Technical note

Project:	Thames Water Stochastic Water Resources	**To:**	Chris Lambert
Subject:	Abingdon Reservoir Resilience Assessment Method	**From:**	Doug Hunt
Date:	17 Oct 2017	**cc:**	Lesley Tait

1. Introduction and Purpose

Although a resilience assessment has already been carried out for the Abingdon reservoir based on a random selection of 30 stochastically generated droughts, GARD has expressed reservations about the results of the analysis. GARD has presented results, but these do not consider the level of risk to the conjunctive system and there appear to have been some mis-understandings/errors in the GARD analysis.

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 timeseries, this relies on outputs from the Catchmod lumped parameter hydrological model of the River Thames, which produce different results to the more accurate, catchment distributed model contained within WARMS2 (Catchmod gives around 150Ml/d lower yield, with a +- 150Ml/d range). Some form of drought selection is therefore required to allow evaluation of drought resilience to the level of accuracy that GARD require, but it is apparent that an analysis based on standard 'rule of thumb' measures of statistical significance (30 samples is usually considered to be statistically significant) is not acceptable in this case unless a much more focused sampling approach is used.

This proposal therefore contains details of a proposed sampling and analysis protocol that is both entirely transparent and incorporates a total of 40 droughts that lie within a range of severity between the worst historic drought and a 1 in 500 year event[1].

The analysis proposed within this note effectively takes circa 25% of all of the droughts in the 1 in 100 to 1 in 500 return period range and examines the expected yield of the reservoir under all those events. This is done by running WARMS2 at 100, 200 and 300Ml/d yield increments, choosing the increment that closest resembles the yield for that drought and then calculating the exact yield from the WARMS2 results.

This will effectively demonstrate the yield behaviour of the reservoir under all conditions that would need to be considered in terms of drought resilience for Thames Water. It is similar to the method that has already been used, but has been modified to be more fully representative of the range of resilience drought events and is both more flexible and transparent in calculating yield from the reservoir under each drought

[1] According to IRAS – some of these will be less severe once the meteorology is run through the WARMS2 hydrological model.

Technical note

2. Proposed Method

The method for selection is focused on identifying a set of droughts that is fully representative of droughts that lie within the 1 in 100 to 1 in 500 return period range within the stochastically generated data set, and is clearly randomly selected without bias, whilst using the full accuracy of the WARMS2 hydrology. In accordance with accepted good practice the focus is on determining the expected benefit and range of benefit that might be expected from the UTRD scheme, given its conjunctive use with the existing London system.

The proposed method is as follows:

1) *All* droughts that fall within the expected 1 in 100 to 1 in 500 range according to the yield calculated in IRAS are identified and the list provided to GARD. This will include approximately 160 drought events. As noted in the stage 2/3 report, yield from the IRAS hydrology tends to be less than WARMS2, so this covers all droughts in the range 1860 to 2140Ml/d demand according to IRAS.
2) Once the actual number of droughts is known, these will be listed in order according to:
    a. Run number
    b. Year within that run
3) From the list generated under item 2), every fourth drought will be selected, resulting in a sample of approximately 40. Where a drought is selected and this was modelled in the previous sample then the selection will skip onto the next drought and sampling will continue. The results of this highlighting the selected droughts will be forwarded to GARD.
4) Four drought libraries will be put together as per the previous assessment method that contain the rainfall and PET for the 5 years prior to and 5 years after the drought (i.e. 10 droughts per library, 40 droughts in all). Each library of PET and rainfall will be run through the version of WARMS2 that includes the UTRD.
5) WARMS2 will be run for each library to calculate the minimum yield of the droughts contained within that library based on a Level 4 failure constraint. Other yield failure constraints will be turned off. The following WARMS2 runs will then be carried out for each library:
    a. A ‘minimum baseline’ run (nominal library DO) with the reservoir turned off and demand set to the lowest expected yield.
    b. A ‘mid range baseline’ run with the reservoir turned off and demand set to the lowest expected yield of the existing London system for that library, plus 50Ml/d.
    c. 6 additional runs that evaluate the benefits of the UTRD:
        i. 3 runs where the reservoir is turned on and demand set to the ‘minimum baseline’ for that library plus 100Ml/d, 200 and 300Ml/d respectively
        ii. 3* runs where the reservoir is turned on and demand set to the ‘mid range baseline’ for that library plus 100, 200 and 300Ml/d respectively (i.e. nominal library DO plus 150, 250 and 350Ml/d).
6) The reservoir levels generated for London and UTRD for each run in WARMS2 will be forwarded to GARD (8 runs for each library, so 32 WARMS outputs in total)
7) The net yield from the UTRD reservoir for each drought in each library will be calculated as follows:
    a. Either the minimum or mid-range baseline results will be used as the basis of the analysis. The selection will depend on which run produces a reservoir minimum that is closest to L4 without breaching it.
    b. The reservoir storage outputs from the relevant yield run (baseline plus 100, 200 or 300Ml/d) that produce a minimum storage value for that drought that is closest to, *but below* the relevant baseline will be taken and input to the spreadsheet.

Technical note

c. The reservoir yield is then equal to the demand increment that produces a minimum storage with the reservoir that is the same as the minimum storage without the reservoir. As this will not be exactly equal to the 100, 200 or 300Ml/d runs, the actual yield will be estimated using the spreadsheet calculator. This uses a simplified differential calculation to calculate how far the yield is away from the 100, 200 or 300Ml/d nearest estimate. This calculation spreadsheet will be set to GARD and works as follows:

   i. Demand for the relevant reservoir yield run (i.e. where the minimum storage is at or below the relevant baseline) is progressively reduced in 10Ml/d increments and this difference is added on a daily basis to the WARMS2 results for that run.

   ii. Modified reservoir storage outputs for each 10Ml/d increment are calculated by adding the relevant demand reduction to the previous day's modified final storage, bounded by:

      1. The maximum reservoir storage

      2. The control curve condition in comparison to the original WARMS2 results, which accounts for:

         a. Differences in demand management

         b. Differences in allowable flow rate according to the LTOA.

   iii. The estimated yield for the reservoir is equal to the demand increase within the selected WARMS2 run (i.e. 100, 200, or 300Ml/d), minus the spreadsheet increment that is required to match the with and without UTRD minimum storage values for that drought.

8) The output estimated yield results for each drought will be summarised into a table that indicates the range and average of the expected benefits from the reservoir across the 40 droughts. A suitable probability curve (Weibull, Normal etc.) will be fitted to an output histogram and the 90% confidence interval of the mean yield benefit will be calculated based on the observed variance. This calculation will be sent to GARD.