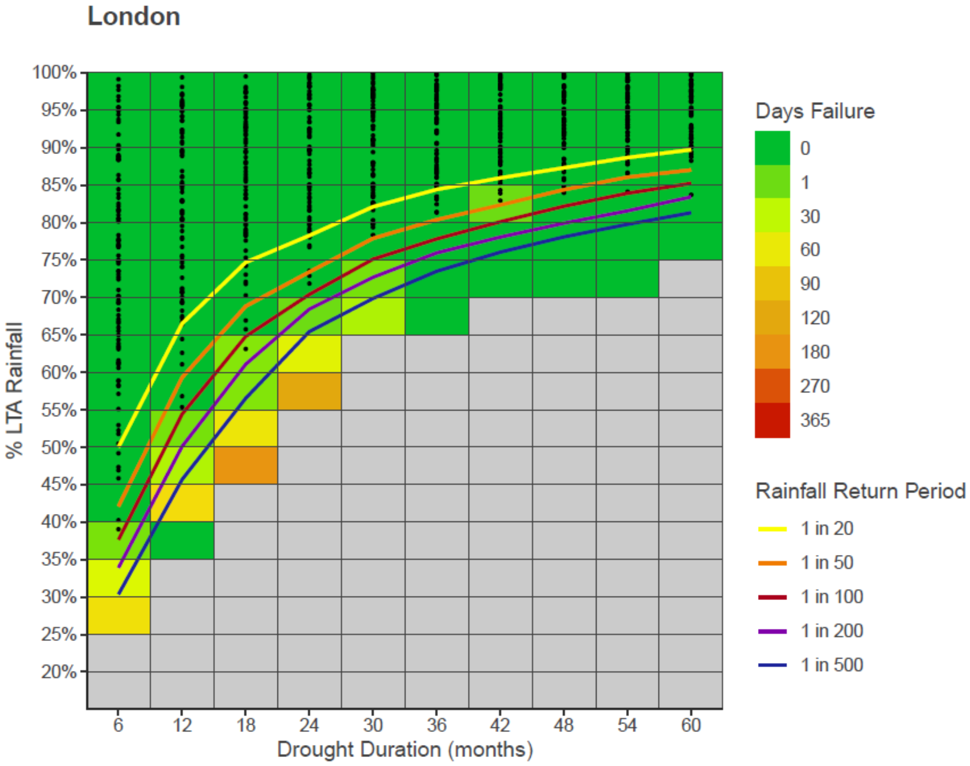


The purpose of drought response surfaces is to visually present the potential risks of droughts of varying durations and severities. The plot is made up of a grid of cells, where each cell represents drought of a given different duration (in months on the X axis) and rainfall deficit (% of average rainfall on Y axis). The axes are such that extremely long and dry droughts appear in the bottom right of the grid, while short and less severe droughts appear in the top left of the grid.
On the "Z" axis, the colours represent how severe the impact of the drought in that cell is - this can be represented using different metrics, but in our case, the colours show a number of days of "failure" i.e., the length of time, in days, that emergency restrictions will be required. Cells are green where the assessment does not indicate that emergency restrictions would be required, and red where the assessment indicates that emergency restrictions would be required for a long period of time. Droughts which are deemed unrealistic, or where our assessments do not give us an

appropriate level of confidence, are shown in grey. Additional data is also presented for context: black points show events that have occurred using historic rainfall records, curved lines show the probability of a rainfall deficit of a given duration and severity occurring. Note that on the X axis, the duration scale is divided into discrete categories of 6-month intervals – for example, where a line cross from 6 to 12 months, this is not indicating a drought of 9 months duration.

London

Figure 2 N1 London Drought Response Surface



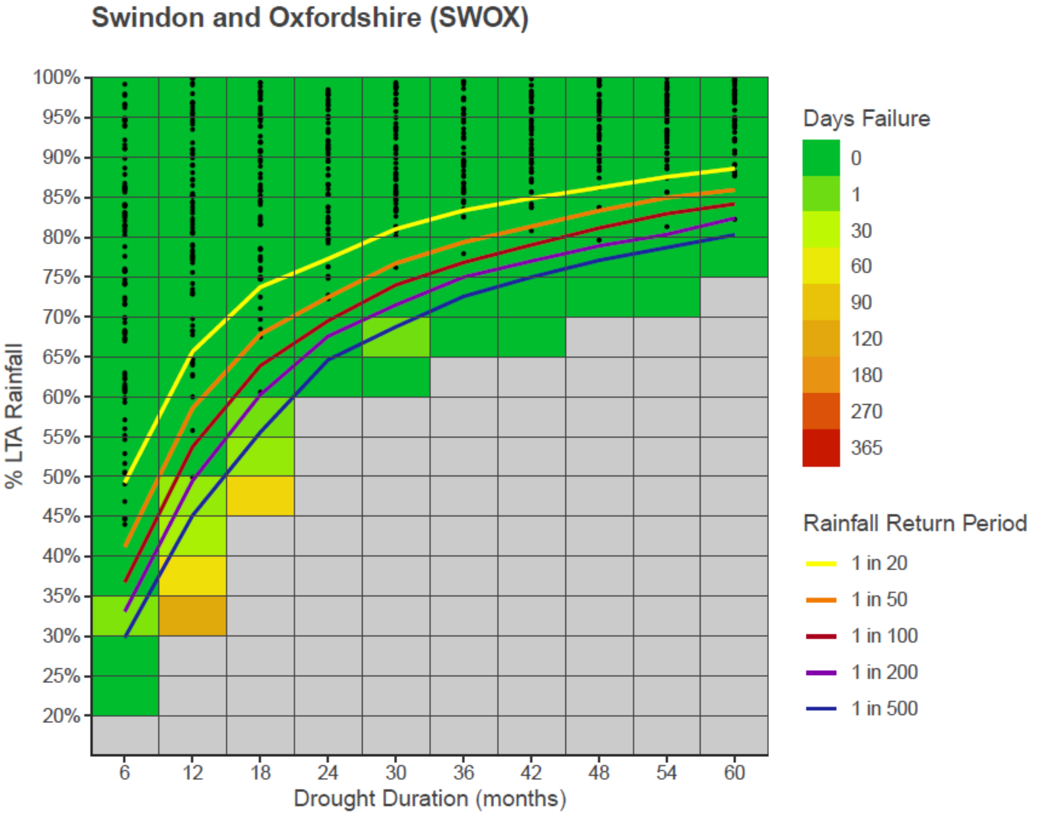
The DRS for London, Figure 2, uses results from the Pwyr modelling carried out for WSRE regional plan and WRMP24 and was produced using *Calculation Approach 1a* in the UKWIR Drought Vulnerability Framework[1]. This has involved use of the stochastic weather record that has been developed for WRSE & WRMP24. The stochastic record contains 400 realisations of weather that 'could' have occurred during the period 1950-97 (produced by training a stochastic weather generator) given the underlying climate, giving a representative baseline weather record of a significantly greater length than the historical record (and so including more extreme events than present in the historical record) This gives us an ability to examine more severe droughts than have historically occurred, but with a basis in reality. Using this weather data, a number of days' failure (a failure in London is defined as crossing Level 4 on the LTCD) was produced for each of the 19200 years in the stochastic record under an appropriate level of demand, with demand savings applied. The demand used reflects *Base Year Demand + Target Headroom* as per the EA Drought Vulnerability Framework guidance[2], as-well as an allowance for *Bulk Supplies* (in London specifically, this means that our export to Essex and Suffolk and exports to Affinity Water are included in the water resources model runs used to produce this drought response surface). Each year of the record also has corresponding rainfall statistics (rainfall deficits over different periods) and storage level data. In order to match the rainfall deficits with the failure data for a given year, the timing of the drought was defined as ending when the minimum storage level was reached. The rainfall leading up to that date was then used to define where that event should be plotted. We then plotted the drought response surface using the mean of the numbers of days failure in each cell (many events may fall into a single cell on the DRS).

The DRS for London indicates that London is resilient to a range of droughts up to 1 in 200-year return period. The DRS indicates that London is most vulnerable to droughts between 1 and 3 years long, with average rainfall of less than 75%. For example, figure 1 shows that for an 18-month drought of 45-50% rainfall, up to 6 months of emergency restrictions may be required. It should be noted that we believe that the 42-month event with 80-85% LTA rainfall showing potential risk of failure is likely an artefact of the methods used, rather than an indication of vulnerability.

It is noted that this DRS suggests that London is more vulnerable than the results of the Severe Drought Assessment. This is in part due to the methodology behind producing the DRS. The method outlined above uses rainfall as a metric to identify the severity of droughts, however in the Severe Drought Assessment, drought severity is analysed dependent on reservoir storage modelling (i.e. using a 'system response' metric, rather than rainfall), and so the response to a 1 in 200-year drought would appear different in each of these assessments. For example, for the 18month duration, 60-65% LTA rainfall cell, events in this cell appear to be around a 1 in 100-year events, however the reservoir storage levels associated with those events show they could be anywhere between a 1 in X-year event and a 1 in 2500-year event. In addition, Drought Response Surfaces are sensitive to the statistics used. The mean of days failures within each cell is presented here, but if the median were used, the results would be very different, e.g. the 60-65% rainfall, 18-month drought cell contains several events with 0 days of failure, but includes a handful of events with over 60 days of failure and so the mean presents a much higher risk than the median would. There are also subtleties that the DRS cannot account for, e.g. A drought with 40% LTA rainfall for 12 months, and 80% LTA rainfall for the following 12 months would, in reality, present a different system response to a drought of 60% LTA for 24 consecutive months, however these two droughts would be presented as both having 60% LTA rainfall for 24months.

Swindon and Oxfordshire (SWOX) WRZ

Figure 3 N2 SWOX Drought Response Surface

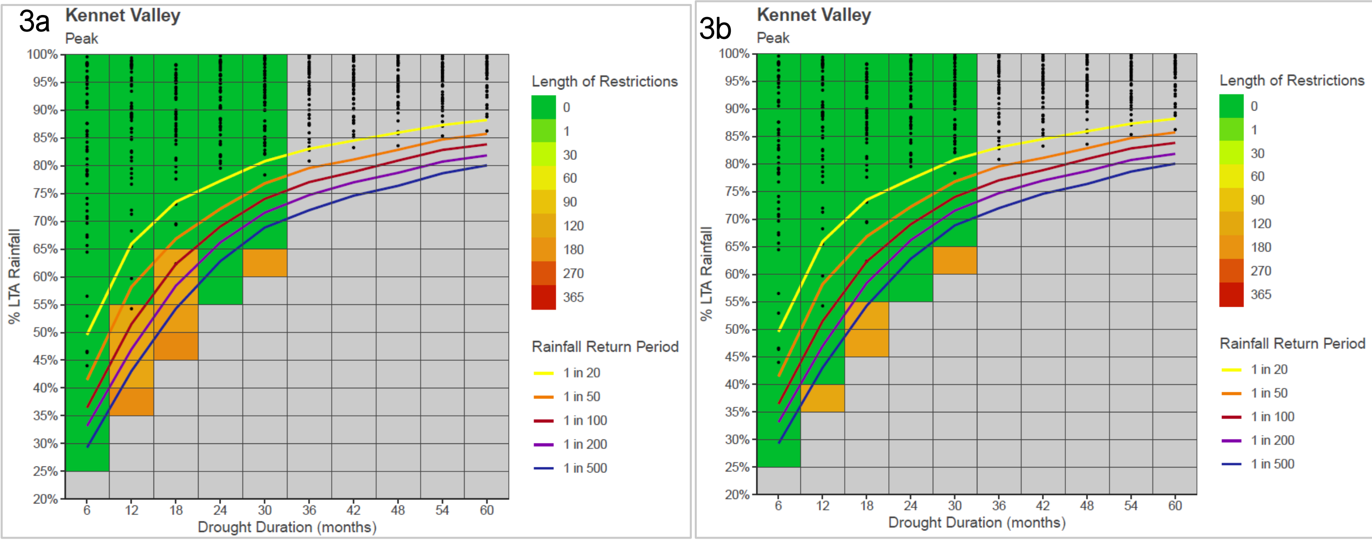


The drought response surface, Figure 3, for SWOX uses the same methodology and Calculation Approach[1] as in London.

The drought response surface for SWOX, Figure 3, shows that we are broadly resilient to droughts up to 1 in 200 years, but for droughts of severity of 1 in 200-year or greater we are at risk of requiring emergency restrictions and so would be reliant on drought permits. This accords with our assessment of risk for SWOX which shows that we would be resilient to a drought similar to 1976 but that if it extended then we would be reliant on drought permits to ensure we did not need to impose emergency restrictions. The drought response surface for SWOX also provides a concordant view of the event type that SWOX is vulnerable to, insofar as SWOX is more vulnerable to 12 to 18-month drought events.

Kennet Valley

Figure 4 N3 Kennet Valley Drought Response Surface



The Kennet Valley DRS, Figure 4, uses a combination of methods following *Calculation Approach 1b and 4b* in the UKWIR Drought Vulnerability Framework[1]. The yield of our Fobney surface water source (run of river) was determined for each year in the stochastic series (using river flows from the same Pywr modelling used for the London and SWOX DRS analysis) and an appropriate stochastic rainfall dataset was used to classify years in the stochastic record to boxes on the DRS. Previously, under very extreme events, the robustness of the methods used to estimate flows in the River Kennet was questionable, particularly for flows below Q99, for WRMP24 these flows have been re-assessed and quantile mapping of flows applied to improve the estimation of lower flows. A stochastic dataset of yields was also produced for Pangbourne and combined with the stochastic rainfall data as above.

Approach 4b was applied for other sources within the Kennet Valley WRZ. This approach involves determining a statistical relationship between rainfall over a given duration and groundwater levels, and then applying these relationships to determine groundwater levels (and so yield) that may be anticipated for different drought durations and severities.

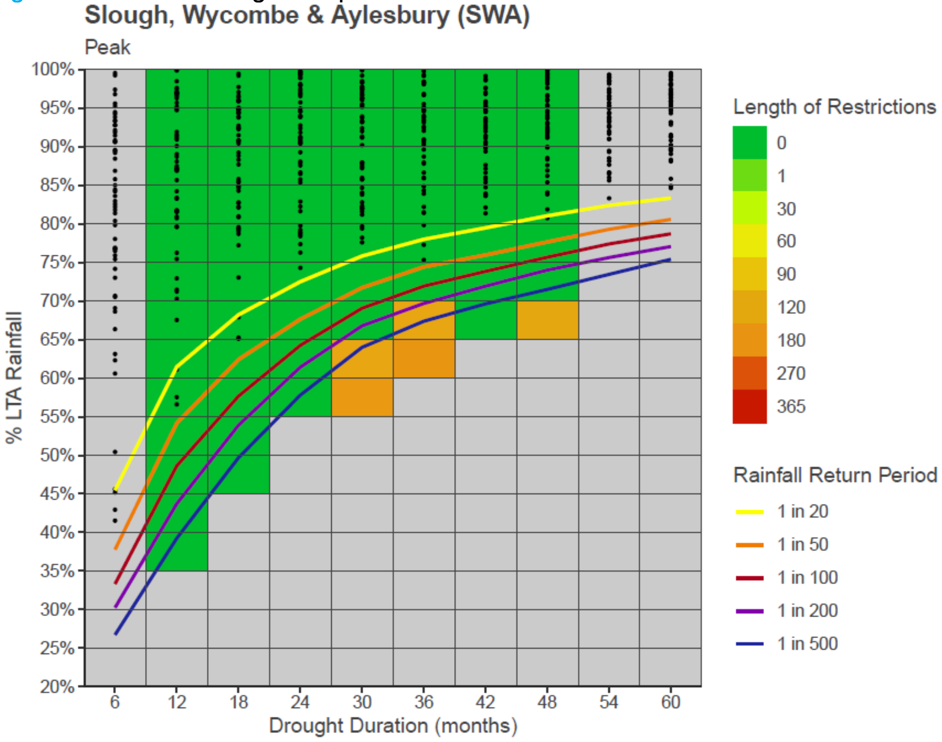
Our analysis using approaches 1b and 4b resulted in yields for each source being determined for each DRS cell. The sum of surface and groundwater yields were used to determine the total yield for the WRZ in each cell, which was compared against an appropriate demand figure (to give an indicative supply-demand balance for each DRS cell) and a calculation applied to determine if, and how long, emergency restrictions might be required for.

Two scenarios were considered in Kennet Valley regarding the availability of the West Berkshire Groundwater Scheme (WBGWS); within the Kennet Valley WRZ this influences only the Fobney run-of-river source. The first (fig. 3a.) was using the current trigger for WBGWS – London's reservoir storage falling below Level 2 on the LTCD., the second scenario (fig. 3b) assumes that WBGWS could be triggered by considering low flows in the River Kennet. The difference between these two figures indicates that there would be benefit for the Kennet Valley WRZ in introducing a trigger for WBGWS which would be based on flows in the River Kennet; introducing such a trigger would require agreement by the Environment Agency. As well as these two versions, DRSs were plotted for both the Peak period (defined as an event ending in August) and Annual Average, only the peak period scenario is presented here. Generally, for the Annual average scenario, there were little or no failures in both versions. For all remaining Thames Valley WRZs, both a Peak and Annual Average scenario have been produced, but only the Peak scenario is presented within this document.

The Kennet valley DRS, Figure 4a, shows that we are resilient to 1 in 500-year droughts of 2 years or more. But that we may be vulnerable to drought events of 1 in 100-year or worse severity lasting 1 to 1.5 years. Triggering of WBGWS, or use of other drought permits, may be required should such an event occur, although as with London this assessment is based on event severity being a function of rainfall, rather than river flows. Note this appears worse than previous assessments partly due to the improved estimation of lower flows. The river flows used in this assessment are lower and therefore produce lower yields at Fobney. Figure 3a suggests that under the new assessment of river flows, there would not be enough flow in the Kennet available to abstract at Fobney for drought events of 12-18 months and a severity of more than 1 in 100-years, whereas in Fig 3.b. our resilience to drought is significantly improved to most droughts less severe than 1 in 500 years with the WBGWS being able to be triggered by need in Kennet Valley. This is important as if London becomes more resilient to drought, the WBGWS is less likely to be triggered regardless of the potential drought risks in the Kennet Valley WRZ.

Slough, Wycombe and Aylesbury (SWA)

Figure 5 N4 SWA Drought Response Surface



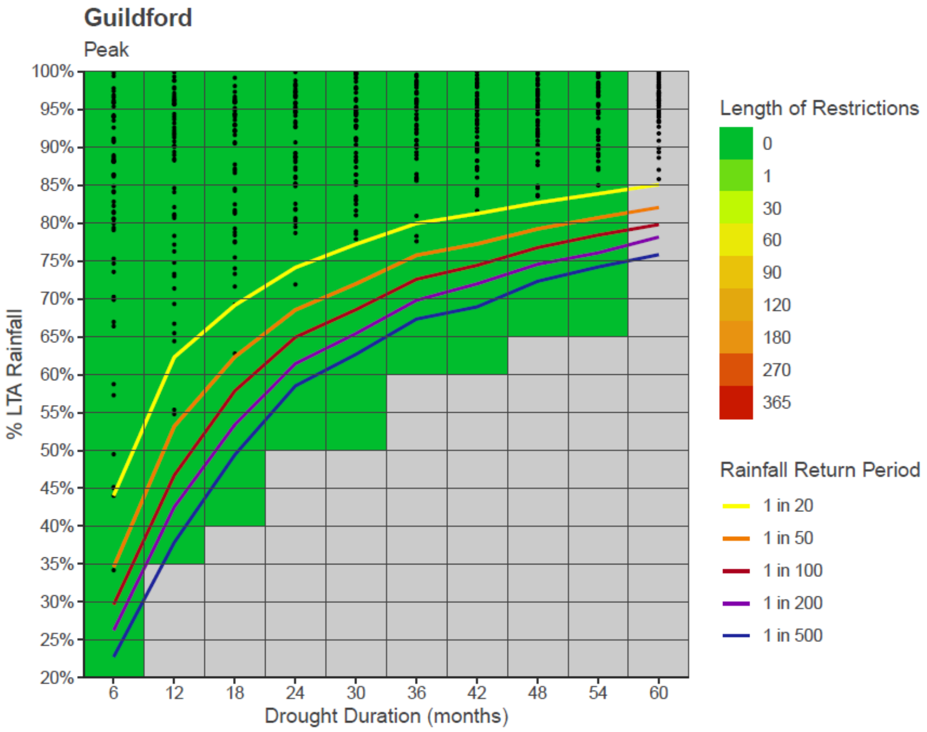
The method used for producing the SWA DRS is similar to that of Kennet Valley – a combination of statistical estimations of groundwater levels and yields at a number of sites added to stochastic yield datasets for Dancers End and Radnage sources.

The DRS for SWA, Figure 5, shows resilience to droughts of up to 1 in 200 years but that beyond that there may be the requirement for drought permits during events of 30 to 36 months with less than 70% LTA rainfall. This reflects the potential vulnerability in the yields of a small number of sources, particularly Hawridge and

Pann Mill. Sustainability reductions have been implemented at Pann Mill, therefore the yield is likely to be resilient to severe drought, and Hawridge is currently planned to be closed at the end of AMP7. It's also worth noting that sustainability reductions have been made at Hampden& Wendover, and that Dancers End is currently disused (due to be brought back into service soon). Radnage is a small source near the catchment divide and, if necessary, could be supported by tankering. In a severe drought we would have implemented demand management measures to suppress demand and so it is expected that the WRZ would be resilient to severe drought because the majority of the zone's supply comes from Thames-side sources which have a high level of resilience to drought. If necessary, in a severe drought of greater than 1:100 or worse the Drought Permit option at Pann Mill could be used.

Guildford

Figure 6 N5 Guildford Drought Response Surface

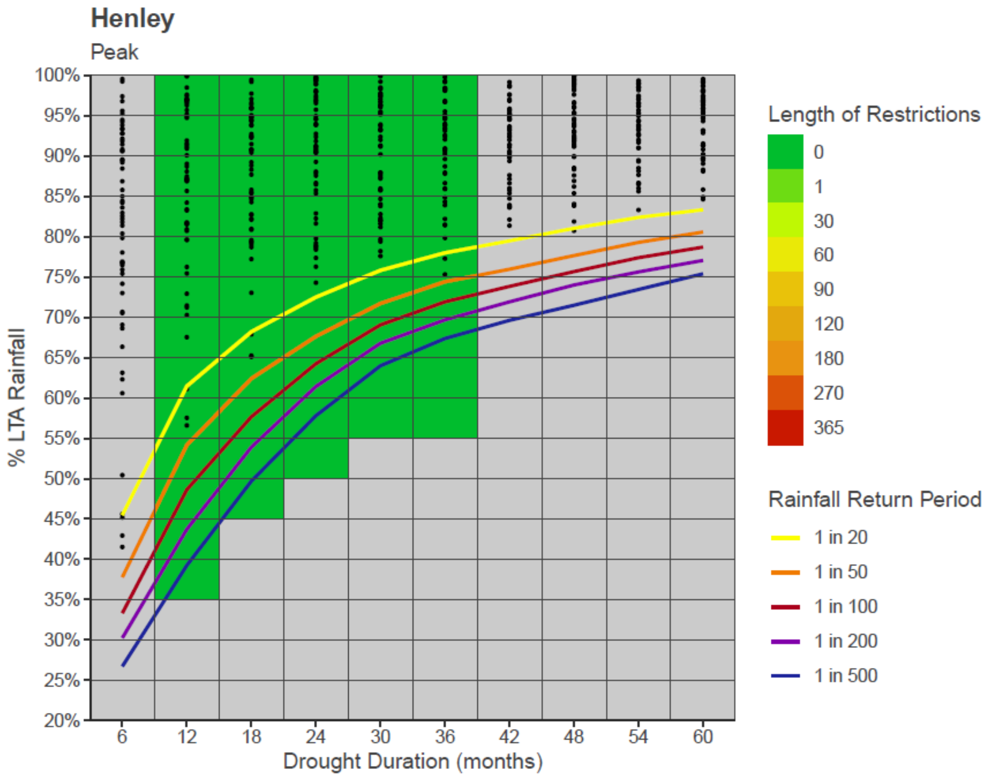


The DRS, Figure 6, for Guildford shows resilience to droughts up to at least 1 in 500-year severity. At this level of drought severity there is a high level of uncertainty but this view accords with our assessment of the drought resilience of the Shalford source which is dependent upon flows in the River Wey being maintained at greater than 30 Ml/d.

The method used to produce this DRS are similar to those used for the SWA WRZ, whereby a combination of modelled flows using the stochastic record and statistically determined groundwater levels have been used to generate this surface.

Henley

Figure 7 N6 Henley Drought Response Surface



The DRS for Henley, Figure 7, shows resilience to droughts up to at least 1 in 500-year severity. At this level of drought severity there is a high level of uncertainty but this view accords with what is known about our Henley sources in that they are Thames-side groundwater sources and so have a high level of drought resilience.

The Henley DRS was produced solely using statistical analysis of groundwater levels (method 4b) under low probability rainfall events.

References

1. *UKWIR 2017, "Drought Vulnerability Framework", UKWIR Report Ref. No 17/WR/02/12*
2. *EA 2017, "Using the Drought Vulnerability Framework in Water Resources Management Plans"*