Technical Stakeholder Meeting, 29 January 2018

Thames Water response to GARD's presentation 'The Resilience of the proposed Abingdon Reservoir to Long Duration Droughts'

Introduction

Thames Water (TW) has complied with the requirements set out in the Water Resources Planning Guideline (WRPG, 2017), the guidance that water companies must comply with when preparing their 2019 Water Resource Management Plans (WRMP19), in respect of assessment of Deployable Output (DO) and undertaking options appraisal, including that of the Abingdon Reservoir. TW has also applied innovative approaches, utilising stochastic methods to better understand supply system vulnerability to drought, facilitating a step change in the form of increased drought resilience of the London Water Resource Zone (WRZ).

The analysis presented by GARD does not comply with the requirements of the WRPG, and the associated methodologies and approaches. Two key errors are:

- The duration of a drought is not defined by the drawdown duration of the combined London reservoirs as defined by GARD (**Slide 4).** A drought usually starts well in advance of reservoir drawdown commencing.
- TW's preferred plan for WRMP19 increases drought resilience from a 1 in 125 year drought event to a 1 in 200 year drought event to align with the WRPG reference level of service for drought resilience. GARD suggests (S**lide 42)** that TW should 'consider up to 1 in 2000 years', a level of drought resilience far in excess of the prescribed reference within the WRPG.

TW's DO modelling has been carried out using the independently audited WARMS2 model[1] which shows that performance is maintained throughout analysis. An independent review[2] concluded that the simulation model used by GARD has a number of limitations. The report from the review states '*From an intrinsic modelling capability perspective GARD2 is inferior to WARMS2*', '*the two models cannot be relied upon to deliver the same outcomes under all operating conditions'* and there is '*significant residual concern as to GARD2's reliability for use as an intervention analysis tool*.' The results from the GARD model presented (**Slides 8 – 12)** should therefore be viewed in this context.

To clarify understanding of the approaches that TW is following to assess the supply forecast and to appraise options for the London WRZ within its WRMP19, and to further address technical questions GARD has posed to TW within the presentation, TW has provided responses relating to:

1. Baseline DO forecast with existing sources: Historic droughts
2. Baseline DO forecast with existing sources plus Abingdon reservoir: Historic droughts
3. Baseline DO forecast with existing sources plus Abingdon reservoir: Stochastic droughts

[1] WRMP 2019 WARMS2 Independent Review, HRW, September 2017
[2] The reliability and fitness for purpose of the GARD2 spreadsheet model of Thames Water's water supply system model, WARMS2, Hydro-Logic Services, December 2016

1. London baseline DO with existing sources: Historic Droughts

On **Slide 3**, GARD presents a misunderstanding of the approach to assess London's supply forecast, of which DO (DO) is a key component. There is no reference to the WRPG definition of DO '*the output of a commissioned source or group of sources or of a bulk supply for a given level of service as constrained by, hydrological yield; licensed quantities; environment (through licence constraints); pumping plant and/or well/aquifer properties; raw water mains and/or aquifers, transfer and/or output main; treatment and water quality*'. Furthermore, GARD suggests that individual 'normal' and 'dry' years within the entire period (historical record) of assessment are looked at in isolation when assessing water available from existing sources within the London WRZ. This is not correct. It is the Dry Year Annual Average (DYAA) DO, the average rate of supply that can be maintained from the London WRZ throughout the entire period of assessment (historical record) with restrictions on customer demand applied in line with TW's Levels of Service which forms the basis of the assessment.

TW has assessed the DYAA DO of London to be 2305 Ml/d with a DO benefit of 126 Ml/d achieved across the historic period of assessment by implementing progressively more enhanced customer water use restrictions to manage demand as combined London reservoir storage and Lower Thames Flow at Teddington weir declines. These demand management measures, and the resultant DO benefit, forms part of the Lower Thames Operating Agreement between TW and the Environment Agency (EA), with defined storage/flow level drought action triggers monitored using the optimised Lower Thames Control Diagram (LTCD). A further yield benefit to London is derived from various strategic schemes progressively 'switched on' at storage/flow level drought action triggers in line with Levels of Service on the LTCD. The yield from these schemes forms an integral part of London's DYAA DO.

Using the historical record, failure of the London WRZ, is described in terms of breaching the Level 4 emergency storage volume of the combined London reservoirs on the LTCD. Failure does not occur as DYAA DO is the average rate of supply that can be maintained from the London WRZ throughout the entire period of historical record without breaching Level 4 storage. Strategic schemes and restrictions on customer demand, applied in combination in line with Levels of Service and the LTCD, support the London reservoir storage and Lower Thames Flow at Teddington weir and so buffer the water supply system against Level 4 failures.

2. London baseline DO with existing sources plus Abingdon: Historic Droughts

The Abingdon Reservoir, also known as the Upper Thames Reservoir (UTR), is a proposed regulating reservoir, into which water is abstracted from the River Thames at Culham when available, releasing the stored water back to the River Thames and so augmenting flows for re-abstraction in London. The Abingdon Reservoir usable capacity provides support to London reservoir storage and Lower Thames Flow at Teddington weir during drought, buffering the downward progression of London storage through the LTCD and Level 4 failures.

The Abingdon Reservoir usable capacity would provide support, in combination with strategic schemes and restrictions of customer demand applied in line with Levels of Service and the LTCD, until the emergency storage level is reached. At this point strategic schemes and restrictions of customer demand applied in line with Levels of Service and the LTCD continue to support combined

London reservoir storage and Lower Thames Flow at Teddington weir and Abingdon Reservoir emergency storage is maintained.

Abingdon Reservoir usable capacity is not acting in isolation to support the combined London reservoir storage and Lower Thames Flow at Teddington weir to buffer Level 4 failures. Rather, Abingdon Reservoir is used in combination with other strategic schemes and restrictions of customer demand applied in line with Levels of Service and the LTCD.

The Abingdon Reservoir, if selected as an option, would provide a DO benefit during the historical record, increasing the London WRZ DYAA DO from 2305 Ml/d by +288Ml/d to 2593 Ml/d. This is due to the fact that the Abingdon Reservoir usable capacity provides support, in combination with strategic schemes and restrictions on customer demand, until Abingdon Reservoir emergency storage is reached. At this point strategic schemes and restrictions of customer demand, applied in line with Levels of Service and the LTCD, continue to support London reservoir storage and Lower Thames Flow at Teddington weir, buffering against Level 4 failures while Abingdon Reservoir emergency storage is maintained.

This DO of 2593 Ml/d is the baseline DO of the London WRZ including Abingdon reservoir and accounts for all 'types' of droughts (durations and intensities) which have occurred during the historic record up to a severity of 1 in 125 years. Operated to a DO of +288Ml/d Abingdon reservoir is resilient to droughts of this type into the future, including droughts such as the 1933/34 and 1943/44 when there was not complete refill over the winter months as referenced by GARD on **Slides 4, 5 and 17.**

With regard to GARD's specific criticisms relating to how the DO benefit of Abingdon has been modelled within WARMS2 (**Slide 16):**

- GARD states that the DO gain ignores Level 1 Service failures (1 in 4 years, instead of 1 in 5 years) and that if the 1 in 5 year standard is maintained DO gain drops. Level 1 failures refer to the frequency of media campaigns and a pragmatic risk based approach has been applied in assessing DO whereby, if the Level 1 curve is crossed for ≤1 week in certain instances the failure is disregarded. As an example, to achieve the London WRZ DYAA DO of 2593 Ml/d including the Abingdon Reservoir, the Level 1 curve is crossed 26 times as opposed to 20 times (100 year historic record / 5 = 20), however in the 6 instances which exceed Levels of Service these failures are for durations ≤1 week.
- GARD further states that TW's modelling assumes no changes to the existing LTCD. This is true: the operating strategy for the Abingdon Reservoir is aligned with the LTCD already optimised based on existing resources as agreed with the EA and in line with the appraisal of all other water resource options within WRMP19. Abingdon Reservoir would operate as a strategic scheme, which releases water during drought periods when storage/flow level drought action triggers, in line with Levels of Service on the LTCD, are crossed. The operating strategy for switching on the Abingdon Reservoir releases to deliver yield benefit are:
    - Naturalised Teddington flow remains at or below 3000 Ml/d for 10 or more days <u>AND</u> Combined London reservoir storage drops below the Teddington Target Flow (TTF) line of 800 / 600-700 Ml/d on the LTCD.

- It is also suggested that a revised LTCD should include Abingdon storage to restrict supplies if Abingdon is well drawn down at start of summer, however the key point here is that Abingdon is a proposed regulating reservoir which provides support to London reservoir storage and Lower Thames Flow at Teddington weir during drought, buffering the downward progression of London storage through the LTCD and Level 4 failures. It is the DO of the London WRZ, the system as a whole, which is considered and not just the Abingdon Reservoir in isolation when assessing the DO.

3. Baseline DO forecast with existing sources plus Abingdon reservoir: Stochastic droughts

GARD states that 500 days / 17 months is the critical threshold for the drought duration to which Abingdon is resilient (**Slide 17).** TW agrees that Abingdon is resilient to droughts of 17 months, however it is also resilient to longer duration droughts as during the assessment of baseline DYAA DO including the Abingdon Reservoir [2593 Ml/d] there are opportunities to preserve Abingdon Reservoir storage by stopping augmentation releases from the reservoir to the River Thames when river flows allow, i.e. when both Teddington flow and LTCD storage/flow triggers are not satisfied. Under these conditions augmentation release ceases and Abingdon Reservoir storage plateaus. This means that for the baseline DYAA DO run including the Abingdon Reservoir, drawdown of the Abingdon Reservoir to emergency storage takes >500 days and there are < 500 days when augmentation releases are made.

Abingdon Reservoir usable capacity (141,000 Ml) is a sufficient volume to provide support to London reservoir storage and Lower Thames Flow at Teddington weir when combined with other strategic schemes and restrictions on customer demand in line with Levels of Service and the LTCD. This applies for 550 days or 18 months of drought conditions, before Abingdon Reservoir emergency storage (9000 Ml) is reached, after which Abingdon Reservoir augmentation release ceases and its support for London reservoir storage and Lower Thames Flow at Teddington ceases. For extended, more severe droughts, emergency storage (9000 Ml) within the Abingdon Reservoir is preserved, with support for London reservoir storage and Lower Thames Flow provided from a combination of alternative strategic schemes and restrictions of customer demand in line with Levels of Service and the LTCD.

It is the drought vulnerability of the London WRZ, the system as a whole, which should be considered and not just the Abingdon Reservoir in isolation when determining which droughts should be the focus of the resilience analysis.

Failure of the London WRZ, which is described in terms of breaching Level 4 emergency storage of the combined London reservoirs on the LTCD, will occur after Abingdon Reservoir emergency storage is reached. That is, LTCD Level 4 failure to maintain emergency storage in the combined London reservoirs will be triggered by an extreme extended duration drought, and for droughts of extended duration Abingdon Reservoir emergency storage is preserved.

Using more extreme droughts from the stochastic data of extended drought duration, failure will occur only once the combined yield benefit from the Abingdon Reservoir, strategic schemes and restrictions of customer demand, applied in line with Levels of Service, is exhausted.

Resilience analysis for TW's WRMP19 carried out by Atkins to date has involved using more extreme droughts derived from a stochastic analysis of historical conditions.

The drought sample has included different 'types' of droughts than those contained within the historic record, droughts both with longer durations and intensities (as referenced by GARD on **Slide 6, 17 and 18**) and more severe droughts > 1 in 125 year drought return period. Such droughts result in a reduction in water available for abstraction, reductions in winter refill (as referenced by GARD on **Slides 4, 5 and 17**) and changes to London WRZ system performance including reductions in yield.

On **Slide 19** GARD describes how they have selected specific droughts 'searched for examples of long droughts' from the stochastic data record. These samples are therefore biased to a particular drought type and there has been no assessment of the risk with which such events might occur and how this risk compares to the EA's reference standard of 1 in 200 year resilience; **slides 21 to 23 and 25 to 30** then present the impact on London WRZ system performance of this biased sample. Atkins's (Doug Hunt's) method[3] avoids sample bias when selecting droughts as it enables the full 15,400 years of stochastic drought DOs, modelled and ranked using IRAS (the simplified lumped water resources model) to be sampled randomly within a prescribed range of return periods to produce drought libraries to be run through WARMS2 (Note: It is too resource intensive to run the full 15, 400 years of stochastic data through the fully distributed WARMS2 model). Mapping the WARMS2 DOs to the results to the IRAS results enables DO vs. return period plots to be generated.

Droughts of a similar type (duration and severity) to those selected by GARD will be included in Atkins' randomly selected sample of droughts which will include a total of 60 droughts. These droughts will lie within a range of severity just below the worst historic drought (1 in 75 years) and a 1 in 750 year event and will include a range of drought durations[3]

By simply selecting specific droughts GARD is conducting resilience analysis which is not appropriate. The way TW has carried out resilience analysis for WRMP19 is to look at the impact of stochastic droughts on yield, not on Level 4 failure days. As a worked example, on **Slide 25** GARD's model output shows London WRZ failing the Level 4 constraint under a 19 month drought for 43 days; this has occurred due to the fact that GARD has applied the baseline DO benefit of the proposed Abingdon reservoir assessed by TW using WARMS2 under the worst historic 1 in 125 year drought. The resilience analysis carried out by Atkins involves using more extreme droughts sampled from the stochastic data which includes 19 months drought of this 'type'. Level 4 on the LTCD remains the constraint on demand, and as a result the yield / the DYAA DO 2593 Ml/d as constrained by yield is reduced and the level of demand applied to the system ensures Level 4 is not breached throughout the period of assessment.

Response to GARD's Conclusions

In response to GARD's conclusions (**Slide 31),** the London WRZ system as a whole is currently resilient to droughts up to a return period of 1 in 125 years (0.8% annual probability of occurrence).

Preferred options which TW includes within WRMP19 will increase drought resilience to a 1 in 200 year event (0.5% annual probability of occurrence). This will be a step change in resilience during the 80 year planning horizon in line with EA's reference level of service, such that Level 4 events will

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[3] Proposal Abingdon Reservoir Resilience Assessment Method, Atkins, February 2018

not occur within the London WRZ up to a drought return period of at least 1 in 200 years. The Abingdon Reservoir is one option which would enable this step increase in drought resilience within the Thames WRZ to meet the EA's reference level of service for drought resilience.

TW's WRMP19 will also examine the impact of a 1 in 500 year drought event (0.2% annual probability of occurrence) on the London WRZ in terms of a reduction in DO.

The DO vs. return period plots to be generated from the stochastic data by Atkins as part of their Abingdon Reservoir resilience work [3] will include long duration droughts. The results from this work will enable GARD to characterise the droughts presented in their presentation in terms of return period (and annual probability of occurrence) and so contextualise the droughts within the EA's reference level of service for drought resilience, as well as TW's WRMP19.

DO vs. return period plots to be generated from the stochastic data by Atkins as part of their Abingdon Reservoir resilience work [3] will include long duration droughts and show the DO reduction under a range of drought durations and severities.

TW response to GARD Outstanding Questions

In response to GARD's outstanding questions **(Slides 32-34 and 39)**

1. DO vs. return period plots to be generated by Atkins as part of their Abingdon Reservoir resilience methodology[3] show the likelihood of London WRZ DOs (supported by Abingdon Reservoir in combination with other strategic schemes and restrictions of customer demand) under a range of different types of drought events (a range of durations) within prescribed return periods (severities) from within the stochastic data set.
2. See Response to GARD's conclusions on slide 31 above.
3. The EA's prescribed reference level of service for drought resilience is 1 in 200 years, i.e. Level 4 events will not occur up to a drought return period of 1 in 200 years, however may occur under droughts >1 in 200 years (this response also covers **slide 44**).
4. The operating strategy for the Abingdon Reservoir is aligned with the LTCD optimised on existing sources as agreed with the EA; this is a consistent approach with all other WRMP19 options (this response also covers **slide 45**).
5. Abingdon Reservoir emergency storage allowance has been taken off the total capacity of the reservoir, which equates to 30 days demand and includes a normal allowance for 'dead storage', water that it would be unadvisable to discharge back to the river due to water quality concerns. Abingdon Reservoir provides support to London reservoir storage and Lower Thames Flow at Teddington weir in combination with strategic schemes and restrictions of customer demand applied in line with Levels of Service and the LTCD. As a result, therefore, the drawdown of Abingdon Reservoir and the combined London reservoirs does not occur in parallel. The emergency storage at Abingdon reservoir would add to that of the London reservoirs which have storage equivalent to 30 days demand.
6. The Abingdon Reservoir is compared with other option types as part of the draft WRMP19 options appraisal.

TW response to GARD Comments on Atkins Proposal
DO vs. return period plots to be generated from the stochastic data by Atkins, sampled as part of the Abingdon Reservoir resilience work will include long duration droughts and show the DO reduction under a range of drought durations and severities. Atkins analysis will include a total of 60 droughts that lie within a range of severity just below the worst historic drought (1 in 75 years) and a 1 in 750 year event and will include the types of drought events, long duration droughts, consistent with those on **Slide 41** ; GARD's statement on this slide that there are 'examples of severe droughts missed by Atkins methodology' is not correct as droughts of this 'type' will be included in the resilience analysis. The results from this work will enable GARD to characterise the droughts presented in this presentation in terms of return period (and annual probability of occurrence) and then to contextualise the droughts within the EA's reference level of service for drought resilience and TW's WRMP19 which has been prepared in line with the latest WRPG.

In response to GARD's 'solution to modelling problem' on **Slide 43**, it is not feasible to run extended stochastically generated sequences of rainfall and PET through WARMS2 given the computation burdens involved. Although the IRAS model can be used to run the full 15,400 year stochastic time series, this relies on outputs from the Catchmod lumped parameter hydrological model of the River Thames, which produces different results to the more accurate, catchment distributed model contained within WARMS2 (Catchmod gives around 150Ml/d lower yield, with a +/- 150Ml/d range). However, the WARMS2 DOs can be mapped to the IRAS results enabling DO vs. return period plots to be generated.

Furthermore, GARD incorrectly state on this slide that WARMS2 uses HYSIM, this is not the case as WARMS2 uses inbuilt rainfall runoff models. In fact, the flows in Aquator not only include the 'natural' catchments, whichever rainfall-runoff model they use, but also include the impacts of return flows, abstractions etc., and so in order to get flows that end up being in Aquator, you have to run Aquator – there's no quick way round it.

TW, 23/02/18