GARD response to

Thames Water's Consultation on

Draft Water Resources Management Plan 2019

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Summary

Key Points

- Key dWRMP assumptions (population, leakage) have changed so fundamentally during consultation that the dWRMP analysis is invalid.
- A second draft WRMP should be produced using the new assumptions, incorporating this and other responses, **and the consultation period repeated**.
- Elements of the dWRMP show bias in favour of the reservoir while downplaying the positive elements of other schemes.
- The water supply deficits forecast by Thames Water contains flawed logic or false assumptions in major areas including deployable output, future pcc forecasts and the effects of climate change. This section should be reworked.
- The over-estimation of future deficits could lead to over-provision and unnecessary investment. This resource would be better targeted at reducing leakage and replacing ageing infrastructure.
- The Teddington DRA is an excellent scheme that uses a large, continuous, resilient resource with limited investment. It could be expanded as future demand materialises.
- The dWRMP approach to effluent reuse is confused and requires further analysis.
- Desalination provides scope for 450 Ml/d of blended desalination schemes. This would reduce pressure on overdeveloped River Thames water resources and bring in 'new water'. Thames Water should revisit this option.
- Water companies repeatedly state that the South East of England is highly water stressed. It makes no sense that inter-regional transfers, as suggested by major independent reports for over 50 years, are not included in the preferred programme.
- In the limited analysis presented, inter-regional transfers are downplayed, perhaps because they would preclude the case for the Abingdon reservoir.
- The case for the reservoir is flawed. It includes a limited SEA that makes false assumptions, ignores public opposition, fails to explore risk and resilience, ignores flood risk, downplays the effect on archaeology, landscape and heritage and miscalculates the amount that should be set aside for emergency storage.
- Selection of an appropriate emergency storage volume for the reservoir reduces its deployable output from 288 to 245 Ml/d. This can easily be provided by other options.
- The environmental impact of the reservoir is underestimated to an extent that questions the integrity of the SEA. Elements are present in the reservoir plan that led to rejection of other options.
- When assessed more appropriately, the reservoir ranks as the 84th worst option out of 85 in terms of adverse effects and only better than 2 of the other 85 in terms of benefits. It should have been screened out of the programme.
- Abingdon reservoir has only 30 days of resilience in droughts more severe than the 1-in-200-year deployable output design standard.
- The failure to address adaptability must be addressed in the next dWRMP.

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1. The need for a second consultation

There have been astonishing reversals of position by Thames Water during this consultation period. It is unacceptable for a draft WRMP to come to the Stakeholder consultation in such an unfinished and un-validated manner.

Leakage targets provide one of the key underlying assumptions for the dWRMP. The published targets have also been abandoned and more stringent ones adopted part-way through the consultation process.

There are many other issues detailed below, and analysed in subsequent sections of this response such as:

- the early abandonment and adoption of new population figures without accompanying explanation and analysis
- the absence of a proper Adaptability Analysis in the Programme Appraisal process,
- the work still in progress on Resilience analysis of the Abingdon Reservoir,
- the medium-size options recently imported into the feasible projects list, but not available for Stakeholder analysis, and
- the release, after the start of the consultation, of the report showing unexpectedly high transmission losses in the Severn.

The mid-consultation changes, the majority without proper published analysis of their full consequences, destroy the credibility of the dWRMP.

GARD therefore calls for a second consultation on the revised proposals when they are produced by Thames Water.

2. Overall weaknesses in the dWRMP and the consultation process

Bias and lack of transparency in cost estimates

There have been large unexplained changes in option costing since WRMP14 and through successive versions of Fine Screening Reports into the draft WRMP. The unexplained changes all make the Abingdon reservoir appear less costly than other options. Thames Water have refused to supply details of cost breakdowns to explain these changes which will have a large effect on choice of options and selection of the preferred programme. There has been no transparency of costings. 17

Unreliable and uncertain deficit forecasts

There has been too much reliance on stochastically generated river flow data which have been shown to be unreliable. This may have led to large over-estimation of the 19

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projected deficit and, certainly, a high level of uncertainty, which has not been recognized.

There are also large uncertainties in the potential deficit due to:

- population projections
- future per capita consumption
- climate change

With this degree of uncertainty in the deficit, avoidance of white elephants should be a high priority in the future development programme. There should be much more emphasis on phasing of options to give modest increments of supply growth, and adaptability of the future development programme. There should be a much more detailed and transparent adaptability analysis.

Failure to engage effectively with stakeholders

Although Thames Water's extensive programme of stakeholder engagement has been effective in keeping stakeholders informed of Thames Water's own views and progress on the dWRMP, it has failed to provide effective engagement with stakeholders where their views don't align with Thames Water's. Thus, GARD's responses to documents made available while developing dWRMP have been largely ignored. 18

3. The future deficit

Demand forecasts

GARD believes the revised figures in Thames Water's new analysis still over-estimate population growth in London by 0.11 million by 2045 and by between 1.1 and 1.6 million by 2100 – equivalent to about 15 Ml/d demand in 2045 and 136-198 Ml/d in 2100.

Thames Water has failed to follow Environment Agency guidelines for population estimation and has abandoned its long-term population forecast based on the University of Leeds model (announced to stakeholders after the release of the draft WRMP). Whilst the full effects of this are difficult to analyse, the principal effect is a drop in the population forecast for 2100 of at least 1.4 million people in the Thames Water area. 25

The dWRMP fails to include discussion on the potential overestimation in the short term forecast due to the use of Local Plan data and rationalise this with ONS 2016 projections. It will now be necessary to re-run the Edge Analytics model for the 2018-2045 period using the newer 2016 ONS projections rather than 2014 data.

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There is evidence that the population increase could be even lower than the 2016 ONS predictions. This is due to reductions in immigration and fertility rates, uncertainty over the effects of Brexit and the impact of technology.

The demand from per capita consumption (pcc) forecasts for the Thames Water supply area is dominated by the forecast that the average pcc for the London WRZ will hardly decline from 2044/5 (128 l/h/d) to 2100 (126 l/h/d). This is in marked contrast to the Thames Valley zones, which show continuous decline for the whole of the planning period, and to the forecasts in other water companies' draft WRMPs.

The arguments given by Thames Water for this stationary pcc, are based on assumptions about social trends (household occupancy), 'unalterable' behaviour of various consumer groups (flat-dwellers, rented accommodation tenants, south-Asian ethnic minorities), and accounting changes in the property classes measured in the pcc statistics. These are not-quantified in a transparent manner and are not justified. Some assumptions, especially those concerning ethnic minorities, are skewed by the outcomes of the abandoned population projections and need revisiting.

There is no allowance for continuing technology improvements in the reduction of the pcc in London or any other Thames Water Resource zone.

Deployable output and climate change

In WRMP14, the deployable output of London's supplies was underestimated by about 150 Ml/d. Although this huge discrepancy has subsequently been corrected in WARMS2 modelling for dWRMP19 (but incorrectly attributed to changes in the Lower Thames Control Diagram), it is indicative of the scale of uncertainty surrounding Thames Water's deployable output assessments. 33

The evidence of modelled operation of London's supplies in the climate since 1950 suggests that climate change over the past 70 years has not led to more frequent or severe droughts affecting London's supplies. 36

In these circumstances, Thames Water's assessment of climate change causing a loss of deployable output for London's supplies of 125 Ml/d by 2045 and 230 Ml/d by 2100 looks to be an improbable worst case, rather than a central estimate.

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The forecast deficit

Thames Water's forecast base case deficits should be viewed as a worst case for contingency planning, not a central estimate for a firm development programme. The over-estimation of the deficit for London could be in the region of: 37

Source of potential overestimate	By 2045	By 2100
Population forecasts	15 Ml/d	170 Ml/d
Per capita consumption	80 Ml/d	80 Ml/d
Climate change	125 Ml/d	230 Ml/d
Total potential overestimate	220 Ml/d	480 Ml/d

With this amount of potential overestimation of the London baseline deficit, there is a grave danger of over-provision of new sources and creation of white elephants. The WRMP should address this uncertainty through proper and transparent Adaptability Analysis and much more attention to the phasing of new sources.

4. Leakage control and demand management

Leakage control

The leakage performance of Thames Water is so bad that it skews the statistics for the entire industry. Thames Water fails to set targets that move it at least toward median performance or better. The principal problem is that artificial constraints adopted in the application of Integrated Demand Management (IDM) limit Thames Water's ability to acceptably improve its performance. These should be removed. 42

Ofwat requirements imply a leakage target for 2025 of 525 Ml/d or below, for 2035 at or below 465 Ml/d and for 2040, 424 Ml/d or below. 45

NIC recommend halving leakage by 2050, a reduction to 300 Ml/d. Meeting this leakage target would save approximately 25% of the forecast London deficit. GARD supports the NIC's target.

The early 2018 cold snap, which resulted in many burst water mains and about 20,000 households without water, shows that capital maintenance in London is below required levels.

Given this capital maintenance requirement, pipe replacement and associated costs should be allocated to the capital maintenance budget, improving the NPV of the pipe replacement programme. 46

Demand management

The dWRMP shows that in London, measured pcc increases as smart meter penetration increases, which makes no sense – these figures should be reworked to 48

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include projected 17% savings.

TW should urgently address the fact that its meter penetration remains significantly behind the rest of the industry. The dWRMP lacks ambition in this respect. Our analysis shows that TW's arguments supporting its poor performance in this area do not stand up to scrutiny. The metering plan described falls below even what TW has achieved historically and there is no plan post 2035. The metering plan should be revisited. 48

We suggest targets for London of meter penetration of 60% in 2024/25, 80% in 2029/30 and 90% in 2030/35. 51

TW should incorporate savings generated by the water efficiency programme which are missing from current plans. Smart home visits should be increased substantially, and more Smarter Business Visits should be conducted and targeted at those sectors that historically have been shown to give the most saving. 57

5. The Teddington DRA scheme

This is an excellent scheme as it uses a large continuous resilient resource with limited capital investment. The scheme offers flexibilities of operation to Thames Water (TW), being capable of expansion to supplement the East and West London systems.

Thames Water underestimate the deployable output of the Teddington DRA scheme under present available flows from Mogden, and in future when available flows will increase as demand grow. The causes of under-estimation are: 60-64

- Inadequate allowance for infiltration and trade flows
- Inappropriate trigger rules
- Inappropriate allowance for emergency storage

The Teddington DRA scheme is forecast to be needed at full output in about 2045, by which time the output from Mogden sewage works will have increased substantially. Taking account of the increased Mogden flows and more appropriate operating assumptions, GARD forecast the ultimate deployable output of the scheme to be at least 450 Ml/d. 66

The Environment Agency is said to be concerned about the effect of effluent discharge on water temperature and ecology in the Thames. Thames Water should clarify and resolve any issues, making allowance for mitigation of impacts, for example by reducing scheme use at critical times of year. This would have some impact on deployable output, so the matter should be addressed with urgency so that realistic estimate of the scheme, which is central to the preferred programme, 67

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can be made for the final WRMP.

Sewage treatment works' flows continue during droughts and such conditions are included when assessing flows. Therefore, the DRA scheme is fully resilient to climate change. Thames Water do not give adequate reasons for their classification of the scheme as 'partially resilient' to climate change, so this should be reconsidered and explained. 67

Thames Water's estimated unit AIC cost of the scheme has trebled since the Fine Screening report of October 2016. The increase should be fully explained, and details made transparently available. 68

6. Effluent reuse and desalination schemes for London

Effluent reuse

Deephams reuse is not in the dWRMP preferred programme but does appear in the development programme shown to the March 2018 Water Resources Forum. Thames Water should clarify their intent. 71

A clearer explanation between the parameters set for Beckton treatment and actual treatment requirements should be made. The treatment at Coppermills WTW (to Drinking Water standards) should also be considered. In the preferred Beckton scheme, mixing expensive reverse osmosis processed water with river water before pumping only part to the Lee valley reservoirs and losing the remainder to the sea makes no sense; the amount of treatment required should be reconsidered. 72

The 2nd scenario for the Beckton reuse option should be reworked as it appears to be incomplete. Discussion should include why parameters fail at higher flows and what additional processes were considered.

A risk-based approach should be used in the Thames Water 'Water Safety Plan' and by extension the dWRMP, which sets out the relevant risk of each parameter and establishes a proper basis for the treatment chain. 75

GARD believes that impacts on the tideway water levels and its ecology, are either within the range of natural variation or will be less than the expected effect of such factors as climate change. This view is borne out by the analysis of Thames Water's environmental consultant. Statements on tideway effects should include the expectation that 80% of the diverted water would be returned as freshwater to the sewage treatment works; this would allow for much larger schemes to be proposed. 76

No consideration has been made of returning the Beckton effluent to the Rye Meads STW, similarly to the Hoddesdon transfer. Thus, there is scope for

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substantially reducing the cost of the Beckton reuse option and increasing the size of such a scheme.

Thames Water's estimated unit AIC cost of the effluent reuse scheme has trebled since the Fine Screening report of October 2016. The increase should be fully explained, and details made transparently available.

Desalination

Freshwater return flow should be included in the planning for these schemes since this would allow schemes to be 4 times larger than proposed without breaching precautionary salinity limits. Were the Teddington DRA to expand to its full potential, then a freshwater supply of 900 Ml/d could be produced, with capacity for blending increased to about 450 Ml/d. 82

TW should consider a pipeline interconnection system since this would provide spare capacity in the long term. The tunnel from the Waldrist Way, 2d, option could be aligned with either Beckton desalination site to allow use of one tunnel.

If space at Beckton is limited, the Lee Valley site would be a viable alternative that could provide 150 Ml/d. The modular nature of desalination plants means that output from Crossness 2d could be diverted to support Riverside 3a when required. 84

There is scope for 450 Ml/d of blended desalination schemes. The water resources of the River Thames basin are already over-developed and there is a strategic need to bring in "new water" for the South East of England. 85

7. Inter-regional transfer schemes

Inter-regional transfers generally

The South East of England has a high and growing population and a shortage of water. The region is over-dependent on reservoirs filled from the River Thames and groundwater abstraction from storage in natural aquifers.

The London reservoirs already have insufficient water to refill reliably in dry winters and this will get worse as demands grow. The groundwater aquifers are over-developed with many cases of ecological damage, particularly to chalk-streams. The existing shortage of naturally available water in the Thames valley can only get worse as demands grow. 87

Fundamentally, the South East of England needs "new water" through inter-regional transfers from wetter and less populated parts of the country. This has been recognized by every significant report on the water resources of England and Wales in the past 50 years, when the work has been undertaken by bodies that are not

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biased towards individual regions or water companies:

- the Water Resources in the early 1970s
- the National Rivers Authority in 1994
- Water UK in 2016
- the National Infrastructure Commission in April 2018

In GARD's opinion, Thames Water has not recognized the strategic need to bring "new water" into the South East of England. The studies leading up to the draft WRMP and the plan itself give the impression that Thames Water have focused on reasons not to transfer water into the region, rather than finding ways to overcome any problems identified. This unfortunate attitude appears to have persisted since the Public Inquiry into WRMP09 in 2010. 88

The unsupported Severn-Thames transfer

The yield of the unsupported Severn-Thames transfer has been under-estimated by around 50% due to use of flawed river flow data generated by stochastic modelling. 90-92

The unsupported transfer, yielding at least 120 Ml/d, is viable, requires almost no inter-company trading and should be the first stage of a phased development of inter-regional transfers from the North West to the South East of England. 89-94

Severn-Thames transfer supported by Vyrnwy reservoir

The yields of Vyrnwy support options have been underestimated through use of flawed stochastic data, failure to consider larger regulation releases to make better use of Vyrnwy storage and unjustified assumptions about climate change. 96

With support from Vyrnwy, the Severn-Thames transfer could provide up to 400 Ml/d of yield for Thames Water and other water companies in the South East. 99

The report on River Severn transmission losses, only produced at the last minute, fails to address the fundamental water balance behind any losses, but makes vague and unjustified suggestions that they could be much higher than feasible from consideration of the water balance. 107

The assessment of adverse effects for the SEA appears to be highly subjective and biased when compared with scoring of the same criteria for the Abingdon reservoir. 111

There has been no transparency of cost estimates, but from the available NPV costings there appear to be huge inter-company trading costs included in the opex allowance, with no explanation provided. 105

Since dWRMP14, the capex cost of the Deerhurst to Culham link appears to have 107

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increased by about 500% with no explanation.

In GARD's opinion, Thames Water's assessment of the Severn-Thames transfer options has been heavily biased to make the schemes appear less favourable than the Abingdon reservoir.

The work should be independently reviewed by an organisation that is neither instructed nor paid by Thames Water or other water companies, making a proper assessment of the Thames Water and GARD analyses, and taking account of the points raised by GARD.

8. The Abingdon reservoir

Thames Water's choice of site and experience of reservoir construction

Thames Water appear to have selected the Abingdon site because it is a large flat area devoid of settlement, ignoring other facts: it is a floodplain, has gravel and greensand seams, is close to heritage assets and in a non-industrialised area. These factors are grounds for rejection at other sites. 116

Thames Water have never constructed a reservoir. This plan is for an experimental, high risk project of unprecedented size. The risk is not reflected in the dWRMP.

Thames Water have misdirected public sentiment, playing on people's feelings about housing development, pretty reservoirs in valleys, leisure amenities, while playing down the unnatural bunded design, flood issues, industrial scale, and disruptive construction and operation. 117

Deployable output and emergency storage

The minimum average usable water depth in the reservoir should be assumed to be 5m to give acceptable water quality. Thames Water's allowance of 15,000 Ml of dead storage for Abingdon reservoir only leaves an average water depth of 2.7m – the dead storage should be increased to 27,500 Ml to give a minimum average usable water depth of 5m. 119

Thames Water's allowance of only 6% of emergency storage is far below the industry norm of 12-25% and would be of unacceptable water quality, being never more than 4.2m average depth. The emergency storage allowance should be 15% of live storage, in addition to the revised allowance for dead storage. 120

With these more realistic provisions for dead and emergency storage, the deployable output of the Abingdon reservoir option should be reduced to from 288 to 245 Ml/d, when determined using the droughts of the 20th Century. 121

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Environmental impacts of the reservoir

TW should re-assess the division and weighting of assessment sections in the SEA for the reservoir since the existing skewed assessment downplays adverse effects and over-emphasises beneficial effects. GARD's reassessment places the reservoir as the 84th worst option out of 85 options under consideration for adverse **effects** and only better than 2 of the other 85 options in terms of benefits. 122

TW should re-assess the effect on historic listed houses and the listed Causeway since it is greater than stated in the SEA. There should be more recognition of their obligation to conserve and enhance heritage assets and their settings. TW must understand that the proposed removal and rerouting of ancient waterways is unacceptable, as is the loss of ancient field systems and boundaries. They must realise that such things once lost cannot be retrieved. 126

TW must acknowledge their obligation to protect archaeologically important sites, including unknown assets which are either known or suspected to be of high importance. The Thames region is rich in unexcavated archaeology, because of its early and uninterrupted settlement. 126

Flood risk

The dWRMP lacks any detail on how the reservoir will affect the local floodplain. TW should conduct a full flood risk assessment for the reservoir and any ancillary works. 130

TW should demonstrate how its planned programme will support and comply with the Oxfordshire County Council flood risk management strategy and how it will meet the requirements of the Thames River Basin District Flood Risk Management Plan to 'enhance and extend the floodplain'. 132

There should be explanation of how its plan to provide deep-shelf flood compensation will provide extra capacity, when local experience shows that such schemes will fill naturally with water due to the high water table.

Since 2009, considerable housing, approved by the local authority, has been built immediately adjacent to the planned reservoir site. TW should demonstrate how it intends to protect these properties and determine how much these have already reduced the space available for the reservoir. 133

Reservoir leakage

TW should provide evidence as to how the 165 million tonnes of stored water will affect the underlying geology and local water levels.TW must acknowledge the geology of the area and the presence of sand and gravel seams. It must explain why these attributes were grounds for rejection of other sites, but not Abingdon. TW 133

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should provide convincing evidence as to how they will protect against leakage and seepage and protect local villages.

9. Resilience to droughts

Resilience design criteria

Thames Water's resilience design criteria have failed to draw the distinction between the return period of droughts to determine deployable output and the criteria for resilience to droughts worse than the deployable output design drought. 135

Thames Water should not have slavishly adopted a 1 in 200-year design standard for deployable output, contrary to the surveyed wishes of 88% of their customers and without a proper risk assessment. The 1 in 200-year deployable output design standard commits Thames Water's customers to pay for about 150 Ml/d of replacement sources at an NPV cost of roughly £1 billion or an equivalent amount of mains replacement to reduce leakage. 136

In determining the resilience standard for London, Thames Water should consider the allowance for droughts worse than historic that is already provided by the generous allowance for emergency storage in the London reservoirs and in headroom. 136

The risk assessment needed for setting the resilience standard should take account of the probability of occurrence of droughts of different durations and intensities, and the availability of short-term emergency sources. There should be a strong focus on long duration droughts that would affect the output of the London Aquifer Recharge schemes and the West Berks Groundwater scheme. 137

Comparison or resilience of main option types

Abingdon reservoir has only 30 days of resilience in droughts more severe than the 1 in 200 year (or other) deployable output design standard; after 30 days the reservoir would be empty and useless. 138

The deployable outputs of Severn-Thames transfer options have been shown by Atkins analysis to be resilient to droughts worse than historic. In the event of a drought more severe than the deployable output design drought, the Severn-Thames transfer could always supply up to the capacity of the transfer via an Emergency Drought order, adding greatly to resilience of London's supplies. The Emergency Drought Order for such a use of the Severn-Thames transfer would be justifiable on grounds of over-riding public interest. if the alternative was standpipes and rota supply cuts in London. 140

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The Teddington DRA, effluent reuse and desalination options would be fully resilient in droughts more severe than the DO design standard, being able to continue supplying indefinitely.

Thames Water's scoring of the severe drought resilience of the various option types has been grossly biased in favour of the Abingdon reservoir, which would have the least resilience of the main option types, in the event of a drought more severe than the deployable output design standard. 141

10. Thames Valley needs

Demand forecasts

The forecast demands in SWA zone have been over-estimated through exaggeration of Thames Water's population growth estimates. The Final Plan peak week demands in SWOX zone have been over-estimated, with the peak week to annual average ratio forecast to increase over the planning period despite the introduction of universal water metering. 143

Needs of SWA, zone Affinity, South East Water and chalkstreams

The planned Teddington DRA scheme will enable the forecast needs of SWA zone, Affinity and South East Water to be met by reallocation of some of Thames Water's lower Thames abstraction licences through trading agreements. These should take account of the return of 80% of water abstracted for the other water companies as STW effluent, leaving it available for re-abstraction to fill the London reservoirs. 144

Thames Water should inform the public and environmental interests of the ability of the Teddington DRA scheme to alleviate over-abstraction in Thames Valley chalk streams, rather than saying that the Abingdon reservoir is the only solution. 146

SWOX zone

SWOX needs, when correctly forecast, can be met entirely by demand management. If eventually needed for SWOX zone, the Oxford canal transfer scheme can be combined with the Culham DRA scheme and GARD's earlier SWOX reuse proposal to boost supplies from Farmoor. 148

11. Option and programme appraisal

The overall approach

GARD welcomes the adoption of long term perspectives, and multi-parameter decision making in the dWRMP. However, we do not believe metrics have been applied in an unbiased manner.

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Adaptability scenarios have yet to be agreed and were not available for the dWRMP. This is unacceptable: the revised draft which we are told will include this metric must be put out to a second consultation.	161
GARD does not agree that the SWOX zone is ‘highly complex’ and Thames Water should revisit its strategic risk assessment.	153
The fundamental data used in the appraisal are largely non-transparent and GARD has no confidence in their accuracy or that they have been produced without bias. Costs cannot be analysed in any meaningful way from the current dWRMP. Thames Water should provide detailed costs so that programmes can be properly assessed. Since WRMP14, costs of various programmes have changed markedly in a way that does not make any sense. Thames Water should explain the basis for these changes. The deployable outputs described for many options in the dWRMP are considered to be wrong.	155
Failure to consider adaptability	
In GARD’s opinion, adaptability to uncertain future deficits is the most important no-financial measure in option and programme appraisal. This has not been considered at all in the current draft WRMP, despite GARD’s emphasis of its importance in responses to Fine Screening Reports and at stakeholder meetings.	161
Adaptability scenarios have yet to be agreed and were not available for this draft dWRMP. This is unacceptable: the revised draft which we are told will include this metric must be put out to a second consultation.	
The SEA assessments	
The SEA treatment of different topics is inconsistent and at times subjective. We do not consider the SEA assessments in the dWRMP to be ‘clear and justified’ as required by guidance. Thames Water should consider including the assessment ‘uncertain’ in its SEA and explain how this uncertainty will be resolved.	156
The expansion of SEA Topics 1, 2 and 3 leads to a more favourable case for the reservoir than would otherwise be so. Expansion of Topics may have led to an element of double accounting of benefits that may not conform to best practice, and expansion of certain SEA Topics has been at the expense of others, leading to an unbalanced weighting between topics. This is a clear instance of bias towards Abingdon reservoir.	156

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Archaeology, cultural heritage and flooding have been downplayed in the SEA and these topics should be revisited to give more detail.

Treatment of similar issues between different options is inconsistent. This undermines the credibility of the dWRMP and we expect relevant sections of the SEA to be reworked using independent input. Due to the substantial changes already made to the dWRMP underlying assumptions, we call for a revised environmental report to be issued for consultation.

Assessment of options and alternative programmes

Constraints placed on the development model relating to leakage and demand management have compromised the attempt to account for intergenerational equity. These constraints have also compromised programme optimisation.

Thames Water should be bold and recognize trending public and political sentiment by including model metrics that consider the effects of mounting debt and the need to be seen to be paying a fair amount of corporation tax. At the same time there needs to be a better balance of long-term value rather than lowest cost.

Attempts to engage customers are applauded, but Thames Water needs to consider how to manage public expectation that runs counter to regulatory pressure.

Adaptability

A true adaptability analysis should be conducted that takes account of the errors and conservatism in the demand forecast. This would produce a programme with actual adaptability to a changing future that favoured flexible 'phaseable' projects. 161

The GARD suggested programme

On the demand side, bringing leakage under control and targeting reductions in pcc through increased metering and educational outreach programmes are the obvious way ahead. For supply, the most flexible programme, best suited for phased development, would comprise the Teddington DRA scheme, supported as necessary by London effluent reuse, desalination and the Severn-Thames transfer. Such a scheme would be resilient to changes in demand and climate change and have the least cumulative environmental impact. Appropriately promoted, they would enjoy widespread public support and provide Thames Water customers with the best long-term value for money.

Pursuing the Abingdon reservoir option risks Thames Water having its own Kielder reservoir 'moment'. 168

1. Introduction

Key points

- GARD is pleased that the Teddington DRA scheme appears to be Thames Water's preferred option for the next major source for London, noting that this was a scheme proposed by GARD in WRMP09, but rejected by Thames Water both in WRMP09 and WRMP14.
- There have been large unexplained changes in option costing since WRMP14 and through successive versions of Fine Screening Reports into dWRMP.
- Thames Water have refused to supply details of cost breakdowns to explain these changes which will have a large effect on choice of options. There has been no transparency of costings.
- There has been little explanation or justification of deployable output of the main option types and little transparency of the WARMS2 modelling used in assessing deployable outputs.
- Thames Water's extensive programme of stakeholder engagement has been effective in keeping stakeholders informed of Thames Water's views and progress on the dWRMP, but has failed to provide effective engagement with stakeholders where their views don't align with Thames Water's
- GARD's responses to documents made available while developing dWRMP have been largely ignored.
- There has been too much reliance on stochastically generated river flow data which has been shown to be unreliable.

1.1 Scope of response

GARD is grateful to have had the opportunity to participate as a stakeholder in the development of this Water Resource Management Plan (WRMP) and to respond to this consultation. We are pleased that the draft WRMP appears to be recommending the Teddington Direct River Abstraction (DRA) as the next major source for London, noting that this was a scheme proposed by GARD during preparation of the WRMP in 2009 and during the Public Inquiry in 2010.

However, we are concerned that Thames Water appear to be favouring the Abingdon reservoir as the next major option for London, following the Teddington DRA scheme, and that this is said to be needed as early as the mid-2040s. The Abingdon reservoir would have a big impact on local people and businesses, both during its construction and through its permanent impact on the local environment. With the long lead time needed for such a major construction project, there would be an immediate threat to local people and businesses in terms of property values.

GARD has always maintained that it would accept the Abingdon reservoir proposal <u>if</u> the need was genuinely proven <u>and</u> proper investigations have shown it to be the best available option. Unfortunately, that was not the case at the time of the Public Inquiry in 2010 and, in our opinion, that remains the case, both in terms of need and option selection.

In Sections 2 and 3 of this consultation response, we have reviewed the proof of need for the reservoir through examination of Thames Water's projections of demand increases and their plans for demand management and leakage control. In Sections 4 to 8, we have considered the main option types for major new sources for London and in Section 9 we have reviewed their resilience to droughts worse than those of the 20th Century. In Section 10 we have considered the needs of the Thames Valley, including the requirements of other water companies. In Section 11, we have reviewed Thames Water's appraisal of options and the development of the preferred programme.

In preparing this consultation response, we have been assisted by John Lawson FREng and Professor Chris Binnie FREng, both eminent water engineers with long careers in the water industry and extensive experience of Thames Water's previous plans.

Through the development of successive WRMPs since 2009, there has been a history of Thames Water ignoring GARD's views, the rejection of GARD's proposal for the Teddington DRA scheme in WRMP09 and WRMP14 being just one example. For that reason, we have written this response with the regulators in mind, the Environment Agency and Ofwat, and we will be following up with them after this response has been submitted.

1.2 Availability of information and transparency

We recognise that Thames Water has made a large amount of information publicly available during the preparation of the draft WRMP and in the Plan itself. However, there has been a serious lack of transparency in two crucial aspects of the WRMP – the estimated costs of options and the WARMS2 modelling that has been used to determine the deployable output of options.

Transparency of option cost estimates

In the case of cost estimates of options, the only information made available has been unit 'AIC plus carbon' costs. There have been large and unexplained changes in costs since the WRMP in 2014, through several versions of option Fine Screening Reports and into the draft WRMP19. This is illustrated in Table 1-1:

	AIC + Carbon Cost p/m^3				
Option	**WRMP14 WRP table**	**FSR Oct '16**	**FSR April '17**	**FSR March '18**	**dWRMP19 WRP Table**
150 Mm^3 Abingdon reservoir	87	129-145	95-110	145-155	117
300 Ml/d Severn-Thames transfer supported by Vyrnwy and Mythe	n/a	85-145	100-165	170-210	265
Beckton effluent reuse	49	130-160	130-160	180-270	261
Crossness desalination	75	95-125	100-130	185-245	224
Teddington DRA, 300 Ml/d	n/a	40-50	35-55	65-80	128

Table 1-1: Unexplained major option costs changes since WRMP14

The table above shows that the unit costs of effluent reuse have risen by a factor of 5 since WRMP14, whereas the cost of Abingdon reservoir has only increase by about 30%. The unit costs of desalination have trebled over the same period. Since WRMP14, Abingdon reservoir has been moved from being almost the costliest option to become the least costly option. Since the FSR in October 2016, the cost of the Teddington DRA scheme has trebled.

The huge increases in the costs of the reuse, desalination and Teddington DRA options demonstrate the unreliability of Thames Water's cost estimates – the upper or lower of these estimates must have been badly adrift, if not both.

GARD has asked repeatedly for breakdowns of cost estimates, for both capital and operating costs. Our requests have been denied on grounds of "commercial confidentiality". We have tried to find a way round this by offering to sign a non-disclosure agreement, an option suggested by Ofwat, but this has been refused, with no reason given. We have put in a much reduced request simply for the present value capital and operating cost cash-flows used in the Thames Water's NPV calculations, but with no response from Thames Water.

Lack of transparency WARMS2 modelling and deployable output values

Thames Water's WARMS2 modelling provides data on deployable output of existing supplies and future options. It also provides data on the operational usage of options and has been used in assessment of resilience of options to droughts worse than those in the historic records. GARD has repeatedly requested model output over the years, but little has been supplied. We acknowledge receipt of model output of existing London and SWOX supplies, which has been helpful, but there has been little provided for the major option types. After numerous requests spread over the preparation of dWRMP19, output was eventually supplied for the Abingdon reservoir in late February 2018. There has been no output supplied for supported Severn-Thames transfer, Teddington DRA, reuse or desalination options.

The deployable output of options has been baldly stated in the dWRMP, as they were in the various versions of the option Fine Screening Reports. No justification or supporting information has been supplied in the Feasibility Reports or the Conceptual Design Reports.

To cover the lack of modelling detail and deployable output detail, GARD has used its own model, developed to mimic Thames Water's WARMS2 model. Output from GARD's model has been used extensively in preparing this response, for example in several plots showing the operation of the London and Abingdon reservoirs. GARD's model has been validated against WARMS2 output providing an almost perfect match for all modelled scenarios. Details are available on request.

1.3 The effectiveness of stakeholder engagement

Thames Water has organised numerous stakeholder engagement meetings in which we have been pleased to participate. We have found the meetings useful for being informed of Thames Water's progress and views, but of minimal value for engaging in proper discussion with Thames Water, especially if we do not agree with their views. The meetings have been too large for proper technical discussion.

In our opinion, the stakeholder meetings have been used by Thames Water to "sell" their own views and they have shown little inclination to take on board the views of others, especially where there has been disagreement. GARD has requested smaller meetings with Thames Water and their consultants to allow discussion of contentious issues, but these have been refused because Thames Water claim that such meetings would not be fair on other stakeholders.

During development of the draft WRMP, GARD has prepared a number of reports to convey our views on the evolving plan. These are listed in Table 1-2:

Date	Topic	No of pages
Aug 2017	Review of resilience of Abingdon reservoir to long duration droughts	32
May 2017	Response to 2nd Fine Screening Report	22
March 2017	Response to Colin Fenn audit report on GARD model	33
March 2017	GARD proposal for effluent reuse in SWOX	16
Oct 2016	Response to 1st Fine Screening Report	62
Dec 2015	Modelling of the Vyrnwy support option for the Severn-Thames transfer	31
Jan 2015	Comments on 1st Option Screening Report	13
Aug 2014	Report on modelling of STT options	24

Table 1-2: GARD reports submitted to TW during development of dWRMP19

Aside from a stakeholder meeting in January 2018 to discuss assessment of the drought resilience of the Abingdon reservoir option, there has been minimal Thames Water response to GARD's submissions. In most cases, there was no acknowledgement from Thames Water and certainly no attempt to engage with GARD for a proper discussion of issues raised.

In particular, Thames Water have not responded to our detailed comments on the two option Fine Screening Reports in October 2016 or May 2017. We have not been contacted by Thames Water or their consultants to discuss the numerous critical points made. We can see no evidence of our views being taken on board in the draft WRMP19. We note that Appendix P of the latest Fine Screening Report, titled 'Stakeholder Comments', is missing from the report. We have twice asked Thames Water for this, but it has not been provided. In our view, this is symptomatic of Thames Water's approach to dealing with stakeholder views that do not match their own.

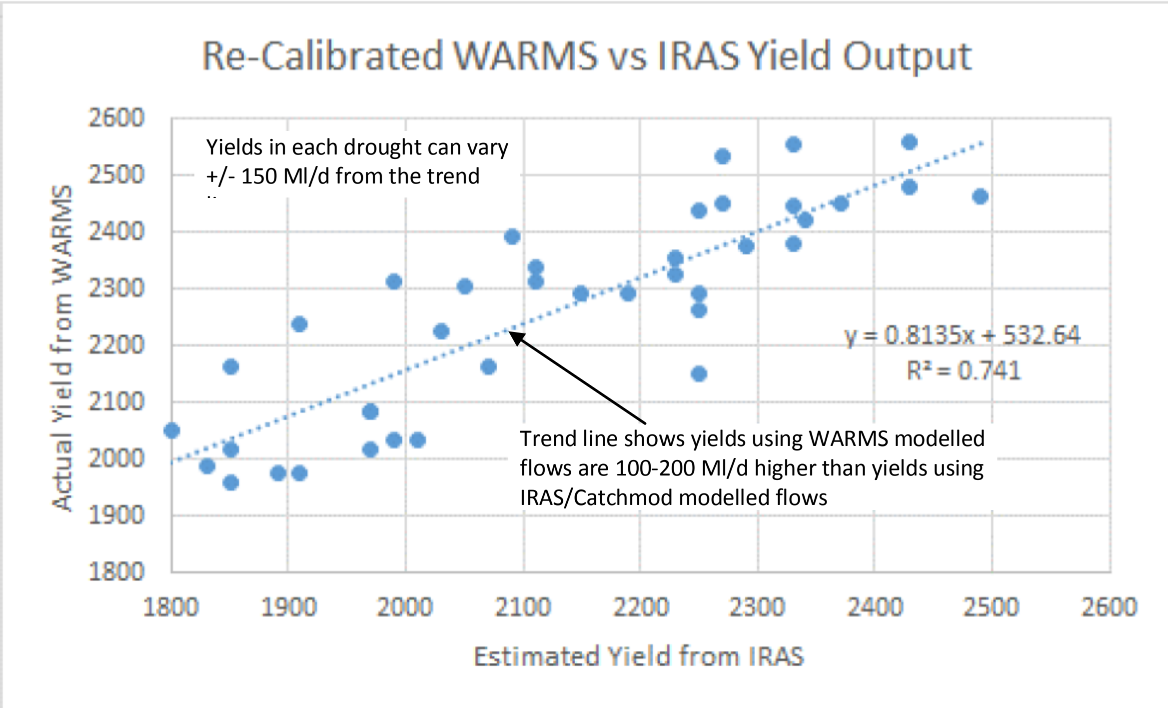
1.4 Over-dependence on Atkins' stochastic river flow data

Thames Water have made extensive use of Atkins' stochastic river flow data in crucial parts of the dWRMP:

- In climate change and resilience assessments for existing supplies – these lie behind a large portion of the forecast c.800 Ml/d deficit.
- In assessing the drought resilience of the Abingdon reservoir and Severn-Thames transfer options.
- In assessing the deployable output of Severn-Thames transfer options.

In our opinion, the reliability of the Atkins' flow data is highly questionable. Stochastic methods have been used to generate 15,600 years of rainfall data, which have been converted into river flows through rainfall run-off modelling. Although we do not question Atkins' experience or competence in undertaking this work, the generation of such a long period of rainfall data from much shorter rainfall records is in itself prone to a high degree of uncertainty.

Conversion of the rainfall records to river flows involves rainfall/run-off modelling which is an inherently difficult and uncertain process, especially when applied to a large and varied catchment like the River Thames, with a high proportion of groundwater contributed from chalk aquifers. When used for assessing the deployable output of London's supplies, the river flows generated by Atkins' stochastic modelling have been found to give very different results to river flows generated by the rainfall/run-off component of Thames Water's WARMS2 model, using the same rainfall data. The differences are illustrated in Atkins' Stage 2&3 report on their stochastic modelling, as shown in Figure 1-1 below[1]:



Notes: 1. TW's WARMS yields use flow data generated by own rainfall-run-off model
2. Atkins' IRAS yields use flow data generated by Atkins' IRAS/Catchmod model
3. Both models use the same rainfall data

Figure 1-1: London supply system yield variation using different stochastic data

In the plot above, each point shows the London system supply yield for each of 40 droughts, as generated by Atkins' and Thames Water's versions of river flows generated from the same stochastic rainfall data. The trend line shows that the Thames Water yields are about 100 to 200 Ml/d higher than the Atkins yields. The biggest differences, about 200 Ml/d, occur during the more severe droughts (ie lower supply yields).

[1] Thames Water Stochastic Resource Modelling. Stage 2 & 3 Report, Figure 5-2. Atkins. October 2016.

There is also about 150 Ml/d of scatter about the trend line. This means that for each of the droughts shown in Figure 1-1, the yield assessed for the existing London supply system could be in error by about plus or minus "half an Abingdon reservoir".

In GARD's opinion, these differences are highly significant. It is a particular concern that the poor match between the different yield assessments using the same stochastic data was the best that could be achieved even after the "re-calibration" undertaken by Atkins (note the "re-calibrated" caption at the top of the plot).

Similar unreliability of Atkins' flow data generated from stochastic rainfall data came to light in the recent Public Inquiry into Southern Water's Test and Itchen abstraction licences. Details can be seen in the Modelling Statement of Common Ground[2] and in John Lawson's Evidence and Rebuttal Evidence[3], all of which can be found on the Inquiry web-site at:

http://www.hwa.uk.com/projects/itchen-candover-and-testwood-water-abstraction-inquiry/

The big discrepancies identified between gauged and modelled flow durations for the Rivers Test and Itchen arose from conversion of stochastic rainfall data using a state-of-the-art regional groundwater model for the chalk-based catchments. For converting the Thames catchment stochastic rainfall to river flows, rainfall/run-off models have been used by Thames Water in WARMS2 and Atkins in their IRAS modelling. These rainfall-run-off models are a much simpler and less accurate method of converting rainfall to run-off than the regional groundwater model used for the Test and Itchen. The River Thames flows are much dependent on chalk groundwater flows, especially in droughts (although less than the Test and Itchen). Therefore, there is a high degree of uncertainty in the River Thames stochastic river flows, probably even more than were shown to be the case for the Rivers Test and Itchen.

In this response, we have also shown big discrepancies between stochastic flows generated for the lower River Severn, when compared with gauged flows, as described in later Section 7.2 and illustrated in Figure 7-2.

In the dWRMP, the stochastic river flows appear to have been used by Thames Water without any consideration of their accuracy. In our opinion, any findings based on using the stochastic river flow data are inherently unreliable and they should not be used for major decision making.

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[2] Statement of Common Ground between the Environment Agency and Southern Water on Modelling, esp. Paragraphs 39 to 48 and 4.1 to 4.5 in Points of Dispute. Inquiry Document SOCG2

[3] Proof of Evidence and Rebuttal Proof of Evidence of John Lawson. Feb/March 2018. Inquiry Documents FL1 and FL/R1

2. Supply/Demand balance and deficit forecasts

Key Points

- Thames Water has failed to follow Environment Agency guidelines for population estimation due to poor execution of Task E of the preferred methodology.
- Thames Water have abandoned their long-term population forecast based on the University of Leeds model (this was announced to stakeholders after the release of the dWRMP). Whilst the full effects of this are difficult to analyse, the principal effect is a drop in the population forecast for 2100 of at least 1.4 million people in the Thames Water area.
- GARD welcomes the announcement that ONS 2016 data will be used in the long-term forecast instead of the University of Leeds model.
- Thames Water has again failed to follow Environment Agency guidelines for population estimation due to poor execution of Tasks E & F of the preferred methodology.
- The WRMP fails to include discussion on the potential overestimation in the short term forecast due to the use of Local Plan data and rationalise this with ONS 2016 projections.
- The Edge Analytics model for the 2018-2045 period should be re-run using the newer 2016 ONS projections rather than 2014 data.
- GARD believes the revised figures in Thames' new analysis still over-estimate population growth significantly: by up to 0.7 million by 2045 and by 1.3 million by 2100.
- Further work is required to smooth the transition between the 2 models that occurs in 2045.
- The University of Leeds model, although abandoned, still contains useful information such as the potential effects of Brexit and identification of the disparity between water usage in Asian and non-Asian ethnic-origin households. The latter should be investigated further and potentially used to target future efficiency initiatives
- There is evidence that the population increase could be even lower than the 2016 ONS predictions. The potential for further reductions in fertility rates and immigration levels, including uncertainty over the effects of Brexit, as well as the impact of technology, could lead to future population forecasts being even lower.
- The demand from Per Capita Consumption (PCC) forecasts for the Thames Water supply area is dominated by the forecast that the average PCC for the London WRZ will hardly decline from 2044/5 (128 l/h/d) to 2100 (126 l/h/d). This is in marked contrast to both the Thames Valley zones, which show continuous decline for the whole of the planning

period (116 l/h/d in 2044/45 to 104 l/h/d in 2100), and to the forecasts of other water companies' dWRMPs.

- The arguments given by Thames Water for this stationary PCC, are based on assumptions about social trends (household occupancy), 'unalterable' behaviours of various consumer groups (flat-dwellers, rented accommodation tenants, south-Asian ethnic minorities), and accounting changes in the property classes measured in the PCC statistics. These are not-quantified in a transparent manner, and are not justified. Some assumptions, especially about ethnic minorities, are skewed by the outcomes of the abandoned population projections and need revisiting.

- There is no allowance for continuing technology improvements in the reduction of the PCC in London or any other resource zone.

- The metering penetration targets remain significantly behind the rest of the industry, and the metering plans described in the dWRMP fall below even what Thames has achieved historically, with effectively no plan post 2035. GARD suggests targets for London of meter penetration of 90% in 2040/45 which could lead to a reduction in demand of 12 Ml/d in 2045.

- In contrast to all other water companies, Thames Water predicts an *increase* of *measured properties* PCC in London of 9 l/h/d. The industry average is a 6 l/h/d *reduction* in that period. Conforming to the industry average would reduce the measured PCC by 15 l/h/d in 2045 and 17 l/h/d in 2100 which would, by GARD's calculation, reduce the demand in London by 80 Ml/d in 2045

2.1 Population Forecasting Issues.

Environment Agency guidelines for population estimation

The Environment Agency (EA) has published clear planning guidelines for developing population projections[4], with further detailed guidance being developed for WRMP 19[5]. The methodology outlined comprises 6 primary tasks:

Task A. Assess needs and make choices

Task B. Assess Local Development Plans

Task C. Calculate population and household forecasts

Task D. Calculate occupancy forecasts

Task E. Analyse uncertainty

Task F. Review and finalise population, household and occupancy forecasts

In the dWRMP, Thames Water initially used 2 different models to develop a population forecast out to 2100[6]. Edge Analytics were tasked to produce a population profile out to 2045 and the University of Leeds tasked to forecast the period 2045-2100. These two activities effectively cover Tasks A to D above. Technical Appendix E: Population and Property Projections contains a wealth of detailed information from both companies as to how they approached this task. The Edge Analytics report notes that Task E, 'Analyse uncertainty', which involves quantifying potential uncertainty in the population, household or occupancy forecasts, was conducted separately by Thames Water.

UKWIR guidance recommends that such sensitivity analysis should include consideration of variant scenarios, plus the quantification of uncertainty. We would expect to find evidence of this work in the Technical Report Section 3, Technical Appendix E, or Technical Appendix V, which deals with risk and uncertainty. Technical Appendix V does consider household population uncertainty in very general terms, but only by considering the effect of higher populations on issues such as per capita consumption, non-household demand and climate change. Nowhere in the main body does the dWRMP try to quantify the uncertainty around its population forecasts or consider variant scenarios as required by the UKWIR guidance. Since the population forecasts underpin the entire investment strategy, this is a major failing.

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[4]Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update Apr 2017

[5] WRMP 19 Methods – Population, Household Property and Occupancy Forecasting Guidance Manual, Environment Agency, Report Ref No 15/WR/02/8

[6] Note that here, as in the dWRMP, the term 'forecast' is used as a generic term to encompass both population projections and population forecasts

The University of Leeds work appears to be incomplete. The report, dated Jan 2017, notes that Phase 2, to be delivered in ‘March’ (presumably March 2017), would contain the work on ‘Estimating uncertainty in long-term forecasts’. Since the Phase 2 work is not included in the dWRMP, it is impossible to know what the outcome of this was, or indeed if it was undertaken. We consider that, based on these findings, the population forecasting element for 2045-2100 also failed to adequately conduct Task E of the Environment Agency guidance on developing population projections.

Abandoned long-term population forecast based on the University of Leeds model

On first release of the dWRMP it was immediately apparent that there were problems with the population forecasts and that the 2 models did not match. A marked point of inflexion at 2045 indicated that they had been joined without rationalising their different methodologies. Nor was the mismatch in growth rate between the models explained. As presented, the 2 models showed an increase in population for the total TW customer base from a baseline 2016/17 figure of 9,779,115 to 11,822,889 in 2045 and 15, 373,754 in 2099/00. These figures, and in particular the high growth rate demonstrated in the second model compared with ONS 2016 projections, were challenged soon after release by GARD and other organisations.

At its Water Resources Forum on 21 Mar 2018, TW announced that the Leeds model had been dropped and that ONS forecasts would be used for the period out to 2100.New figures for estimated population and household were presented that were significantly lower than the original dWRMP figures (reduced by 1.4 million people and 0.6 million households respectively by 2100). However, the lack of detail in how the new projection has been developed makes it difficult to comment on. The new growth figures were presented as fixed with no error boundaries and no mention made of consideration of any of the variant scenarios developed by ONS.

Additionally, ONS 2016 population estimates for England at the sub-regional level will not be released until May/June 2018 so it is unclear how the figures for the Thames area have been calculated, given the assumption that the Southeast region will continue to attract an above average proportion of incoming migration when compared to the rest of the country. **Thames Water has again failed to follow Environment Agency guidelines for population estimation due to poor execution of Tasks E & F of their new preferred methodology**

It seems probable that, at this stage, the work required to perform Task E, above, for the new 2100 forecast has not been carried out. Further, given the speed with which the dWRMP population forecast was abandoned it is clear that TW have failed to adequately conduct Task F which requires the carrying out of appropriate checks and identification of preferred forecast. **The dWRMP fails to include discussion on the potential overestimation in the short term forecast due to the use of Local Plan data**

Short term forecast issues

Problems remain with the short-term forecast. The guidelines are that it is to be based on the local plans produced by local councils and unitary authorities. It is clear from both Section 3 of the Technical Report and Technical Appendix E that this has been done very comprehensively. However, where local plan evidence is insufficient (many only look forward 15 years) the guidance advises that ONS and Department for Communities and Local Government official statistics are used as an alternative. In a GARD meeting with DEFRA in Nov 2017 this specific point was confirmed as being their expectation.

Unfortunately, local area plans often overestimate short term increases in population. Reasons for this, include the incentive for authorities to predict the greatest growth possible, as this increases access to central funding. Further, political and voter pressure on housing provision pushes authorities to over promise and under deliver; reports of house building targets being missed are common. A recent survey by the Royal Institute of Chartered Surveyors[7]identified other reasons why targets will be hard to meet in the near to mid-term. These included a severe shortage of workers, difficulty in finding land for construction and regeneration, the cap on councils' ability to borrow against housing and a shortage of infrastructure funding to build amenities around new developments. There is little indication of forthcoming changes in government policy that will significantly change any of these factors. The difficulty in finding land for construction and regeneration is particularly acute in London, where affordability is a major issue, and it is particularly unlikely that property growth in this region will take place at the anticipated rate. This may result in a higher occupancy rate in existing housing stock than currently expected which, since per capita consumption declines as the number of occupants increases, will tend to produce a lower water demand.

Due to the optimism of local area plans, we would expect to see the early years of any 25-year forecast over-estimate the actual population figures, before returning to historical growth rates as the model reverts to using ONS figures. This can be seen in the graphs presented in Section 3 of the WRMP with a clearly visible bulge in growth between now and around 2030. Growth then flattens, before increasing in the late 2030's up until 2045. We would expect to see more evidence that the latter part of the period up to 2045 is aligned with ONS forecasts and that some attempt has been made to realistically smooth the transition from local area plans to ONS data.

It is clear from discussion at the March 18 Water Resources Forum that TW believe that they are unable to deviate from the local plan data in their early projection and that this would be challenged by DEFRA. This makes no sense since DEFRA already expect the latter part of this forecast to move to ONS figures. The dWRMP should, at the least, acknowledge that there is a mismatch between local plans and ONS data and examine the implications of this

[7] The Telegraph, 'Skill shortage means UK will miss house building target'. 1 Feb 2018

for demand forecasts. **The Edge Analytics model for the 2018-2045 period should be re-run using the newer 2016 ONS projections**

Section 3, para 3.83, specifically notes that since the local plans typically have a 15-20 year horizon, the model 'makes a gradual return to the trend evident in the ONS 2014-based projections, achieving the average annual trend growth by 2045'. It is not clear whether the ONS growth rate is applied to the inflated local plan figures or whether the model overall is forced to match ONS projections at 2045. Furthermore, it is unfortunate that 2014 data has been used since the ONS growth projections were revised significantly downward in 2016 due to reductions in assessed long-term net international migration, a slower rate of increase in life expectancy and a reduction in fertility rates[8]. The Edge Analytics model should, therefore, be re-run using the more up to date 2016 ONS data.

dWRMP revised figures

As a gross error check, GARD has reviewed the 2016 ONS England growth projections and used them to calculate an average growth rate of 12.9% by 2044/45 and 29.3% by 99/00. This would give TW customer populations of 9.78m 2016/17 baseline, 11.04m population by 2044/45 and 12.65m population by 99/00. This compares with the latest figures from TW, given at the Water Resources Forum held on 21 Mar2018, of 11.9m in 2044/45 and 14m by 2100 (estimated from supplied graphs[9]). GARD estimates for 2045 and 2100 compared with TW estimates are shown in Table 2-1 and Figure 2-1 below. The ONS forecasts up until 2045 should be treated with some confidence - in a 2015 analysis, the ONS determined that since 1955 the mean absolute error of the projected total UK population 20 years ahead was about 2.7 per cent overall.

	dWRMP	**March 2018 Water resources forum revision**	**GARD estimate using 2016 ONS England**
2016/17 Baseline	9.78m	9.78m	9.78m
2044/45 Projection	11.82m	11.82m	11.04m
2099/00 Projection	16m	14m	12.65m

Table2-1: dWRMP, Water Forum Revision and GARD Population estimate

[8]Projected net annual long-term international migration reduced from 185,000 to 165,000, long-term average number of children per woman from 1.89 to 1.84 and life expectancy reduced by 0.9 years for males and females.

[9] Note that the population forecasts in the original dWRMP documentation differ from those presented at the Water Resources Forum as being dWRMP based. We are waiting to see why different figures were used.

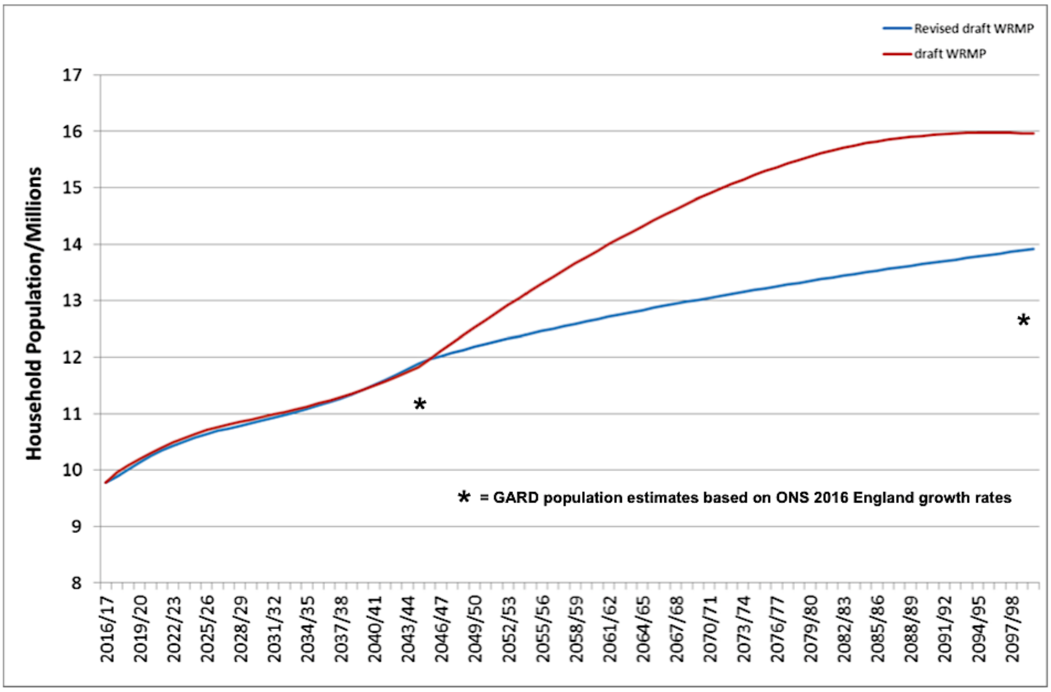

Figure 2-1: GARD population estimates overlaid on TW estimates[10]

The point of inflexion still noticeable in the new graph where the two models meet at 2045 shows the mismatch where the effect of using local plan data and the higher growth-rate predictions of the 2014 ONS model, meet the lower forecasts of the 2016 ONS projections used from 2045 onwards. Further work is required to match the two models' growth rates and better align the period around the common point of 2045.

The GARD figures may underestimate the actual figures since they have been calculated using the average ONS forecast growth rates for England. Once the sub-regional forecasts are published in May/June, we will recalculate these using regional figures. However, as discussed below, various factors may mean that the difference is small.

The University of Leeds model

Many aspects of the University of Leeds model are still relevant. It usefully examines different scenarios, including the effect of BREXIT and also identifies an unexpected difference in per capita consumption between Asian ethnic-origin and non-Asian ethnic-origin households. The report indicates that Asian ethnic-origin households use approximately twice as much water and it would seem advantageous for TW to target these households during future efficiency initiatives.

[10] Original graph taken from Water Resources Forum Slide pack, 21 Mar 18

London projections

Given the importance of London's population in determining future demand, we have produced estimates of future London population figures for use in our analysis. Thames Water has abandoned its dWRMP projections and will not release new sub-area population projections before publication of the revised WRMP. Since the latest ONS sub-area projections are not available until May/June 2018, we have had to estimate our own figures. These have been developed by using ONS 2014 sub-area figures factored for ONS 2016 reduced forecasts for fertility, longevity and migration. Post 2040, it is expected that births will increasingly fall below deaths and natural growth will either flatline or fall. However, ethnic groupings in London may outperform the rest of England and so a natural growth rate of up to 10,000/year has been used. This is likely to taper off and disappear entirely by 2100 as some studies suggest that, as communities integrate, fertility drops toward the national norm. GARD's London population projections are detailed below in Table 2-2. Thames Water dWRMP figures are shown for comparison.

London	TW	GARD
Baseline 16/17	7,595,624	7,595,624
44/45	9,079,484	8,971,000
99/00	12,018,057	10,868,600

Table2-2: GARD produced London population projections

A number of factors could affect these figures. If London follows the expected England reductions in natural growth, the 99/00 figure would drop by up to 500,000. Higher than expected migration levels or increases in the 'Southeast pull factor' could increase the numbers. GARD will continue to follow future Thames Water and ONS projections and other work so that these figures can continue to be refined.

Future trends in population

There is some evidence building that future population forecasts may be even lower than the 2016 ONS figures. The effects of BREXIT are an obvious factor, although the extent of this is still to be determined. A recent House of Commons Briefing Paper[11] notes that on 20 July 2016, the Prime Minister reiterated earlier statements that 'we need to bring net migration down to sustainable levels, and the Government believe that means tens of thousands'. There does appear to be some evidence of recent downward movement. Net annual migration reached 336,000 in the year ending March 2015 but dropped to 273,000 in Sep 2016, before falling again to 244,000 in Sep 2017.[12] While net migration of EU nationals in the year ending Sep 2016 was 189,000, by Sep 2017 this figure had fallen to 90,000.[13]

[11] House of Commons Library, Briefing Paper Number SN06077, 'Migration Statistics' dated 23 Feb 2018
[12]ibid, p 10
[13]ibid, p14

Whether this trend continues beyond the short-term remains to be seen, but even if it only lasts a few years, it will create a smaller baseline figure for future growth projections.

The dWRMP notes that the Southeast attracts a higher proportion of migrants than other regions. As migrant numbers fall and competition for them increases, we may see market forces driving other regions to offer incentives to workers to locate away from the Southeast. Initiatives such as the ‘Northern Powerhouse’, if successful, may increase ‘pull’ factors. In addition, there are already reports of technology being developed to replace falling numbers of migrant labour, particularly in agriculture. As well as improving productivity, such developments will reduce demand for labour and reduce pull factors.

The global fertility rate has halved in the last 50 years from 5 children per woman to 2.5 children per woman.[14]It was recently reported that the world has passed ‘peak baby’[15] meaning that from now on, the number of children born across the world will decrease. Although the effect of this decrease will be masked initially by people living longer, numbers will eventually fall. Fertility rates in India are already down to 2.4 and in Italy down to 1.34, if unchanged this latter figure will lead to a collapse in their population. Indeed, the Japanese population fell by 244,000 in 2013 and faces losing a third of its population in the next 50 years. American fertility rates have fallen from 2.12 births per woman 10 years ago to 1.77now. There is a strong correlation between increases in education and prosperity and decreasing fertility; generally, to below 2 births per woman. In 2015, taking into account infant mortality, it was calculated that a global fertility rate of 2.3 was required to keep the world’s population constant. In the United Kingdom, the fertility rate is currently 1.81. This is why estimates of migration are so important to forecasting, as it is the main driver of population growth.

These examples are given purely to illustrate the very complex nature of forecasting population growth. The population of the UK can go down as well as up, as it did between the late 1970s and early 1980s. This is why it is vital that the WRMP clearly explains its assumptions, quantifies uncertainty and examines variant projections. As stated, the population assumption underpins the entire future investment strategy. Underestimating will lead to a failure to meet demand, while overestimating will lead to wasted investment, potentially on major capital projects, which would be better spent addressing the issues, such as leakage, already faced by TW.

2.2 Per Capita Consumption

Thames Water has dealt with issues of Per Capita Consumption (PCC) alongside issues of Leakage, Demand Management and Water Efficiency in an integrated manner as part of their Integrated Demand Management (IDM) process. As a result we have structured our analysis along similar lines and so a detailed discussion of the issues of PCC and its reduction

[14] https://ourworldindata.org/fertility-rate
[15] The Telegraph, ‘We’ve reached peak baby and the consequences will be monumental’. 8 Mar 2018

are given in Section 3.2. In this section we concentrate on the brief headlines of Thames Water's forward look on PCC, and on the major shortcomings which help to lead to an overestimate of demand in the dWRMP19 documents.

Per Capita Consumption in the Preferred Plan

The *average* per capita consumption (PCC) for London is shown in the dWRMP *Preferred Plan* to go from 146 litres per head per day (l/h/d) in 2017[16] to 128 l/h/d in 2044/45[17] . Thereafter the London PCC hardly declines for the rest of the 21st century (126 l/h/d in 2100). The corresponding figures for the Thames Valley are[18] 137 l/h/d (2017) to 116 l/h/d (2044/45) and 104 l/h/d (2100).

In Section 3.2 of this report we cover many reasons for the prediction of failure to reduce the PCC for the London WRZ in any significant way. These include that Thames Water has a meter penetration which remains significantly behind the rest of the industry, and the metering plans described in the dWRMP fall below even what Thames has achieved historically, with effectively no plan post 2035***. GARD suggests targets for London of meter penetration of 60% in 2024/25, 80% in 2029/30 and 90% in 2040/45.***In Section 3.2 we show that this increased meter penetration could lead to a reduction in demand of 12 Ml/d in 2045.

As shown in Section 3.2, making a comparison with other water companies[19]**,** we see that there is an average *reduction* in average PCC of all the companies of about 15 l/h/d and a fall in measured PCC of all the companies by about 6 l/h/d by 2045. On the contrary, Thames Water forecast an *increase* in measured PCC in London WRZ from[20]119 l/h/d in 2016/17 to 128l/h/d in 2045, thereafter the measured properties' PCC hardly declines for the rest of the 21st century (129 l/h/d in 2100).Thames Water cite the fact that: "*Household occupancy continues to decrease across the period...the number of adults is also continuing to grow as a percentage of the population."[21],* but without giving any calculation to support this allegation. They also cite what is effectively an 'accounting windfall' where the re-classification in 2014 of large blocks which had been *"…historically…billed as a single entity..*[and]*…counted as a single non-household property*…*are now counted as household properties,..*[and]*…the number of flats in the building included within the property count."[22].* This change, which led to a one-off increase in London properties of 133,714, had the biggest effect in London, bringing into the PCC calculation a large number of low-PCC units, and lowered the average PCC for London from 130 l/h/d for AR16 to 119 l/h/d for AR17. Thus they claim that as other properties are added to the measured property category, they

[16]AR17.
[17]dWRMP19, section 11(Preferred programme), fig 11-13, page 50.
[18] dWRMP19, s11, fig 11-12, page 49.
[19] Presentation to Waterwise Annual Conference 6th March 2018
[20] dWRMP19, section 3-168
[21]dWRMP19, section 3-168.
[22] dWRMP19, section 3-169

will, on average have a higher PCC than this new group of flats and hence average measured PCC will increase. Whilst this effect has been noticeable, there is no justification for its indefinite persistence in the Thames Water accounting. It cannot be used as an excuse for not proceeding with water efficiency measures at an accelerated rate, and for allowing PCC to increase. Thames Water seem too eager to give up on measures to improve PCC in London. They cite four reasons why London will be exceptional in PCC terms[23]: the higher proportion of rented properties, with relatively high turnover in tenancy, giving reduced incentive to invest in water efficiency fittings and fixtures; the higher proportion of properties with complex supply arrangements (hence a lower proportion of individual households paying for their water on a measured tariff); the higher proportion of flats which lowers the opportunities for discretionary water use savings; and the higher ethnic population of London with cultural and religious beliefs which result in higher water usage than other sectors of the population.

The effect of the last one of these is blown out of proportion by Thames' use of unjustified population statistics, which emphasise higher ethnic birth-rates. These are now, as indicated already in Section 2.1, discredited, and a re-evaluation of the population forecast should also be followed through into these PCC predictions. In any case, there are other factors which would lead to scepticism of the size of this effect, as the South Asian ethnic origin population of London is only around 18% of the total, and there is moreover, the well-known phenomenon of ethnic minorities' social and cultural habits moving more towards the norms of the 'host' population.

As regards the first factor, it cannot be allowed to go unchallenged as a value-judgement on a mainly lower-income section of the population. It has no place in a progressive democracy and it should not be allowed to be used as an inalienable fact, which targeted programmes and technology would be unable to overcome. In short, we do not find Thames Water's arguments at all persuasive.

Adjusting the PCC increases in London of 9 l/h/d to conform with the industry average would reduce the measured PCC by 15 l/h/d in 2045 and 17 l/h/d in 2100. The forecast population for London in the dWRMP is 5.37m in 2045.[24] ***Applying the factors above would, by GARD's calculation, reduce the demand in London by 80 Ml/d in 2045.***

2.3 Existing deployable output and allowance for climate change

Base case deployable output

The base case deployable output of existing London supplies, currently assessed as 2305 Ml/d, is fundamental to the supply demand balance which is the basis of Thames Water's proposals for new supplies. Since WRMP14, there has been a large increase in the base case

[23] dWRMP19, section 11.164
[24] dWRMP19, table 3-12 page 25.

deployable output of London's existing supplies as reported dWRMP19 paragraph 4.20 and Table 4-1:

• WRMP14	2144 Ml/d
• Annual Review 2016 and dWRMP19	2305 Ml/d
• Change	+ 161 Ml/d

The huge change in base case deployable output is explained only vaguely in paragraph 4.20 of dWRMP19: *"The redevelopment of WARMS and the introduction of an optimised LTCD resulted in a significant change in London's DO".* There is no detail provided as to how such an increase in deployable output can have arisen, but Thames Water imply it arises from the optimised Lower Thames Control Diagram (LTCD). This was also implied in the explanation of the base case deployable output changes in Thames Water's Annual Review 2016[25]:

> *"The deployable output associated with each LTCD was maximised as much as possible, given the significant supply demand imbalance in London, the cost of developing new water resources and associated impact on customers' bills."*

However, GARD's modelling shows that the "optimised" LTCD only contributed 31 Ml/d increase in base case deployable output. This is illustrated in Figure 2-2 below, which shows the base case modelled with the old LTCD and the WRMP14 assumptions for demand savings at each Service Level, but using latest WARMS2 Teddington river flows:

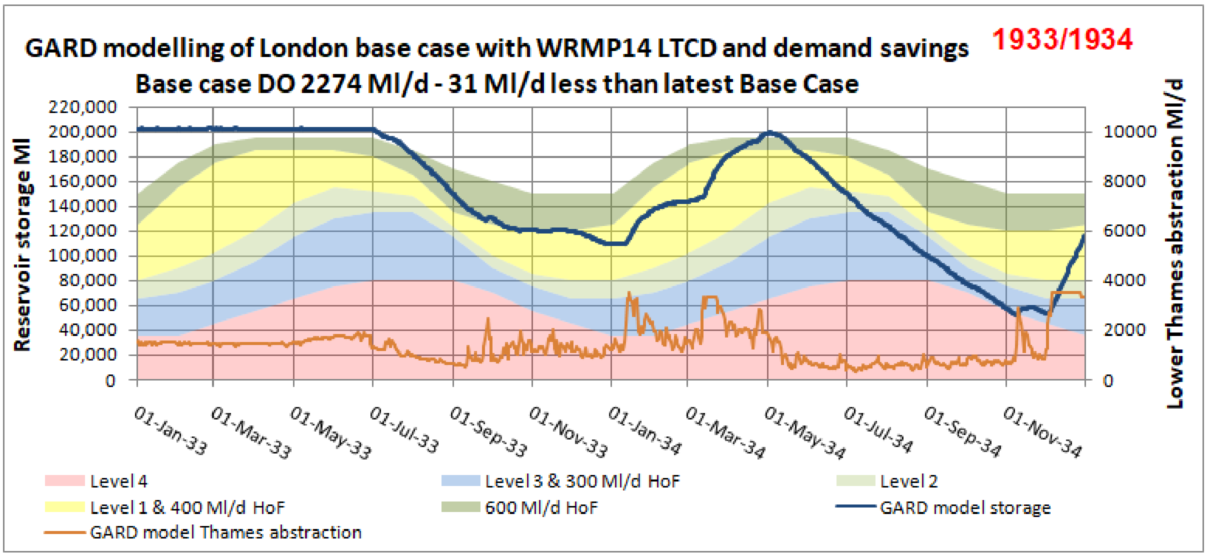

Figure 2-2: London base case deployable output modelled using the "old" LTCD

The real explanation of the huge increase in deployable output since WRMP14 is that there have been big changes to the historic river flows used in the WARMS2 modelling. This is shown in Figure 2-3, comparing the Teddington natural flows used in the WARMS1 modelling for WRMP14[26] and the equivalent used in the latest WARMS2[27] modelling:

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[25] Thames Water Annual Review 2015-16, page 15

[26] TW Excel output file "WARMS verification AR12 DO 2146 Mld"

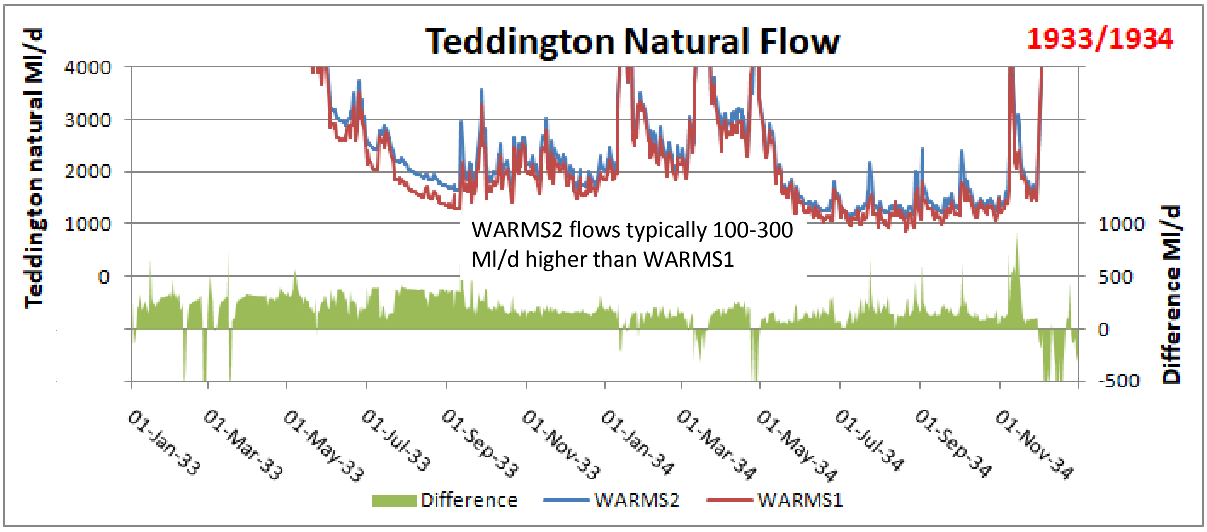

Figure 2-3: Changes in Teddington natural flows WARMS1 to WARMS2

The Teddington natural flows used in WARMS2 are typically about 200 Ml/d higher than in the WARMS1 modelling. In the run-up to dWRMP14, GARD repeatedly raised concerns about the under-estimation of base case deployable output. These concerns were brushed aside by Thames Water and their consultants, leading to the following in GARD's response to the consultation on dWRMP14[28]:

"In November 2012, GARD raised concerns that TW's baseline deployable output of existing supplies to London, stated as 2146 Ml/d, could have been under-estimated by up to 200 Ml/d. GARD's concerns are:

> *1. Based on TW's own evidence, the flows available for abstraction from the lower Thames above Kingston appear to have been under-estimated by about 200 Ml/d in droughts. GARD's modelling has shown that this could cause deployable output to be under-estimated by about 100 Ml/d.*
>
> *2. TW's assessment of existing DO has allowed for effluent returns from upstream abstractions by Water Only Companies at recent actual rates, rather than the future abstraction rates when their licences will be fully used. In GARD's opinion, the principle behind this is unsound. Our modelling shows that this leads to an unjustified loss of deployable output of 46 Ml/d.*
>
> *3. TW's modelling allows for process water losses in their assessment of amounts supplied, but does not appear to have allowed for the equivalent returns of process water to the Thames above Teddington. This leads to an under-estimate of water available for pumping to fill the Lower Thames reservoirs. GARD's modelling has shown that this reduces deployable output by 59 Ml/d."*

[27] TW Excel output file "Copy of GARD AR17 London DO 2305 Mld 2017-04"

[28] GARD Response to Thames Water's Consultation on their Draft Water Resource Management Plan 2014, Section 2.3, page 4

Thames Water's response to GARD's criticism was predictably dismissive:

> *"TW's DO estimates are independently audited each year as part of the Annual Return reporting process to Ofwat and the Environment Agency and the information has previously been reviewed and certified as robust and fit for purpose. In response to the detailed points raised by GARD in relation to DO, TW commissioned a further independent review of its water resources model (WARMS) undertaken by recognised water industry experts HR Wallingford (HRW). HRW concluded that "The DO assessment is regarded as sufficiently robust for the draft plan and in my opinion the uncertainties are of the order of +/- 5% or just over 100 Ml/d. Further model improvements and sensitivity analysis would clearly be beneficial along with greater transparency of the upper Thames WR model"*

Whereas GARD is pleased that the gross error in the WRMP14 base case deployable output appears to have been corrected in the WARMS2 modelling for dWRMP19, it is nevertheless indicative of the high degree of uncertainty that surrounds Thames Water's assessment of the deployable output of existing and future supplies. It is also a concern Thames Water that have used the opinion of "*recognised water industry experts"* to dismiss GARD's valid concerns and failed to acknowledge the error in the WRMP14, instead subsequently claiming the correction of the error to be the result of optimisation of the LTCD.

Allowance for climate change

The DWRMP makes the following assessment of the losses of deployable output of existing London supplies due to climate change[29]:

	Loss of DO
• By 2044/45	125 Ml/d
• By 2085/86	185 Ml/d
• By 2099/00	230 Ml/d

Therefore, Thames Water expect that there will be large losses in deployable output due to climate change in the next 25 years, driving the need for a major new source in the mid-2040s. Whilst accepting that it makes sense to make contingency plans for the possibility of reductions in supply due to climate change, we would comment that these reductions are highly uncertain. We made this point in our response to the Fine Screening Report in May 2017, but, in the absence of any response from Thames Water, we repeat our concerns here.

We unreservedly accept the premise of global warming and consequent climate change – the evidence of rising temperatures over the past 100 years appears irrefutable. However,

[29] dWRMP paragraph 4.4 and Table 4-14

we are not aware of any evidence that the climate changes that have already taken place have led to any increase in the frequency or severity of droughts affecting London's water supplies. In fact, the frequency and severity of droughts affecting London's supplies has reduced over the past 100 years as illustrated below:

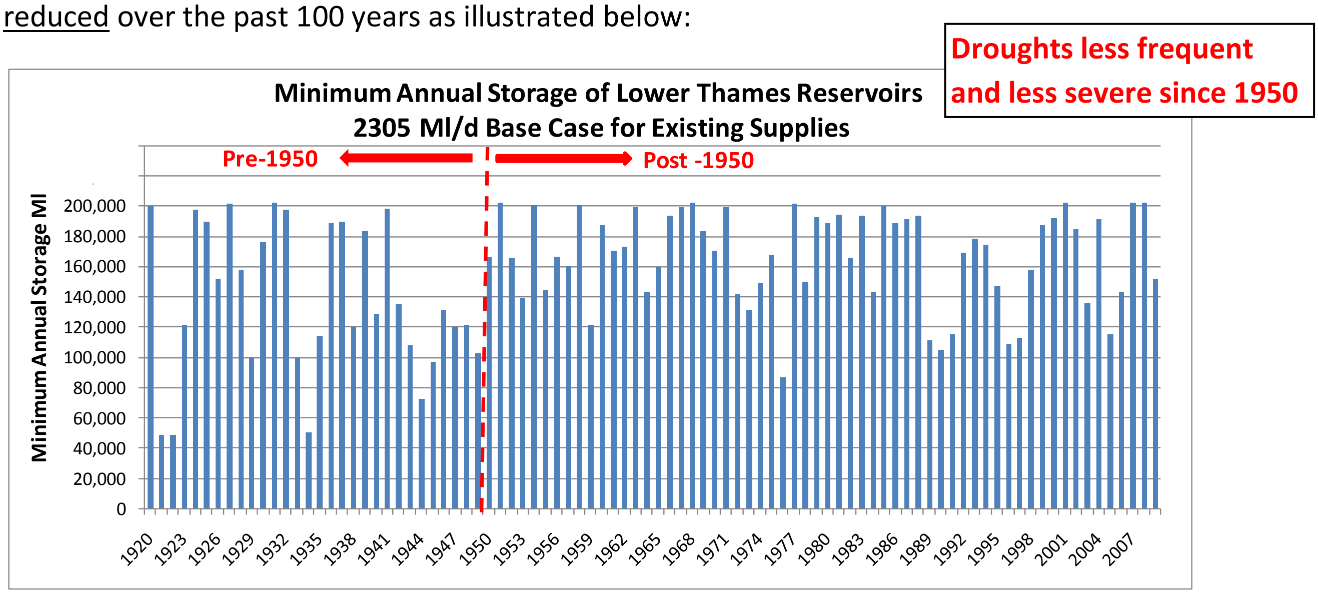

Figure 2-4: Frequency and severity of droughts affecting London's water supplies

This plot shows the WARMS2 minimum annual storages from simulation of existing London's supplies at the base case maximum output of 2305 Ml/d, under the historic flows since 1920. From visual inspection of the plot, it is clear that that the effects of droughts have become less frequent and less severe since about 1950. In our opinion, this is strong evidence that London's supplies have not become more vulnerable to droughts over the past 100 years, despite the climate change that has already occurred.

We accept that this should not be used as evidence that climate change will not make London's supplies more vulnerable to droughts in the future – there are no grounds for complacency. However, it puts the likelihood of this happening into perspective – the climate change impacts are highly uncertain and planning for new supplies needs to take account of the uncertainty.

2.4 Uncertainty in the deficit forecast

Uncertainty and the need for a flexible planning approach

Thames Water's forecast deficit for London, as shown in the WRZ summary Table for London Zone[30] is shown below:

[30] TW Excel WRP Tables for London, 'WRZ Summary' tab

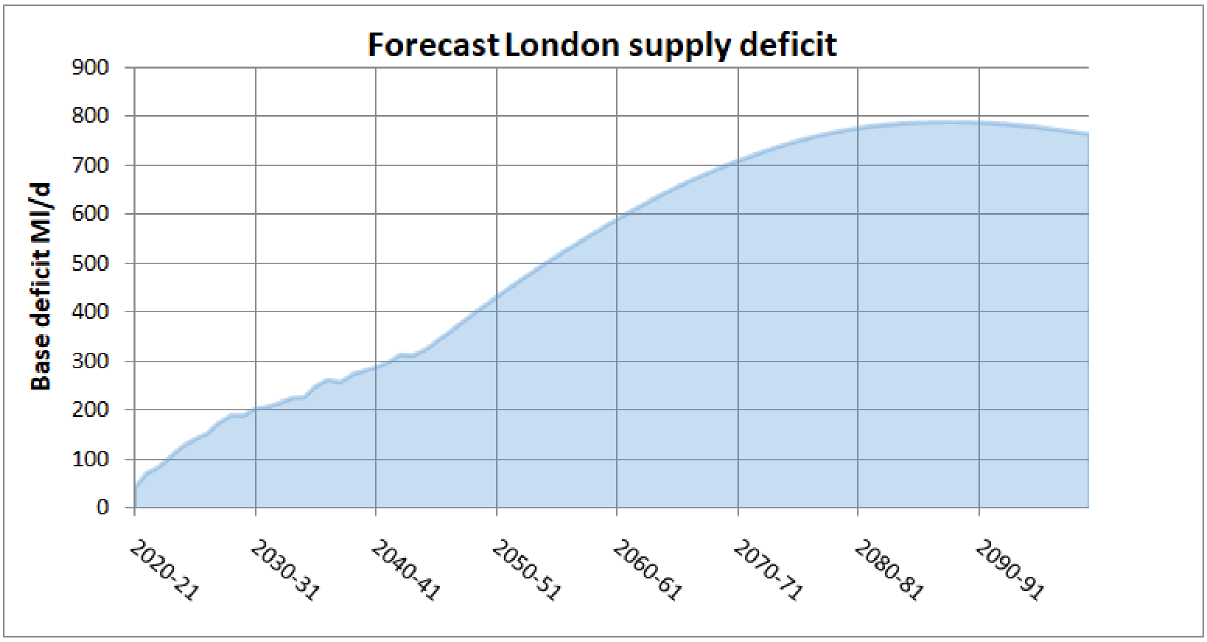

Figure 2-5: Forecast London supply deficit

In Section 2.1 we have shown that the population for London in could be over-estimated by about 1.1 million, equivalent to a demand of about 130 Ml/d. In Section 2.2, we have shown that more ambitious and realistic ppc targets would reduce London demands by 80 Ml/d by 2045. In Section 2.3, we have shown that in WRMP14 the deployable output of London's supplies were underestimated by about 150 Ml/d and that Thames Water's projected loss of 125 Ml/d in London deployable output due to climate change looks to be excessively pessimistic, if not highly improbable.

This all points to a high degree of uncertainty in Thames Water's deficit forecasts, with the London deficit being potentially over-estimated by large amounts:

Source of potential overestimate	By 2045	By 2100
Population forecasts	15 Ml/d	170 Ml/d
Per capita consumption	80 Ml/d	80 Ml/d
Climate change	125 Ml/d	230 Ml/d
Total potential overestimate	220 Ml/d	480 Ml/d

In our opinion, the deficit forecast shown in Figure 2-5 should be used as a 'worst case' for contingency planning and not as the central forecast driving a firm programme for development of major new sources.

In view of the large uncertainty in the forecast future deficit, in our opinion, the ability to adapt to deviations from the deficit forecast should be a central feature of the dWRMP. This does not appear to be addressed at all in the plan:

- Section 5 of the dWRMP, "Allowing for Risk and Uncertainty", focuses on a highly statistical approach to determining potential errors in the deficit forecast, with no attention to means of adapting to changes in the forecast, especially not to possibility of the forecast deficits not materialising.

- Section 7 of the dWRMP, "Appraisal of Resource Options", makes no mention at all of the need for flexibility and ability to phase options as criteria for option appraisal.
- Section 10 of the DWRMP, "Programme Appraisal and Scenario Testing", para 10.39 states *"In developing a long-term plan uncertainties are thrown up. It is important, therefore, to test the effect that these could have on the plan and ensure the plan is flexible and robust in the face of an uncertain future."* Unfortunately, the possibility of Thames Water's huge forecast deficit failing to materialise does not appear to have been considered part of the *"uncertain future".* It is not covered in the scenario testing.

In our opinion, the failure to plan for the forecast deficit not materialising is a major weakness of the dWRMP. Therefore, the plan as it stands has a good chance of producing a white elephant like Kielder reservoir. There should be more emphasis on avoiding unnecessary development of schemes, particularly schemes with irreversible impacts. There should be a clear 'no regrets' policy in choosing the preferred programme and this should be one of the measures for assessing individual schemes.

3. Leakage and demand management options

Key Points

- Leakage and demand management targets provide two of the key underlying assumptions for the dWRMP. The need for Thames Water to abandon published targets and adopt more stringent ones at almost the start of the consultation process destroys the credibility of the dWRMP.
- Tackling leakage and regaining customer trust should be the number 1 priority.
- Leakage performance is so bad that it skews the statistics for the entire industry. Thames Water must set targets that move it at least toward median performance or better.
- Artificial constraints adopted in the dWRMP that limit Thames Water's ability to acceptably improve its performance should be removed.
- The leakage target for 2019/20 should be 617 Ml/d or below, Ofwat requirements imply a target for 2025 of 525 Ml/d or below, for 2035 at or below 465 Ml/d and for 2040, 424 Ml/d or below.
- NIC recommend halving leakage by 2050, a reduction to 300 Ml/d
- Meeting the leakage targets would save approximately 25% of the forecast London deficit.
- The early 2018 cold snap, which resulted in many burst water mains and about 20,000 households without water, shows that capital maintenance in London is below required levels.
- Pipe replacement and associated costs should be allocated to the capital maintenance budget, improving the NPV of the pipe replacement programme.
- The dWRMP shows that in London, measured pcc increases as smart meter penetration increases – these figures should be reworked to include projected 17% savings.
- TW should urgently address the fact that its meter penetration remains significantly behind the rest of the industry. The dWRMP lacks ambition.
- While the executive summary speaks of 'metering of all connections' this is beyond any plans described in Section 8. Our analysis shows that TW's arguments supporting its poor performance in this area do not stand up to scrutiny.

- The metering plan described falls below even what TW has achieved historically and there is no plan post 2035. The metering plan should be revisited.
- We suggest targets for London of meter penetration of 60% in 2024/25, 80% in 2029/30 and 90% in 2030/35.
- TW should incorporate savings generated by the water efficiency programme which are missing from current plans.
- Smart home visits should be increased substantially.
- London demand projections should be adjusted to properly include demand reduction measures.
- More Smarter Business Visits should be conducted and targeted at those sectors that historically have been shown to give the most saving.

3.1 Introduction

Thames Water's (TW) appalling record on controlling leakage, and their laggard attitude to Demand Management in general, are widely known and understood. We do not have the space to detail all the press (both general and industry) comment, and the regulatory reports which have criticised Thames' performance over the past decade or more. Some of the up-to-date relevant references are cited below in this chapter. We would like to point out the very telling way in which Thames' proposals for Demand Management have lagged their work on new Water Sources during the period of Stakeholder Engagement running up to the publication of the dWRMP. It is of real significance that there were no sections on Demand Management in either the original Fine Screening Report, or the update – even though the latter was produced as late as April 2017. Instead the Demand Management Options Screening Report did not appear for Stakeholder discussion until June 2017.[31]

With this background of an ill-prepared programme, it is not surprising that the extensive dWRMP modelling of Leakage did not survive early stakeholder scrutiny. Further, the TW dWRMP targets and proposals are simply discarded in the Executive Summary[32] *"Whilst we cannot change the draft WRMP modelling at this point, we will clearly signal in the draft WRMP consultation that our ambition on leakage reduction is to achieve the 15% reduction in the 2020-2025 period (AMP7)."* Given the preparation time available to TW for the dWRMP this is not acceptable, nor does it go far enough and throws doubt on the whole TW target setting methodology.

3.2 Leakage

It is now widely appreciated that the UK Water Industry risks public confidence in its continued inability, or unwillingness, to reduce leakage. GARD can only echo the Consumer Council for Water (CCW): *"Leakage can affect customer's willingness to save water and does not contribute to reducing water demand. We continue to question whether the rate that companies are reducing leakage is quick enough to meet customer's expectations...Customers tell us that leakage is a key concern for them, and that companies' performance in this area can have a big impact on their attitude to water saving, as well as their perceptions of water companies."* [33]. It should be the first priority of any water company to reduce leakage, especially if they are above the industry norm, as is the case with Thames Water.

[31] https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/Water-resources/Document-library/Past-meetings/19th-June-2017/Demand-Management-Options-Feasibility-Paper-June-2017-FINAL.pdf.

[32] Steve Robertson, dWRMP19, Executive Summary, Foreword, p2.

[33] https://www.ccwater.org.uk/wp-content/uploads/2017/12/Water-water-everywhere-Delivering-a-resilient-water-system-2016-17.pdf. December 2017.

Current leakage

TW's current leakage performance is uniformly bad over its entire supply area. In 2017 in London its actual leakage was 524 Ml/d (out of 2105 Ml/d), about 25% of distribution input (figures from AR17, Table 3.8). This was against an AR17 target of 498 Ml/d. The total network leakage was 668 Ml/d out of a total supply of 2680 Ml/d (again about 25% of distribution input), against a target 630 Ml/d (AR17).

In 2017/18 TW are forecast to have a leakage in all zones of 694 Ml/d, compared with a leakage target of 620 Ml/d.[34] This is a shortfall of 70 Ml/d. Ofwat have fined TW £8.55m for missing its leakage target. Sir Tony Redmond CCW London and South East Chairman has stated *"Thames Water's failure to meet its leakage target sends completely the wrong message to its customers at a time when households are being encouraged to use water more wisely."*

Comparison with other water companies

TW's unit leakage for London is 177 l/property/d (l/pr/d), and, for the whole supply area, is 171 l/pr/d.[35]TW have probably the densest number of properties per km of pipe and should do more favourably by this yardstick than other water companies. However, their leakage compares with a 2016/17 water industry average of 121 l/pr/d.[36]Thus, TW leakage is already about 40% higher than the average of all water companies. Indeed, TW's performance is so bad that it skews the entire statistical distribution of the industry. Of the 21 water or water and sewage companies, only 6 are worse than average, the outlier being TW by a long way. The next highest company unit leakage was United Utilities (UU), which supplies the old towns of Manchester and Liverpool (133 l/pr/d).Thus, TW is also appreciably higher, 29%, than the second worst company for leakage.

TW are required to, and have committed to, lower their total leakage to the AMP 6 target of 606 Ml/d by 2019/20.[37] This would be about 155 l/pr/d. This still leaves them appreciably higher than the next worse company.

Thames Water's Leakage reduction policy and methods

TW's chosen activities to reduce leakage include *"mains rehabilitation, Pressure Management and DMA [District Metered Areas] enhancement."*[38]Although they claim to

[34]dWRMP19 Executive Summary, page 10 Table 0-2.
[35]AR17 Appendix A.
[36]Ibid CCW 'Delivering a Resilient Water System', table 2, (2017).
[37] Executive Summary Table 0-2 page 10.
[38] dWRMP19 section 8.133.

have "*…set ourselves ambitious targets to cut our leakage*"[39], Thames' plans are full of artificial constraints which should be reconsidered.

- They have artificially constrained their model to do a minimum number of kilometres of mains rehabilitation in each AMP[40]
- In the *current* dWRMP, they aim to *"…deliver more than the 15% leakage reduction target but over a longer period of time which is aligned to the roll out of our progressive metering programme, so that it is a cost effective and efficient programme."*[41] As noted in section 3.2 on Demand Management, the metering programme is unambitious. The metering programme should be increased thus removing this artificial restriction on the leakage reduction programme.
- "*…we have constrained the number of DMAs that can be chosen in IDM to a maximum of 80. These DMAs have also been constrained to be completed in AMP7 with no further DMA Enhancement in AMP8 and 9."*[42] There is no justification for this constraint.

Given the importance of leakage reduction to TW's customers and others, the number of restrictions is unwarranted. Further, TW's assumptions about the fall-off of effectiveness of mains rehabilitation: *"The leakage savings associated with mains rehabilitation were projected to reduce to 1Ml/d for approximately 13 km of mains replacement for the period 2010-2015 and I Ml/d for approximately 33km of mains rehabilitation for the period 2015-2020"*[43], is unusually large and is unsupported by evidence in the dWRMP.

What should dWRMP19 Leakage Targets be?

From the statement of the TW CEO alluded to above, the current dWRMP19 does not yet include the Ofwat required 15% leakage reduction in AMP7. *"Companies will need to find new and improved ways of reducing leakage. We expect companies to adopt ambitious leakage commitments for 2020-25 that reflect the challenges we set, which include a 15% reduction by 2025 and forward-looking upper –quartile performance on leakage per property per day*."[44]

GARD has therefore performed its own analysis of what the dWRMP19 forward looking Leakage Reduction targets should be to match:

- Ofwat requirements 15% less;
- Customer expectations of 15% of distribution input

[39] dWRMP19, Summary. Foreword page 1.
[40] dWRMP19 s8.153.
[41] dWRMP19 s10.157.
[42] dWRMP19 s8.179.
[43] dWRMP19 s8.150.
[44] Ofwat Service Delivery Report 2016/17, January 2018, page 8.

- Ofwat's forward look;
- Thames Water's own recently-professed halving aspiration;
- National Infrastructure Commission objective to halve by 2050.

Baseline for Leakage Reductions

The method for defining and measuring leakage was changed by Ofwat in July 2017 with the requirement to report leakage following the newly defined guidance developed by UKWIR.[45]Using the new reporting methodology for AMP7 has consequences for TW. But these are variously stated as: "*…. our reported leakage levels will increase by 40 Ml/d using the new methodology*"[46], on the contrary "*we estimated that applying the new reporting methodology...gave an increase of 11 Ml/d beyond that built into the draft WRMP baseline forecast."*[47] Since it is agreed that under the previous WRMP the 2019/20 leakage would be 606 Ml/d and it is now estimated by TW that the difference due to change in reporting is 11 Ml/d then the total in 2019/20 should be 617 Ml/d.

Ofwat Requirements

Ofwat state[48]*"… Companies will need to achieve the following minimum reductions or justify why not:*

- At least a 15% reduction and
- Largest actual percentage reduction achieved by a company since PR14."

A 15% reduction would be a reduction of 92 Ml/d, i.e. from 617 Ml/d to 525 Ml/d in 2025. That would be a reduction in leakage in 2025 of another 65 Ml/d above that proposed in the current dWRMP, to be incorporated in the next version of TW's dWRMP19.

Customer expectations

Customer expectations have been emphasised by Ofwat:"*We expect companies to explainhow their five-year performance and their long-term projections for leakage take account of the views of their customers, local stakeholders and CCGs*."[49]
Indeed, TW make much of the role of customers in the dWRMP process:
"*Customers are at the heart of our decision-making process*."[50]
"*Many customers consider that the current levels of leakage are unacceptable. They understand that it is not cost effective to fix some leaks but would like to see us go beyond what we are currently doing."*[51]Leakage reduction is customers' highest priority: "*Water*

[45]dWRMP 2.20.
[46]dWRMP 2.20.
[47]dWRMP19, Appendix M 'Leakage', para M58.
[48]Ofwat delivering Water 2020: Consulting on our methodology for the 2019 price review, July 2017 4.3.8.
[49]Ofwat Delivering Water 2020: consulting on our methodology for the 2019 price review. (July 2017) 4.3.8. page 69.
[50]dWRMP section 10 page 1.
[51]dWRMP 1.51. page 20.

efficiency has received strong support from our customers as a priority only second to leakage reduction."[52]

According to TW, "C*ustomers expect that leakage will decrease over time to around 15% of water put into supply."*[53]This compares with the very unfavourable current leakage rate of about 25%, and with the dWRMP19 aspirations, see above.

This customer-led imperative is in line not only with Ofwat, but also the requirements of the Environment Agency[54] and the CCW[55].Indeed, customers are very specific that TW should aim to be: *"… on par with the leaders in the industry aiming for 16% leakage*."[56], and *"… the strongest level of customer support[for leakage reduction scenario] is for us to target the industry upper quartile level (16% leakage)".*[57]

A reasonable period to achieve the reduction would be three AMPs, (15 years) i.e. by 2035. Water into supply in 2035 is hard to find in the dWRMP, but from the plots in section 3-228 the 2020 demand would appear to be about 2,600 Ml/d and the coloured growth to 2035 about 500 Ml/d, a total in 2035 of about 3,100 Ml/d, thus leakage, 15% of supply, should be about 465 Ml/d. The current dWRMP has a leakage in 2040 of about 530 Ml/d (Summary – page 9). Thus, to meet customer expectations of leakage coming down to 15% of water into supply would require a further drop in leakage of about 65 Ml/d by 2035.

Ofwat's forward look

Ofwat state: *"We expect companies to adopt ambitious leakage commitments for 2020-25 that reflect the challenges we set, which include a 15% reduction by 2025 and forward-looking upper –quartile performance on leakage per property per day*."[58]Referring to the CCW 'Delivering a Resilient Water System' (2017), table 2, for 21 companies the bottom of the upper quartile would be the sixth lowest, with a leakage of 88.2 l/pr/d, about half the current TW leakage. There is no date in the Ofwat requirement, but a reasonable expectation would be delivery by towards the end of the normal 25-year plan period, i.e. 2040. Applying the Ofwat forward looking expectation of leakage dropping to the upper quartile and using the yardstick 88.2 l/pr/d, then for about 4.8m total properties in 2040[59] the total leakage should be no more than 424 Ml/d in 2040.

Thames Water's recently-professed aspiration

[52]dWRMP 8.182.
[53] Summary report page 9.
[54] Environment Agency, 'Leakage in WRMPs' (revised Aug 2017).
[55]https://www.ccwater.org.uk/wp-content/uploads/2017/12/Water-water-everywhere-Delivering-a-resilient-water-system-2016-17.pdf. December 2017.
[56] T. page 43.
[57] T.110.
[58] Ofwat Service Delivery Report 2016/17, January 2018, page 8.
[59]dWRMP19, Section 3, Table 3.11.

At the Water Resources Forum meeting on 21st March 2018 TW presented *"Our long-term ambition is to halve leakage".* This is very appropriate. GARD have asked "*from what to what and by when*" and, several weeks later, still awaits the answer. Since Thames Water has said it proposes ambitious leakage targets and several other companies have assumed that their leakage can be nearly halved, then it would seem reasonable to presume that this is from the general leakage level in recent years, 644 Ml/d, to half, 322 Ml/d, at the end of the standard WRMP period, 2045.

National Infrastructure Commission

In their April 2018 report '*Preparing for a drier future*' the National Infrastructure Committee recommend "*The Department for Environment, food and Rural Affairs should set an objective for the water industry to halve leakage by 2050, with Ofwat agreeing 5 year commitments for each company (as part of the regulatory cycle) and reporting on progress."*[60] *"Costs are expected to fall with a long-term programme and better use of technology making halving leakage by 2050 part of the most cost-effective pathway."* Although this is an industry wide objective, considering that TW have a major and expensive capital programme it would be expected that their reduction would be at least halving, if not significantly more. Since this is part of the Ofwat 5-year cycle, it would be reasonable to assume that this would start at the beginning of the coming AMP, 2020, when TW leakage will be 606 Ml/d, i.e. reduce to 300 Ml/d by 2050.

Summary proposed Leakage programme targets

These are shown in Table 3-1:

	2019/20	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2050**
dWRMP19 targets:						
dWRMP leakage (Ml/d)	617	590	564	531	530	?530
Properties (000)	3,770	4,024	4,220		4,803	
Unit leakage (l/pr/d)	164	146	134	-	110	
Proposed revised plan		**Ofwat 15% reduction**		**Customer 15% of input**	**Ofwat fwd upper quartile**	**NIC 50% objective**
Total leakage (Ml/d)	**617**	**525**		**465**	**424**	**300**
Extra reduction (Ml/d)		**65**		**66**	**106**	**230**

Table 3-1: Summary of proposed Leakage

GARD believes that the above programme reductions represent an appropriate benchmark which regulators should apply in seeking to rectify the shortcomings of the dWRMP19

60 NIC Preparing for a drier future, April 2018 page 13.

programme. It is noticeable that the amount saved in leakage by the latter half of the 21st century approaches 28% of the forecast London deficit.

Capital maintenance

Water companies are required to maintain their assets which means replacing assets when they can no longer provide full performance. Many of the pipes in central London are old, many over 100 years old. The pipes will not last indefinitely, so replacement is inevitable at some point. Some of these have inflexible joints which, when the ground gets cold and the metal of the pipes shrink, result in leaks occurring or even pipe bursts. During the cold spell at the beginning of March 2018 many of TW's pipes burst and this resulted in Thames Water not being able to maintain supply to about 20,000 homes.[61]This showed that TW has not done sufficient capital maintenance in London to replace pipes that no longer provide satisfactory service.

Pipe replacement, and its costs, should be allocated to the capital maintenance budget. Thus, the only cost allocated to the mains replacement activity should be the cost of replacing pipes substantially before the end of their useful life. In London this would much improve the NPV of the pipe replacement programme. Not only would the increased capital maintenance reduce leakage, but pipe replacement as a means of reducing leakage would become more economical.

Comparison with other companies' dWRMP

According to the Environment Agency's anonymised summary plot,[62] see below, within the 25 years WRMP period, four water companies plan to reduce their leakage by about 40% and one company by nearly 50%.

[61] Daily Telegraph, Thousands of homes left without water because of burst pipes as Storm Emma gives way to great thaw, 5 Mar 2018.
[62] Presentation to Waterwise Annual Conference 6th March 2018.

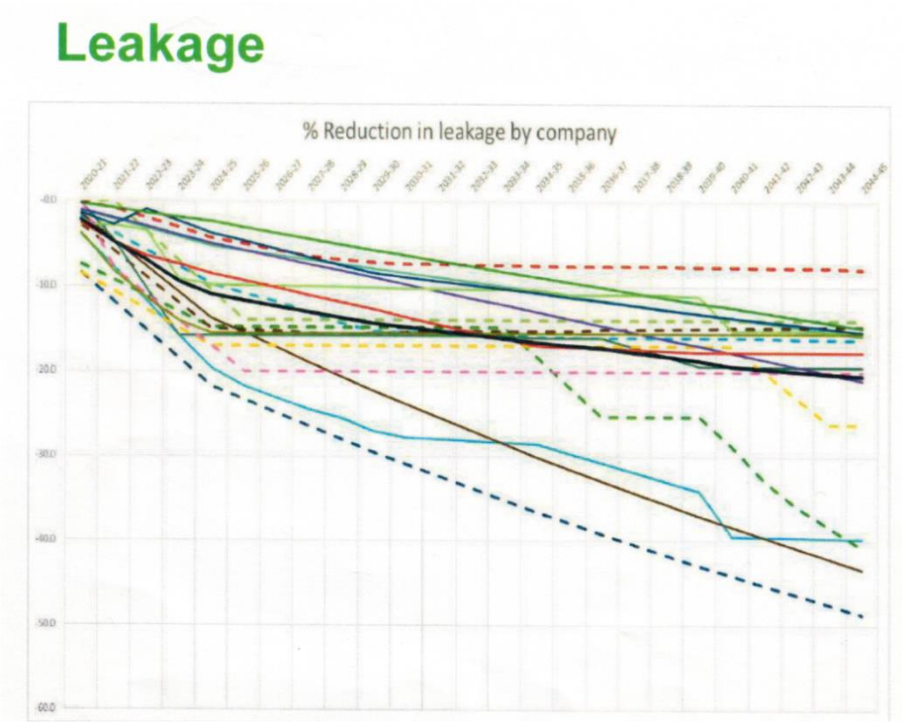

Figure 3-1: Comparison of water company leakage reduction plans

As a further illustration, Affinity Water, which supplies northwest London and other areas, had, in 2016/7, leakage of 116 l/pr/d (already below the industry average then of 121 l/pr/d). In AMP 6 Affinity is reducing leakage by 14%.[63] The preferred plan for AMP7 shows a further 11% reduction thereafter, a total of 25% reduction in two AMPs.[64] The Affinity Alternative Plan shows 15% reduction by 2025 and 33% reduction by 2080, i.e. 47% since 2015. This gives an indication of what leakage reduction one company believes can be achieved in the WRMP period and shows that the TW long term target of 50% reductionis not over ambitious.

Conclusion

Compared with other water companies, Thames Water currently has by far the highest level of leakage. TW in the London area has generally older pipes than most of the other water companies and older pipes in urban areas can leak more. Pipes that no longer provide satisfactory service and have come to the end of their life should be replaced, with the cost from the capital maintenance budget. This would both reduce leakage and make mains replacement less costly.

Ofwat requires TW to reduce leakage by 15% by 2025. TW have not yet incorporated this and need to change their dWRMP to conform. Considering the smart metering penetration, significant CSL leakage should be identifiable. Similarly, smart metering should enable areas of mains leakage to be more readily identifiable. Thames do not appear to have allowed for

[63] Affinity dWRMP page 19.
[64] Affinity dWRMP page 19.

the development of leak detection and repair technology. Thames customers expect TW to reduce leakage to 15% of that put into supply. Ofwat forward thinking proposes that companies achieve current upper-quartile. TW long term aim is to halve leakage and NIC has proposed that DEFRA require that to be met in 2050.

GARD recommends that TW reduce leakage to the level of customer expectation by 2035, Ofwat expectation by 2040 and the NIC objective of halving leakage by 2050.

3.3 Demand Management

In analysing TW's non-leakage Demand Management programme, we focus on two areas: Metering and Water Efficiency measures

Metering

Metering of supplied properties has benefits in the location and fixing of leakage. Historically TW used dumb meters but in AMP6 started installing smart meters that could relay their reading to a central location. In this respect, TW are to be congratulated on now installing AMI smart meter technology.

As TW itself cites: "*leakage on our customer water supply pipes accounts for around 28% of our total leakage"*[65]and, ***"****Metering is the only feasible demand option that delivers both a leakage and a usage (usage and wastage) reduction."*[66]Thus extending metering, and especially 'smart' metering, should enable much of this to be identified and fixed.

The Southern Water dumb metering programme found a saving of 16.5%.[67] TW state, that TW have found the benefit of metering is to reduce demand by 17%.[68]Moreover this figure is "*… considered to provide an underestimate of usage savings"*[69], as it *"does not include any savings achieved from wastage and CSL fixes."*[70]

Further "*Artesia have been advised by Thames Water that smart metering will prompt a 12% saving over standard metering. There is facility in the model dashboard to change the 12% saving to whatever is required."*[71]Since in London the current dWRMP shows measured pcc increases as the smart meter penetration increases, it is not clear how this extra saving has been incorporated, if at all. This needs to be reconsidered.

The dWRMP also mentions that using the AMI meters installed by TW to enable customers to interact online with their usage "*… can yield further usage reductions... in the 2-5%*

[65]dWRMP19, Summary Page 10.
[66]dWRMP19, Appendix N.49.
[67]dWRMP19 section 8.99.
[68]dWRMP19, section 8.88.
[69]dWRMP19, section 8.92.
[70]dWRMP19, section 8.88.
[71]dWRMP Appendix F 13.2 page 65.

range."[72] This benefit may not yet have been incorporated into the dWRMP.***ThamesWater should clarify if this further benefit for the demand management has been modelled into their dWRMP forecasts. If not, it should be during the preparation of the August dWRMP.***

Current situation

At the end of 2016/17 the meter penetration in households in London was about 35% and the penetration in the Thames Valley about 55%, this gave an overall proportion of billed measured households of 37.7%.[73]

The industry average meter penetration in 2016/17 was 55%.[74] This shows that TW was again way below the industry norm. Northumbria Water with the vast water reserves of Kielder reservoir, was the only water & sewage company with a lower meter penetration (35%). Thus, TW has much catching up to do, especially as it also needs expensive investment in extra water resources.

dWRMP proposals

Southern Water, a large water company with an appreciable urban population, went from 52% meter penetration in 2011/12 to 82.5% in 2014/15, an increase of over 30 % in three years. This illustrates what can be done. However, TW has held back until it is able to install smart meters which make it easier to identify leakage, particularly on a customer's premises. Whilst this may have been a valid excuse in the past, it is surely no longer a real constraint, yet the dWRMP19 continues to show poor ambition.

Once again, in this area of Demand Management, corporate spin is not to backed up by an appropriate action plan. The CEO Summary Foreword page 1 claims *"… ambitious targets... to increase our metering penetration.* "Section 10 page 1 states: *"The preferred programme is demand management...the metering of all connections."*These are laudable, and presumably TW consider the latter feasible or they would not have mentioned it. However, there is no mention of metering all connections in Section 8, Appraisal of Demand Options.

TW admit that: *"… due to the effectiveness of metering, IDM [Integrated Demand Management] chose to achieve almost full meter penetration by the end of 2034 for every demand scenario."*[75]As its dWRMP19 goes nowhere near these levels of penetration, it is very pertinent to establish why. ***GARD has analysed this and found that the reasons for not pursuing the goal of full meter penetration do not stand up to scrutiny.***

Although TW's plan to install 441,000 meters by 2020 has been hampered by several setbacks, they now have a revised programme which aims to install approximately 300,000

[72]dWRMP19, Appendix N. 59.
[73]AR17 page 23.
[74] CCW Water 2016/17
[75]dWRMP19 section 8.124

smart meters in households by 2020.[76]Executive Summary Table 0-2 shows actual and forecast of progressive metering in AMP 6 with 103,000 meters installed in the year 2016/17.***Thus, the progressive metering programme should be able to achieve this level, if not more, in the subsequent years.***

Compared to what is already being achieved, the dWRMP19 proposals fall significantly short. Without justification, TW assert*: "We do not believe our teams can increase the rate of successful meter installations and remain cost effective"[77],* but Table 0-2 in the Executive Summary shows progressive metering went from 42,000/year in 2015/16 to 103,000/year in the following year 2016/17.

GARD's analysis of the London WRZ metering plan shows:

- the AMP7 plan to install 320,000 smart meters by 2025, achieving 54% meter penetration [78] corresponds to about 64,000 meters a year. This is about half what it has already achieved and far below what Southern Water achieved;
- the plan to install 45,000 meters per year to only reach 75% penetration in London by 2035[79], when in 2016/17 TW installed over 100,000, is even more unambitious and needs to be improved;
- there is no plan for increasing meter penetration post-2035.

This plan is completely unacceptable, when TW ought to be targeting the London WRZ where there would be increasing water deficiencies. TW's own modelling shows that [80]*"...the cost-effective level of metering indicated up to 680,000 meters (out of 790,000) could be installed in AMP7 in London."* That is 136,000 meters/year.

Thus, there is plenty of scope for TW to be able to fit more meters in London, and still be able to implement their full-penetration targets for SWOX (installation of around 125,000 meters - achieving 98% penetration by 2030.[81]). Serious metering in SWA WRZ does not start until about 2030. Installation of over 75,000 meters would occur between 2030 and 2040 – achieving 96% meter penetration by 2040[82] .

GARD suggests that a target be set for London of meter penetration of 60% in 2024/5, 80% in 2029/30, and 90% in 2034/35. When compared to TW's penetration of 77% of3.66 Million properties,[83]this would save about a further 12 Ml/d in 2035.

[76]dWRMP19, Summary page 10.
[77]dWRMP19, Section 8.127.
[78]dWRMP19, Summary page 39.
[79]dWRMP19, Summary page 40.
[80]dWRMP19, Section 8.126.
[81]dWRMP19, Summary page 42.
[82]dWRMP19, Summary page 43.
[83]Table 3.12

Metering constraints as perceived by TW

TW aim to: "*fit a meter on all new build properties*."[84] This might be taken to mean that a new build block of multiple properties would only have one meter. In other countries where water supplies are constrained, such as Singapore, there is a meter for each flat, thus ensuring that each new build apartment is individually metered. Such an approach should be adopted in London for new build multi-occupancy buildings. Table N-1 which shows large block of flats with 83% metered internally implies this can be done. Wherever possible it should be, particularly on new build.

Although TW has a larger number of existing blocks of flats which are more difficult to meter, doing so is generally not impossible, and, even if resisted, could be done on change of occupier. Considering the need for major expenditure on new water resources and the lower cost of the metering option, then, in our view, TW ought to accelerate its metering programme in London.

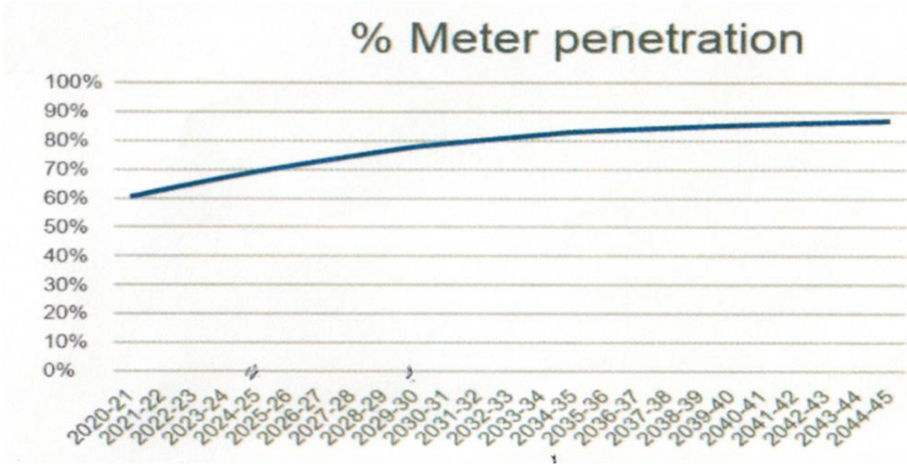

Figure 3-2: Thames Water planned meter penetration

Comparison with other water companies

The industry average meter penetration in 2016/17 was 55%, whilst Thames was 37.7%.[85] Thus, TW has more than 15% less meter penetration than the industry average at a time when it was planning extra water resources.

The industry average meter penetration is projected to be about 78% in 2035 and about 88% in 2045.[86] At about 80% in 2035 and about 90% in 2045 GARD's proposal for TW in London is similar to the industry average. Affinity, which provides water to parts of London and the area between the TW London WRZ and the TW Thames Valley WRZs, has in their preferred plan for their Central area, 2015/16 45%, 2020 60%, 2025 90%.[87] This is much more ambitious than the GARD proposal.

[84] dWRMP19, Appendix N.21.
[85] CCW Water 2016/17.
[86] Presentation to Waterwise Annual Conference 6th March 2018.
[87] Affinity dWRMP Figure 17 page 96.

"*Commission analysed the potential benefits of metering compared to a baseline of continuing at the current rate of roll-out with near universal conventional and smart metering by 2030 and 2035...These results suggest that, if the wider benefits are considered, quicker and more comprehensive smart metering should result in savings and is at worst cost neutral.*"[88] Near universal in London should mean 90%. NIC expects this to be achieved earlier than 2035.

Conclusion on metering

GARD suggests that a target be set for London of meter penetration of 60% in 2024/5, 80% in 2029/30, and 90% in 2034/35. This is considerably slower than Southern Water achieved in its total supply area and is considerably slower than Affinity's programme for its Central Area in its Preferred Plan. This would reduce demand by about 12 Ml/d in 2034/35. It would also help find and reduce customer supply pipe leakage.

Water efficiency programme

In order to promote Water Efficiency, TW have instituted a Smarter Home Visits (SHV) programme, which *"… comprise tailored water and energy saving advice in parallel with the installation of water saving devices."*[89]The benefit on a newly metered property is found to be 36 litres per household per day (l/hh/d), representing a further 6% saving in addition to the 17% saving achieved by installing a smart meter.[90] The equivalent savings on existing metered properties and unmeasured properties are found to be 11 l/hh/d[91] and 25 l/hh/d[92]respectively. GARD cannot find text as to whether this effect has been included in the plan pcc, but the graphs would indicate not yet. It should be.

"At the time of writing the dWRMP19, TW had carried out 100,000 SHV since 2015[93]*"*. Again, this initiative by TW is to be praised and welcomed. Moreover, we note that TW's own analysis is that: "*The Water Efficiency interventions are one of the most beneficial demand management options available in the IDM. This means that when left unconstrained IDM will choose to conduct as much water efficiency activity as possible."*[94]

However, as is ubiquitous with TW's forward plans on Demand Management actions, artificial constraints are applied *ab initio* which serve to limit their effectiveness,*"…due to the connection between a SHV and the level of metering, the volume of SHVs that the IDM model will select depends on meter penetration. This is because the number of SHVs that can be conducted on newly metered properties is dependent on the number of properties which become metered in that year. Therefore, due to the modelling constraint that we will do up*

[88] National Infrastructure Commission, Preparing for a drier future, April 2018 page 24
[89]dWRMP19 Section8.187.
[90]dWRMP19 Section 8.188.
[91]dWRMP 8.194.
[92]dWRMP 8.196.
[93]dWRMP 8.187.
[94]dWRMP8.222.

to 400,000 meter installations across our area per AMP, the number of SHVs to a newly metered property is also limited."[95]

GARD has indicated already that the number of meter installations itself is unnecessarily constrained, but additionally, considering that water efficiency measures are one of the most beneficial demand management measures, and are strongly supported by customers, these artificial constraints should be removed and the SHV programme increased. It has already been shown above that even unmetered properties show an appreciable benefit.

GARD recommends that TW increase the SHV programme substantially.

Per Capita Consumption overall

The per capita consumption (PCC) for London is shown in the dWRMP to go from:

2017[96]	159 l/p/d (unmeasured properties);	119 l/p/d (measured properties),
2045	154 l/p/d (unmeasured);	128 l/p/d (measured)

Thereafter the measured properties' PCC hardly declines for the rest of the 21st century (129 l/p/d in 2100).

The increase in measured PCC from 2017 to 2045 is explained by TW: "*Household occupancy continues to decrease across the period...the number of adults is also continuing to grow as a percentage of the population."*[97] These factors overlap as one reason for the lowering of occupancy is that there are fewer children. No calculation could be found to support this allegation. There is no mention that household appliances are getting much more water efficient and that measured households have an incentive to buy appliances that are more water efficient and operate them in a more water efficient way such as not using part loads in a washing machine, or smaller flushes for a dual flush WC when appropriate.

Furthermore, the equivalent SWOX PCC figures by 2100 are 120 l/h/d (unmeasured) and 109 l/h/d (measured). Metered households in SWOX would have more space for exterior water use than those in London yet are projected to have 20 l/h/d lower use than London's at 2100. This does not seem logical.

Below is the pcc plot for the London WRZ and the Thames Valley WRZs.[98] The large, and increasing differences seem illogical.

[95] dWRMP 8.224.
[96] AR17.
[97] 3-168.
[98] dWRMP Figure 3-10.

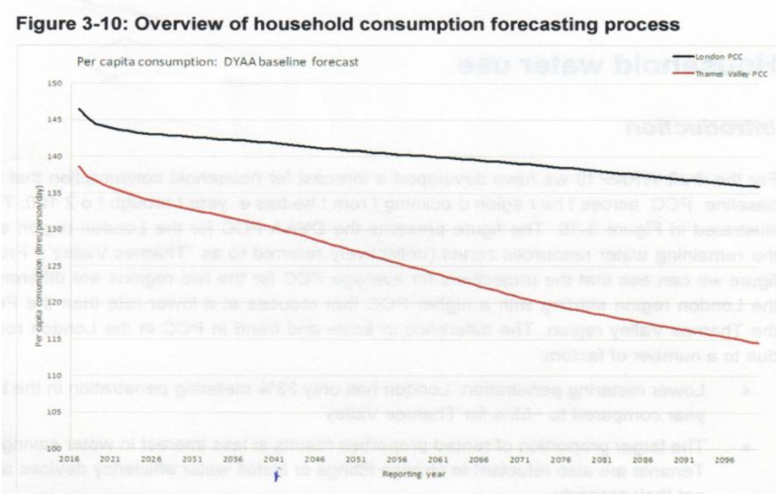

Figure 3-3: Planned reduction in pcc in London and Thames Valley

GARD proposes that, for the next version of the dWRMP, TW should be asked to justify the future measured PCC for London or reduce it similar to the Thames Valley.

Southern Water has announced Target 100. This aims to reduce household use to 100 l/h/d by 2040.[99]Making a ***Comparison with other water companies,***[100]we see that there is an average ***reduction*** in average PCC of all the companies of about 15 l/h/d and a fall in measured PCC of all the companies by about 6 l/h/d by 2045, see graph below.

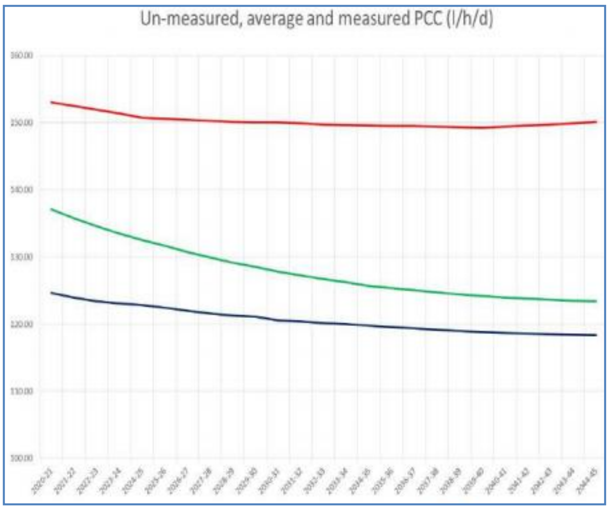

Figure 3-4: Forecast ppc reduction of other water companies

It would be reasonable to assume it would reduce further thereafter, but since TW has already shown its population figures to be in error, post 2045, it is not worth making an estimate of the potential further PCC reduction at this time.

Adjusting the PCC increases in London of 9 l/h/d to conform with the industry average would reduce the measured PCC by 15 l/h/d in 2045 and 17 l/h/d in 2100. The forecast

[99] Wwtonline.co.uk/ news/proactive-network-management-key-inpr19—Ofwat/409 23/03/2018.
[100] Presentation to Waterwise Annual Conference 6th March 2018.

population for London in the dWRMP is 5.37m in 2045.[101] Applying the factors above would, by GARD's calculation, reduce the demand in London by 80 Ml/d in 2045.

GARD requests that TW revisit the London measured PCC and adjust to take proper account of these factors and to match industry average reduction unless there is strong specific evidence to the contrary.

3.4 Non-household water use

Demand

Non-household demand in the TW supply area amounts to about 440 Ml/d[102]. TW project that it will generally be in the range 420-430 Ml/d during the plan period.[103] This oscillates around in an unusual way. This is about 20% of the water supplied, an appreciable amount.

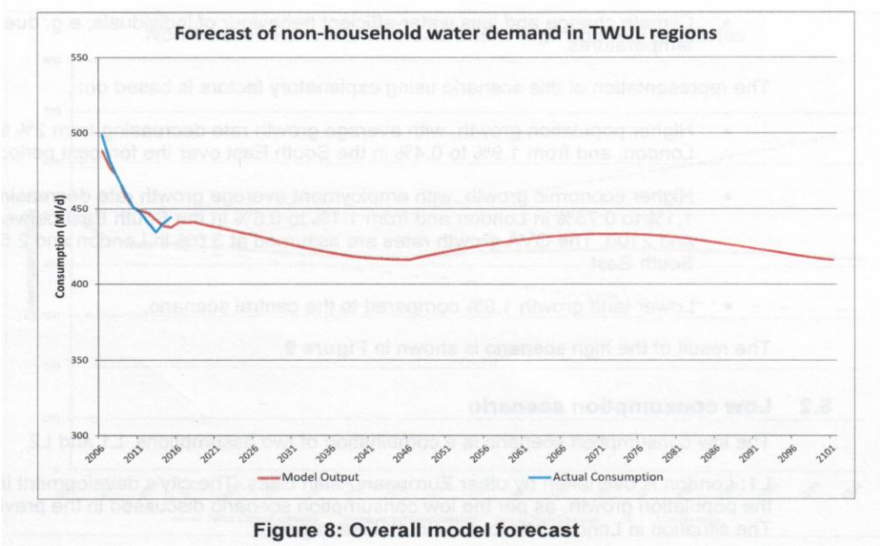

Figure 3-5: Forecast non-household demand in TW regions

Metering penetration

The Thames Water current metering penetration of non-households is reported as 81.9%[104]. However, this compares poorly with an industry average of 90.6%. Of the 21 companies only one, a very small one, Hartlepool, has a lower non-household meter penetration. There is no reason to believe that the non-household mix in the TW area is that different from almost all the other water companies. However, no mention could be found in the dWRMP of Thames doing any further metering of non-households. Thames should be required to get to at least the industry average meter penetration by the end of AMP7.This should somewhat reduce non-household water supplied and will improve the water balance and make it easier to trace leaks.

[101] dWRMP19, table 3-12 page 25.
[102] dWRMP19, Appendix G Figure G-8.
[103] Fig G-8.
[104] CCW Water 2016/17.

Smarter Business Visits

TW have carried out Smarter Business Visits (SBV) with percentage savings varying from 2% to 85%.[105]. Once again the familiar mantra of constrained options is applied: *"SBVs ...Wastage Fixes...there is a limit on the number of these Water Efficiency interventions. This means the size of the Water Efficiency programme chosen by IDM is less than it would have been without the imposition of other intervention constraints*."[106]

SBVs can save between 25% and 85% of non-household water use. Appendix G does not give any breakdown of water use by classification. TW should target the sectors where the most water could be saved. No data on this is provided. However, In London there are many hotels and catering, where the savings are reported as 24%.[107] Thus TW should raise the SBV uptake rate from 13%[108] to say 20% per year for those sectors where more water could be saved such as hotels, catering and business (offices).

On the basis that the hotel and catering sector is 30% of the water use of the non-household sector in London and the saving is the 24% as quoted, then the potential saving from SBV over AMP 7 would be about 7 Ml/d. SBVs in the following AMP should be able to not only maintain this benefit but improve on it. On the assumption that Business (offices) is another 20% of supply then the quoted 67% saving from that would be about 16 Ml/d. As an instance TW's own bathroom water efficiency trial at Clearwater Court resulted in an 83% saving of water from a system that was already considered water efficient.

Non-household users may now switch supplier, but the provision of SBVs should reduce the amount of switching, i.e. TW could retain more business in this way.

Judging by the graphs in Appendix G of the dWRMP and lack of mention in the text, this non-household saving has not yet been included in the demand total. Thus, this would be a total saving due to extra SBVs and non-household metering of some 20 Ml/d. In our view TW should be required to take account in their next dWRMP of such measures to reduce non-household use of water.

Conclusion

Thus, GARD's conclusion is that TW should reduce their demand projections as set out above, which, in GARD's assessment, could well be by 2050:

Leakage reduction	230 Ml/d
Increased metering	12 Ml/d
Measured pcc adjustment	80 Ml/d
Non-household measures	20 Ml/d
Total	340 Ml/d

[105]dWRMP10, section 8.200.
[106]dWRMP19, section 8.224.
[107]dWRMP19, Table 8-2.
[108]dWRMP19, Table 8-3.

4. Teddington Direct River Abstraction

Key Points

- This is an excellent scheme as it utilises a large continuous resilient resource with limited capital investment.
- The scheme offers certain flexibilities of operation to Thames Water (TW), being capable of expansion to supplement the East and West London systems.
- TW underestimates the Deployable Output (DO) capability of the Teddington DRA scheme:
  1. under present Available Flow conditions and
  2. In future when Available Flows will, according to TW's own estimates, increase.
- The present DO capability of the scheme is somewhere in the region of 316 Ml/day if sensible alterations to TW's operating philosophy are implemented.
- TW should analyse the effect of alteration of Operating Philosophy of the Teddington DRA to take full use of DO
- The TW presentation image of 21st March 2018 shows the DRA not being needed at full output until about 2050.
- TW should quantify and model their predictions that a future larger flow could be made available for transfer from Mogden STW during drought conditions after 2045.
- TW are conservative in discounting certain flows to Mogden when estimating the DO. TW should:
  1. clarify the contribution from discounted flows to Mogden, and
  2. Using the revised figures, give a new estimate of current and future DO from the Teddington DRA.
- GARD has assessed the DRA deployable output in 2050 as 479 Ml/d.
- It is stated that the Environment Agency is concerned about the effect of effluent discharge on water temperature and ecology in the Thames. TW should clarify and resolve any issues, since this will affect DO during drought.
- TW should explain why they do not give adequate reasons for their classification of the scheme as 'partially resilient' to climate change.
- *In common with all the large schemes*, TW need to provide justification for costs and cost movements of the DRA scheme. There are recent unexplained rises in the quoted AIC and AISC values.

4.1 Scope and Deployable Output

Scheme concept

The scheme[109] takes tertiary treated effluent from Mogden STW, pumps it via a new tunnel and discharges it at Teddington Weir. The scheme would then abstract an equivalent amount from upstream of the Teddington weir and pump it into the Thames/Lee tunnel to increase the supply to the Lee Valley reservoirs. "*Option 3 involves transferring up to 500Ml/d of tertiary treated effluent."*[110] This is an excellent scheme as it utilises a large continuous resilient resource with limited capital investment.

New Mogden/Teddington tunnel

The original concept was that the flow could be taken from Mogden to the Teddington discharge site by a 1.7m pipeline but this is a heavily congested area so a 2.4m dia tunnel was proposed. The Mogden to Teddington weir tunnel would be 3.5m dia[111] as this is quoted as the minimum size tunnel to meet HSE guidelines. This has about four times the capacity needed to take the envisaged Dry Water Flows (DWF) so would be well able to take any increases in flow available, enabling a scheme with larger Deployable Output (DO) in future. The tunnel length would be about 4.5km. In order to avoid going underneath much of the housing and buildings with deep foundations its route is not straight: because of its length it would have an intermediate shaft on the stick and ball ground of the Ham Polo Club. The drive site would be from the Teddington end shaft.

Capacity of the Thames/Lee tunnel and extension

"*Currently the Thames/Lee tunnel is understood to have a capacity of 410 Ml/d and at times this capacity is fully utilised. For the option to have a deployable output benefit, it must be possible for the water that is currently conveyed in the tunnel to be abstracted further upstream into the existing reservoirs so as to allow the Thames lee tunnel capacity."*[112]

The report on the design and construction of the tunnel by Cuthbert and Wood, ICE 6578 says the tunnel is designed to carry 120 mgd. This is about 545 Ml/d. It is believed that the difference in flow is that the original design had more pumping capacity near the downstream end. Thus, the capacity could probably be raised appreciably. There is an option "*to upgrade the TLT to remove the existing constraints to maximise transfer capacity"*[113]. However, the need to implement this option does not appear on any of the

[109] TW dWRMP19 Direct River Abstraction Report, February 2018.
[110] Direct River Abstraction Report - s 4.2.3
[111] CDR reviewed 28th March 2018
[112] Direct River Abstraction Report – s 5.1.3.1
[113] dWRMP section 7.50

alternatives[114]. Instead the Thames/Lee Tunnel Extension tunnel from Lockwood Shaft to the KGV reservoir inlet is selected in almost every instance.

There is no comment in the dWRMP that GARD can find on the distance, size or cost of the TLT extension, but the implication is that this would be either 360 Ml/d or 800Ml/d, with some allowance for the Beckton reuse scheme as well. The minimum size of tunnel, said to be 3.2m dia for health and safety reasons, would be satisfactory for this size or more.

The links between Mogden STW and Teddington, Teddington to Lockwood shaft, and there to the King George V inlet are all in tunnel, with the new ones quoted at minimum size of 3.2m to suit health and safety considerations. Thus, all the conveyance mechanisms would be able to cope with flows up to at least 500 Ml/d.

Deployable output in dWRMP

The Preferred Plan includes the Teddington direct abstraction at a deployable output of 268 Ml/d. The Reuse Feasibility Report does not explain how this number has been derived. Therefore, GARD has carried out its own analysis.

Our analysis shows that the deployable output of the Teddington DRA scheme is under-estimated by Thames Water. This applies both to the capability under present available flow conditions, and to the future capability when available flows will increase, as demands in London rise. In GARD's opinion, Thames Water's assumed deployable output of 268 Ml/d is grossly underestimated for four reasons:

i) As London demands rise, generating the need for the Teddington DRA scheme, the available effluent at Mogden will also rise.

ii) Critical droughts for London's supplies are always at least 12 months duration, so the deployable output will depend on the volume of effluent available over the duration of the drought, not the minimum daily flow.

iii) The operating assumption that the scheme is triggered by the same rules as the existing Beckton desalination plant results in unnecessary lost deployable output due to delayed start up in droughts.

iv) There appears to have been an invalid assumption over the need for additional emergency storage in the London reservoirs.

Deployable output under present available Mogden effluent

The present available dry weather flow (DWF) is estimated in the DRA Feasibility Report: *"Over the period from 2011 to 2031 the minimum projected domestic flow received by Mogden is 305 Ml/d. This does not include infiltration or trade flows, and therefore provides*

[114] dWRMP Table 7-5 page 19

an indication of the reliable effluent discharged from Mogden STW during drought conditions...Losses will occur during treatment and therefore the quantity of effluent discharged to the River Thames will be less than the above flow received at the STW."[115] The basis of this is the SOLAR table[116] which shows DWF inflow increasing in future years so the 305 Ml/d would be the baseline situation in 2016. The main cutbacks during drought are bans on use of hosepipes and garden watering. These would not have drained to the Mogden STW anyway, so the bans would not have an effect on STW flows. *"It is assumed that domestic flows will not reduce significantly during drought."*[117] Thus the base flow from Mogden STW allowable for diversion during a drought would be the amount allowed for domestic flow of 305 Ml/d.

The STW losses would be minimal, so Thames Water appear to have assumed a discharge flow of 300Ml/d, matching the nominal capacity of their proposed scheme.

We have simulated the operation of the 300 Ml/d Teddington DRA scheme using GARD's model. Figure 4-1 below shows the water that would be available for abstraction to fill the London reservoirs, with the 300 Ml/d Teddington DRA scheme in action, during a drought like 1933/34, probably the worst on record.

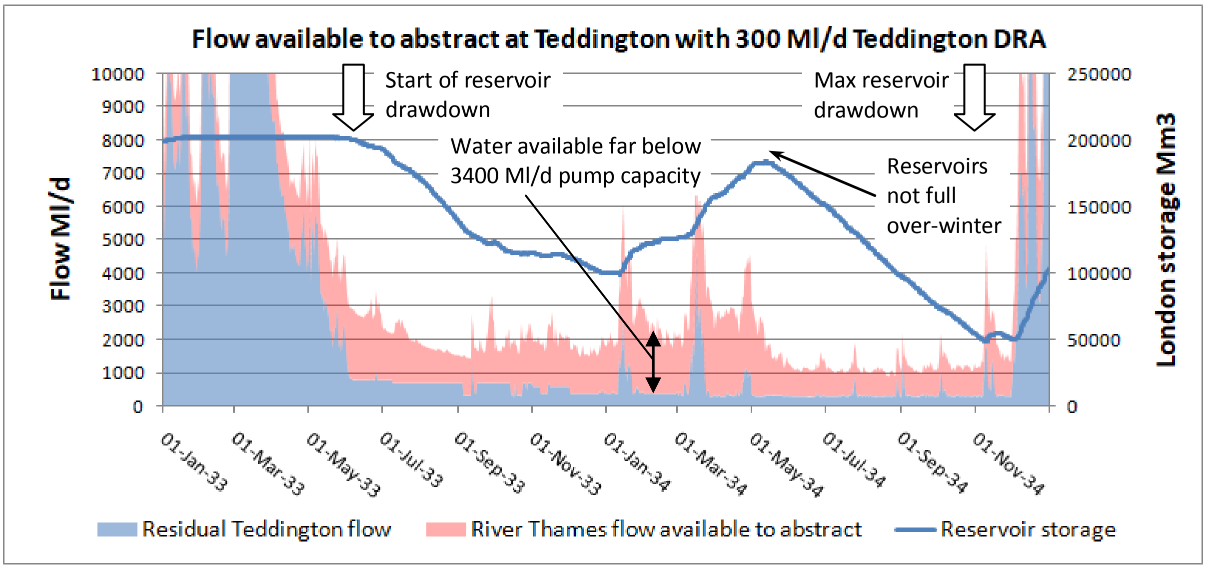

Figure 4-1: Deficit in water available for abstraction in droughts

Almost entirely throughout the drought, from June 1933 to November 1934, the water available for abstraction at Teddington would be far below the 3400 Ml/d abstraction capacity of the existing reservoir refill pumps, even in the winter. The reservoirs would be well short of re-filling over-winter. Therefore, virtually all Mogden effluent discharged at Teddington from June 1933 to November 1934 would be usable for reducing the drawdown of the London reservoirs and adding to deployable output. As this drought, and any drought

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[115] DRA Feasibility Report 2018 page 44.
[116] SOLAR Table provided by Lesley Tait as attachment to email dated 9th April 2018.
[117] D 3.1.3.

that would be critical to London's supplies, extended over the winter, there would be some additional wet weather effluent available for refilling the reservoirs. Even in an extreme drought like 1933/34, there are significant wet periods during the winter during which Mogden effluent would be well in excess of the dry weather domestic flow. Thames Water themselves note that *"average dry weather flows for discharge are typically 500 Ml/d with diurnal and annual variation, Mogden experiences a large percentage of infiltration."*[118]

Therefore, all effluents arising from trade discharges and wet weather infiltration would add to the water available for pumping to the reservoirs. This should be allowed for in the deployable output assessment by estimating the volume of effluent available over the duration of the drought, not merely the minimum daily domestic flow. Records of existing outflows from Mogden over droughts like 2011/12 should be used to estimate the available volume in droughts.

Assumption for triggering scheme operation

According to the dWRMP[119] *"It has been assumed that the new Mogden treatment plant would operate continuously at full capacity. When the Teddington abstraction option is not in operation, the treated effluent would be discharged via the existing Mogden outfall. Once the option triggers have been activated, the effluent would be diverted from the existing Mogden outfalls to Teddington."*

This option trigger was originally proposed for the desalination scheme, which has very high head pumping (around 30 bar or 300m head) and thus very high operational costs, hence its operation had to be limited to periods when it was really needed. The pumping head from Mogden STW to Teddington Weir is low (quoted at about 10m – 17m)[120], so the energy use in pumping would be low. Thus the energy use in operating the discharge all the time when the DRA is required at full DO would be very limited. The deployable output should be assessed on the assumption that the effluent is continuously available for discharge at Teddington, avoiding the delayed start up. GARD's modelling shows that adds about 10-15 Ml/d to the deployable output (see below).

The need for additional emergency storage

Thames Water have established a 30-day emergency storage criterion at Level 4 for sources dependent on river flows in droughts. However systems such as desalination plants that have a guaranteed output in droughts do not require the 30 days emergency storage. The Teddington DRA scheme should be treated the same as the Beckton desalination plant – guaranteed output in droughts, so no additional emergency storage is provided.

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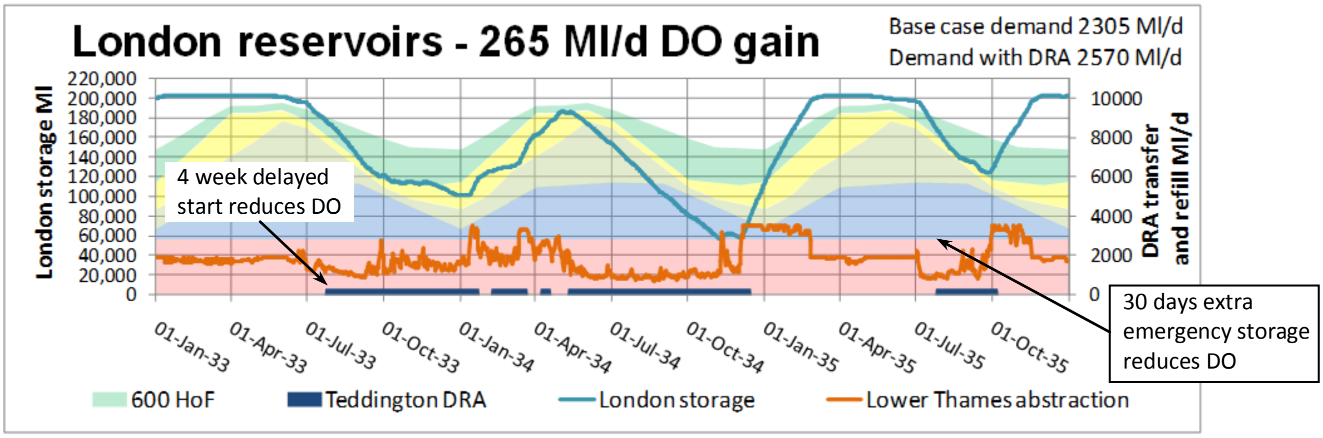
118 DRA Feasibility Report, page 42
119 Options Operating Philosophy: Feb 2018, section 4.1.4
120 DRA Feasibility Report, D3.3, Page 147.

GARD assessment of DO based on TW's assumption of existing domestic effluent only

Using GARD's simulation model, we have assessed the DO of the scheme using Thames Water's assumption that the available effluent is only 300 Ml/d, with Thames Water's trigger assumption and additional emergency storage of 30 days of deployable output, ie the same assumptions that we believe were made in deriving the DO of 268 Ml/d. The simulated operation of the scheme in the 1933/34 drought is shown below, delivering a deployable output of 265 Ml/d:



Notes: 1. Using TW trigger and 30 days extra emergency storage (7980 Ml)

2. The GARD result for the existing TW operating conditions (265 Ml/d) benchmarks well with TW's analysis using WARMS2 (268 Ml/d)

Figure 4-2: Effect of adding DRA to base case demand in 1933/34 drought

We have also used GARD's model to test the significance of Thames Water's assumptions for the operating trigger and emergency storage as shown in the table below:

Case	Deployable Output (Ml/d)	Notes
TW option trigger and 30 days extra emergency storage	265	Benchmark case – see figure 4-2
Continuous transfer and 30 days emergency storage	275	See Appendix A
TW option trigger and existing emergency storage	302	See Appendix A
Continuous transfer and existing emergency storage	316	See Appendix A

Note: modelled assuming 300 Ml/d effluent

Table 4-1: Effect of different operating conditions on DRA scheme Deployable Output

From this it can be seen that Thames Water's inappropriate assumptions for triggering the scheme and emergency storage have reduced the deployable output by about 50 Ml/d. More details of the GARD modelling runs are shown in Appendix A. This Appendix also explains how a 300 Ml/d transfer of effluent can, under drought conditions, give a yield gain of more than 300 Ml/d (in essence, because demand in droughts is suppressed by water-use restrictions).

Future Deployable Output

The dWRMP fails to take any account of the future potential for increased DO from the Teddington DRA, which can be clearly seen from TW's own analysis and in SOLAR, and recognised in the DRA Feasibility Report:

"average dry weather flows for discharge are typically 500 Ml/d with diurnal and annual variation, Mogden experiences a large percentage of infiltration."[121]

The analysis period in SOLAR is 2016 to 2031. However, the DRA scheme would not be commissioned until about 2030and its full output would not be required until about 2050 (according to Slide 34 presented at the Thames Water Resources Forum (WRF) on 21/3/18), and thus the Mogden STW flows of about 2050 are the relevant ones.

The dWRMP report says that the flow to Mogden is expected to increase, due to "*predicted growth in the catchment*"[122]. The SOLAR[123] table shows no increase in trade flows but an increase in DWF from 503Ml/d in 2016 to 561 Ml/d in 2041, an increase of 58Ml/d. A reasonable assumption would be that this is the increased amount of domestic flow that would be available when the DRA was needed to provide its full output.

The trade flows have been excluded from the TW analysis on the assumption that they vary over a week. Whilst that may well be so, the DRA would be supplied to either King George V reservoir or the large west London reservoirs. These are large reservoirs which would be partly drawn-down during a drought. Thus, some temporal variation would be taken up within the reservoir storage so that the relevant flow would be the average during the drought drawdown period.

The SOLAR[124] shows the trade flows as 106 Ml/d constant throughout the period up to 2041.

However, trade flows would be affected by Level 3 non-essential flow bans for part of the drought period. Looking at Figure 4-2 for the 1933/34 drought it would appear that these bans would have occurred from about 1st June year 2 to 1st December year 2, a period of 6 months out of the18 month drought period.

To assess this for the longer return period droughts, GARD has taken all the saving going from level 2 to level 3 as applicable to a reduction in trade flows. The monthly reductions are set out in the WARMS2 modelling system documentation. GARD has assumed that the

[121] DRA feasibility Report Page 44
[122] Ibid 1: Appendix B, section 1.3.1, para 1
[123] Strategic Overview of Long Term Assets and Resources (SOLAR) provide by Lesley Tait email 9th April 2018.
[124] Strategic Overview of Long Term Assets and Resources (SOLAR) provide by Lesley Tait email 9th April 2018

drought drawdown would start on 1st June and the level 3 ban would run from 1st July in year one to 30thNovember in year two of the drought, an 18-monthperiod.Considering that in the worst historic drought it would appear that the level 3 bans would only have lasted from August to November 1934, for 4 months, GARD's assumptions are conservative. This results in a 2.6% average reduction of distribution input (DI). GARD has then taken the distribution input to London WRZ, Table 3-8, 2,100 Ml/d and the non-household as a total of 365 Ml/d, Table 3-4, to result in a ratio of 5.75. Thus, the reduction in the trade flows would be about 15%.

It would seem appropriate to take a conservative assessment that an average of about 80% of the trade flow, 106 Ml/d, would be available over the18-month drought period. This would increase the available flow for the DRA by about 85 Ml/d. The SOLAR analysis shows the trade flows at a constant 106 Ml/d throughout the period so assume that trade flows continue at this level throughout the plan period.

Infiltration

Infiltration comes from rainfall soaking into the ground and infiltrating into the sewer system. Whilst rainfall during a drought will reduce, in the UK there will always be a significant amount. In London much of the ground is impermeable tarmac or impermeable roof. Thus, rainfall infiltration is limited. Drought would have some limited effect on this infiltration.

Infiltration also comes from leaking water pipes. The water network has already had its pressure reduced to close to the minimum,[125] thus the scope during a drought for reducing pipe leakage and leakage sourced infiltration will be very limited.

…"A proportion of infiltration flows is likely to be reliable during drought conditions, however no infiltration is included in the above value as this proportion is unknown and therefore conservatively not included."[126]
… "there may be a potential to increase this level, by undertaking a review of historic drought period flows to assess what percentage of infiltration could be relied upon, using 10-20% for the larger catchments would give a significant increase."[127]

Deducting the trade flow, 106 Ml/d, and the domestic flow, 305 Ml/d, from the DWF, 503 Ml/d, provides the infiltration, 92 Ml/d.

Thus, assuming that 20% of normal infiltration would be available during a drought would seem a conservative approach. Thus, infiltration would be about another 20 Ml/d.

[125]dWRMP 8.156
[126] DRA Feasibility Study February 2018 Appendix D 3.1.3
[127] Reuse feasibility report page 69

Estimation of Deployable Output at time when required

Thus, the available DO would appear to be:

DO corrected for transfer and storage	316 Ml/d
Addition of future domestic flows	58 Ml/d
Trade flows	85 Ml/d
Infiltration	20 Ml/d
Total	479 Ml/d

Any further losses

Process water losses from Thames Valley water treatment works are returned to the Thames upstream of the Teddington Target Flow assessment point. Coppermills process water loses are recovered on site. There no allowance is needed for process water losses. Evaporation from the reservoir surface is taken account of in the WARMS2 and GARD modelling. Therefore, there are no losses that need to be taken into account.

4.2 Need for additional treatment

The process added to the Mogden STW effluent would be ferric added to remove phosphate, a nitrifying sand filter to remove nitrates and a mechanical filter.[128] The dWRMP does not foresee that the anticipated change in effluent quality would be difficult to achieve or require the use of unusual processes.

4.3 Environmental and Other Impacts

There are several potential impacts on the tideway and further modelling is proposed in the next stage of investigation. In general, the impacts are considered not to have combined significance.

Regarding ***Navigation***, the reduction of discharge from Mogden STW at Isleworth Ait will result in less flow in the tidal upper Tideway. There is a dredged channel in this section, so it may mean that some shallow draught boats will have to use the dredged channel for a limited distance.[129] The dWRMP19 concludes that" The *assessed risks with regard to navigation are minimal."*[130]

If discharge were to be immediately below Teddington Weir, then part of the weir could be adapted to have tilting gates thus to maintain navigation water depth, and actually to provide increased capacity during flood flows.

Regarding ***Salinity,*** there are potential impacts on water quality in the middle and upper Tideway. This is considered in Annex L to Appendix L," the *potential for local salinity*

[128] Fine Screening Report update February 2018 PAGE 118.
[129] DRA Feasibility Report page 141
[130] dWRMP19, Appendix L. 192.

impacts on the Middle Tideway for individual options" such as DRA *"is minor to negligible as local salinity levels are not expected to exceed background levels. Any resulting effects are local and will not have a significant effect on the local ecology."*[131]

Regarding ***Ecology in general:*** "*The tertiary effluent treatment will operate continuously at minimum utilisation*"[132] Since the river is tidal this would provide benefit both upstream and downstream.

Moreover, the further treated effluent at Teddington Weir would have additional oxygenation.

GARD understands that the Environment Agency (EA) has concerns that, at certain times of the year, the effluent discharge water will adversely affect the temperature of the river Thames water and thus affect its ecology[133]. EA has requested that the operating rules reduce, or cease, discharge in autumn and early spring. The reasoning for this is not understood, especially as these are not the periods when the biggest changes would seem likely. If implemented this could have a significant impact on the deployable output during a drought. It is possible that the changes are to protect against impact on salmon migration. However, since 2010 few, if any, salmon have been recorded in the River Thames, to the extent that the EA has now removed the fish counter. The EA has been told "...*it is very unlikely that a self-sustaining salmon population is viable in the Thames..."*[134] Clarification of the EA's views is required, especially as no reasoning has been produced.

Regarding ***Construction impact***: Since the scheme would utilise a new tunnel with a drive shaft its construction impact would be low. The only significant construction impact would be the drive shaft and the low head pumping station connecting the River Thames to the existing Thames/lee tunnel.

Regarding ***Scheme Resilience***: the scheme is described as only *"partially resilient"*[135] to climate change. The scheme source is treated sewage effluent. Under climate change conditions the amount of effluent is expected to increase somewhat as people take more showers and drink more fluid. Thus, the volume of sewage effluent would increase. Thus, the reference to only being partially resilient is not understood. It would appear that the scheme is as resilient as any scheme could be.

4.4 Cost Estimates

In common with all the dWRMP19 information, the costs of the Teddington DRA are not disclosed or set out in a form which can be assessed. GARD has asked repeatedly for more details on the various schemes, but our requests have been refused by TW on the grounds

[131] Executive Summary.
[132] Fine Screening Report Update February 2018 3.5.5 page 18.
[133] Thames Water Presentation at Water Resources Forum 21st March 2018, image of the DRA scheme.
[134] Environment Agency Regional Fisheries, Ecology and recreation Advisory Committee 20th September 2010 page 2.
[135] DRA Feasibility Report, page 106.

of ‘Commercial Confidentiality’. This is completely unacceptable, particularly considering the huge changes in ‘AIC + carbon’ cost estimates for the Teddington DRA scheme in four versions of Thames Water reports in the past 18 months:

AIC + carbon cost p/m^3			
FSR	FSR	FSR	dWRMP19
Oct ‘16	April ‘17	March ‘18	WRP Table
40-50	35-55	65-80	128

Part of this cost change arises from the downward revision of the DO for the scheme from 300 Ml/d (FSR) to 268 Ml/d, but the rest remains unexplained. We have already indicated above that the DO should be revised, and all likely revisions increase DO to levels at or above the FSR-level, so will lead to a reduction in the DRA scheme normalised costs.

The recent cost estimates have led to a reversal of relative cost position with the Abingdon (UTR) 150 M m^3 reservoir, which was 138 – 150 p/m^3 in the FSR tables and is now quoted as 86p/m^3 (AIC) to 117 p/m^3 (AISC). The Teddington DRA remains at the low-cost end of TW’s large schemes, but, in common with all the large schemes, TW need to provide justification and transparency for costs and cost movements.

4.5 Conclusion

Whereas TW have assessed that the DO of the DRA at Teddington would be 268Ml/d. However, no calculations have been provided to shows has TW arrived at this number except that TW had assumed that during a drought period no trade flows and no infiltration could be relied on.

GARD has assessed that 265 Ml/d could be obtained under the constraints that the scheme was required to allow 30-day storage and continuous abstraction did not occur. For an effluent treatment plant flow is continuous so neither of these restrictions is appropriate and the DO from the current domestic flows should be 316 Ml/d.

The DRA is not required to reach full capacity until about 2050 and flows are projected by TW to increase by then by 58 Ml/d. GARD has made conservative assessments for trade flows, 85 Ml/d, and infiltration 20 Ml/d.

Thus, GARD concludes that the DO of the DRA scheme would be 479 Ml/d by 2050.

This is an excellent scheme as it would provide water resources to both the west London reservoirs and the east London reservoirs through the Thames/lee tunnel. It should be utilised as early as needed and to the greatest extent.

5. Effluent reuse options

Key Points

- The decision to include only those reuse schemes whose effluent has no abstraction downstream is unnecessarily restrictive and should be revisited.
- Detailed costings should be published to enable full analysis of the Deephams and Beckton reuse schemes.
- A clearer explanation between the parameters set for Beckton treatment and actual treatment requirements should be made. The treatment at Coppermills WTW (to Drinking Water standards) should also be taken into account.
- In the preferred Beckton scheme, mixing expensive reverse osmosis processed water with river water before recovering some and losing the remainder to the sea makes no sense; the amount of treatment required should be reconsidered.
- The 2nd scenario for the Beckton reuse option should be reworked as it appears to be incomplete. Discussion should include why parameters fail at higher flows and what additional processes were considered.
- A risk-based approach should be used in the Thames Water 'Water Safety Plan' and by extension the dWRMP, which sets out the relevant risk of each parameter and establishes a proper basis for the treatment chain.
- While there could be a number of impacts on the tideway water levels and its ecology, we believe that these are either within the range of natural variation or will be less than the expected effect of such factors as climate change.
- Statements on tideway effects should include the expectation that 80% of the diverted water would be returned as freshwater to the sewage treatment works; this would allow for much larger schemes to be proposed.
- Issues of land availability should be reviewed following recent changes to the underpinning population and leakage assumptions for the dWRMP. Further, if more space is required, treatment could be carried out anywhere along the connecting tunnel from Beckton to Lockwood.
- Deephams reuse is not in the dWRMP preferred programme but does appear in the development programme shown to the March Water Resources Forum. Thames Water should clarify its intent.
- No consideration has been made of returning the Beckton effluent to the Rye Meads STW, similarly to the Hoddesdon transfer.
- Thus there is scope for substantially reducing the cost of the Beckton reuse option and increasing the size of such a scheme.

5.1 Introduction – options and locations

Scheme concepts in the dWRMP plan versions

The Re-use schemes at Deephams and Beckton were taken forward from the Phase 2 Fine Screening Process.[136] The Deephams scheme appears as one of the selected options in the 'Lowest Cost' Plan for implementation in the early 2040s[137], and at a similar time, and deployable output, in the 'Most Able to cope with future challenges' Plan. It does not, however appear in the 'Preferred Plan'. The Beckton Scheme, on the other hand, appears in the 'Lowest cost', 'Most Able to cope with future challenges', and (most importantly), the 'Preferred' Plans. The Thames Water preferred plan is to "*Develop a water re-use scheme at Beckton from 2061 providing around 285 Ml/d of water."* [138]

It is interesting to note the public perception movement which is beginning to support the implementation of Re-use schemes in general, as expressed by Thames Water's own Customer Challenge Group: *"The Customer Challenge Group specifically highlighted the customer preference that "water that has already been captured into supply should be fully used. Reuse of wastewater is preferred to massive capital expenditure on new resources such as a reservoir."*[139]

Restrictions on reuse schemes

The January 2018 Water Reuse feasibility report set out criteria for treatment standards etc. One of these is "*To comply with the Catchment Abstraction Management Strategy (CAMS) as set down by the Environment Agency, only waste water sources which are not contributing to current water supply (i.e. unplanned IPR) and environmental health were selected.*"[140]

While the May 2014 Thames catchment abstraction licensing strategy detailed criteria for abstraction from streams and river water, no such specific criteria for, or even mention of, wastewater reuse could be found.

As about 80% of the water put into potable supply would be returned to the catchment for use downstream,[141] reuse up a catchment would seem beneficial in water resources terms. As an illustration, about 80% of the water used in Oxford returns to the River Thames through the Oxford STW and provides flow in the Lower Thames available for pumping into Thames Water's west London's reservoirs. Thus, using a water resource higher up a catchment and then treating the effluent, discharging it to a river where it mixes and generally improves in quality so that part of it can be abstracted downstream for public

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[136] dWRMP19, Phase 2 Fine Screening Report Update Rev04, table S.2, (210218)
[137] dWRMP19, Summary Overview, page 17.
[138] dWRMP19, Executive Summary page 40.
[139] Phase 2 Fine Screening Report page 33.
[140] dWRMP19 Appendix L, L.10.
[141] Thames Water Review of Effluent Returns for the Water Resources Management System (WARMS) July 2013 page 31.

water supply, is beneficial to water resources but is specifically rejected by Thames Water. "*As a result, Thames Water have excluded all reuse schemes except those whose effluent has no abstraction downstream. This is unnecessarily restrictive*".

As an illustration the Oxford Canal, 15Ml/d, is brought in to serve London. Were it utilised to first serve SWOX or Affinity, then the 80% return to the River Thames would also be available to serve London, increasing its effective DO and reducing its AIC. ***Thames Water should revisit the decision to exclude all re-use schemes except those whose effluent has no abstraction downstream.***

5.2 Deephams and Beckton options

The information about the included Deephams and Beckton Schemes in the dWRMP is limited with no capital cost or its breakdown given.

Deephams reuse

Deephams STW effluent would be pumped to the River Lee close to the abstraction point for the nearby KGV reservoir. The capacity is limited for ecological reasons and has been reduced "*to take account of the water required to pass over Three Mills Lock and requirement for the Hoddesdon Transfer (12.5Ml/d).*"[142] The CDR states that an input of 65.9 Ml/d would be required to provide 45 Ml/d of DO. This loss of 30% is not understood and should be explained. For instance, there may be periods during the critical drought period when the drought plan and the Hoddesdon transfer are not in operation and more effluent is available to the Deephams reuse scheme.

Interestingly GARD believes the Hoddesdon Transfer is a scheme whereby sewage, which would otherwise be treated at Deephams STW, is, at times of low flow in the River Lee, pumped upstream to be treated at Rye Meads STW so it can augment the water for abstraction into the KGV reservoir. This is almost the same as a reuse scheme but utilising only conventional sewage treatment process for discharge into the River Lee. Thus, instinctively one would assume that similar treatment to that from the Rye Meads STW would be sufficient for discharge into the River Lee.

Beckton reuse scheme

Beckton STW in east London has a dry weather flow of 1,111 Ml/d[143]. The Beckton reuse scheme would further treat the current Beckton STW effluent to provide a source for the Coppermills WTW.

"For the indirect reuse scenarios it has been assumed that conveyance of the raw water would be to Lockwood shaft from where it would be forwarded to the intake of King George

[142] TW Fine Screening Report update February 2018 Appendix L.
[143] Water Reuse feasibility study January 2018 Appendix L Ricardo Report 2.23.

V reservoir through the proposed Thames-lee tunnel extension. Discharge directly into the King George reservoir would provide additional flexibility and this would benefit from further consideration during future design development."[144]

In the preferred Beckton reuse scheme the Reverse Osmosis (RO) treated water is discharged into the River Lee before being pumped into the KGV reservoir. One must question if a scheme that produces water to a near distilled water standard, mixes it with river water before recovering some but losing the remainder to the sea is a sensible use of resources. Common sense would answer 'no' to this question. The Rye Meads STW discharges into the River Lee not far upstream and that does not have this amount of treatment.

The alternatives of discharging Beckton sewage into the relevant sections of the Rye Meads works, augmented if necessary, (similar in concept to the Hoddesdon transfer) or discharging the Beckton treated effluent into the Lee, with extra treatment if appropriate, have not been considered properly

Considering that the water will anyway be treated to Drinking Water Standards at Coppermills WTW, Thames Water should reconsider the amount of treatment applied to the Beckton STW effluent.

Treatment of reuse water

The Water reuse feasibility report stated that: *"The reuse treatment technology assumed in this report uses surrogates from WRMP14 as follows: for final effluent water options microfiltration + reverse osmosis + advanced oxidation process."*[145]

Further, WRMP14 refers to the Report of the Independent Expert Review Panel (IERP),[146] which states that there were "*currently no equivalent EU or UK regulations or guidance for indirect potable reuse* (IPR) *water quality*."[147] The IERP recommended the Micro Filtration/Reverse Osmosis/Advanced Oxidation Process (MF/RO/AOP) multi barrier technology choice as sound and in line with international practice. However, the IERP acknowledged that the alternative approach would be *"to aim for good quality reclaimed water and factor in the treatment at the subsequent WTW"*.[148] This is the normal approach in the UK, where an upstream STW discharges into a river upstream of a WTW abstraction. An instance of this is where the Swindon, Oxford and Reading STWs discharge into the River Thames upstream of the abstractions to the West London reservoirs for supply to London.

In the supporting documentation to dWRMP19, Thames Water state that *"These treatment trains* [i.e. MF/RO/AOP] *were selected as they were comparable with treatment technologies*

[144] Phase 2 Fine Screening Report (Rev04) February 2018 page 72.
[145] dWRMP19, Water Reuse feasibility report, Executive Summary vii.
[146] Technology Choice for Planned Indirect Potable Reuse for London March 2013.
[147] IERP report page 20.
[148] IERP report page 20.

likely to be selected as resulting from the Mott MacDonald Report 2017 'Discharge Design Standards Cross Option Study' assessment developed with Thames Water in liaison with industry regulators. These treatment trains are deemed most suitable for the different reuse options raw water streams to be treated."[149]

In the later Fine Screening Report Update, February 2018 it is said:

"Three scenarios are envisaged for the Beckton water reuse option;

1. Development as an indirect reuse option using treatment processes including Reverse Osmosis,

2. Development as an indirect reuse option using a lower level of treatment, and

3. Development as a direct reuse option using treatment processes including Reverse Osmosis.

The conceptual design of the option has been prepared on the basis of the first scenario above, recognising that the second and third scenarios may offer future opportunities."[150] There is no doubt that providing RO to the Beckton effluent is indeed very effective, but also very expensive both in capital cost and in operating cost. RO takes virtually everything out of the water.

The only consideration of option 2 states: "*scheme 2 utilises sand filtration, ozone, GAC adsorption, and nitrate removal. The second scheme is more selective, treating just those parameters that are considered high priority, this is only effective up to discharge flows of 150 Ml/d. Above this flow this treatment scheme would not be effective."*[151] ***Treatment parameters***

The treatment requirements are discussed in the Mott Macdonald report *Discharge Design Standard Cross-option Study* (November 2017). Under Beckton reuse in Volume 2 Table 3.1 six parameters are shown with target values.

It is notable that whereas there will be substantial mixing in the large KGV reservoir with a minimum 30 day, 25% Emergency storage during a drought, the quoted concentration numbers are for the '95th percentile' value[152], not the average. This is a conservative approach.

Secondly one of the parameters, Ammoniacal Nitrogen, is listed in Appendix D of Volume 1[153] as not applicable, and the standards for BOD and Phosphate have no mention as,

[149] Water reuse feasibility report, Executive Summary vii.
[150] Fine Screening Report Rev04, February 2018, page 72.
[151] Fine Screening Report Rev04, February 2018, Appendix A page 114 section A.1.
[152] This refers to the value where 95% of analyses fall below the level.
[153] Discharge design Standard Cross-Option Study Volume 1 Methodology November 2017

presumably, they are not relevant, or because Coppermills WTW can treat them. Thames Water should be asked to confirm that this is the case.

For chlorides in the Beckton effluent the 95% level is 192 mg/l which is well below the drinking water permitted concentration (PCV) of 250mg/l. Similarly sulphates in the Beckton effluent have a 95% of 123mg/l compared to the allowed drinking water permitted concentration (PCV) of 250 mg/l. Thus, for these parameters, the Beckton effluent meets the relevant drinking water standards without any further treatment.

For nitrates, the permitted concentration is 50 mg/l whereas the Beckton effluent has an average concentration of 48 mg/l with a 95% of 67 mg/l. Thus, for this parameter it would be appropriate to consider the concentration of nitrates in the other water sources to the Coppermills WTW and, if high, whether Coppermills WTW treats sufficiently for nitrates. In the Thames Water reports no consideration of these issues could be found.

The third oddity is that Table 3.1 shows that at increasing Beckton flows the quality of its effluent would need to reduce. As it would make up a greater proportion of the flow into the Coppermills WTW, that is understandable. However, whereas the chloride drinking water standard is 250 mg/l, the required discharge standard is 109 mg/l. But this is less than half the DWI PCV. The Coppermills WTW output is already meeting this standard so the need for the Beckton effluent to have to reach a much lower standard is not understood. Thames Water should explain the logic behind this.

There is mention of zinc and phosphates in the evaluation of Beckton re-use treatments.[154] There is no Drinking Water Standard for zinc and no EQS standard in the table. This is an industrial metal and, if its removal is required, then the cheapest way of dealing with it is to locate the industrial source and get the zinc recovered there. In the Discharge Design Cross-option study, table 3-1[155] shows the phosphate concentration of Beckton effluent as 6.052 (but no units are shown so it is difficult to understand what this means) and there is no mention of a phosphate standard. In any case, phosphate treatment is now a relatively standard STW process.

Table 3.5 and its footnote state that the critical condition for most of the parameters is that the relevant parameter should not increase downstream by more than 10%. This results in many of the parameters failing at larger discharges. However no reason for this criterion could be found. Surely more appropriate criteria would be the relevant discharge standard for the river, and that the relevant parameter could not be treated by the Coppermills WTW to drinking water standards.

[154] Fine screening report Rev04, February 2018 Appendix A, Table in section A.1.
[155] Discharge Design Standard Cross-Option Study Volume 2.

Thames Water must reconsider this aspect, clearly spell out the issues, and demonstrate properly what is the most economical treatment process considering also the treatment provided at Coppermills WTW.

The dWRMP does not set out what treatment is available at the existing Coppermills WTW but it is likely to include GAC for the treatment of parameters such as pesticides. GARD asked for information on this on 13th April 2018[156], but no information has been received.

Treatment option 2

The only consideration of treatment option 2 states: *"the second scheme (Scheme 2) utilises sand filtration, ozone and GAC adsorption and nitrate removal……The second scheme is more selective, treating just those parameters that are considered to be high priority. This is only effective up to discharge flows of 150 Ml/d. Above this flow this treatment would not be effective and scheme 1 would be required."*[157]

Drinking Water Safety Plan Risk Appraisal

The approach of the DWI has changed from previous WRMPs, as it has now *"introduced the risk-based approach to regulation. Water that has been used is now just another component in the regulatory risk assessment and water safety plans of companies, so the focus for companies in a new proposal is the risk assessment and the underpinning data. In some instances, there will be a case for uprating treatment at the point of discharge to the environment and in other cases there will be a case for uprating treatment at the point of abstraction, sometimes both."*[158]

Water safety plan

Table 3.2[159] mentions Thames Water's Water Safety Plan. This should set out the relevant risk of the various parameters and establish the proper basis for the treatment chain. This was requested from Thames Water, (email Binnie/Tait 13th April 2018) but no information has been received.

Requirement to be efficient

The Drinking Water Inspectorate requires water companies to be efficient. "*5.3 The case for justification must be accompanied by the following information. How the company has derived the most appropriate technical and cost effective options."*[160]

The Reverse Osmosis treatment of the Beckton effluent and subsequent mixing with River Lee water before abstraction, storage, and further treatment does not appear to meet the

[156] Email from Chris Binnie to Lesley Tait of Thames Water.13/4/2018
[157] Fine Screening Report Rev04, February 2018, Appendix A, page 114.
[158] J. Colbourne personal email 10.4.18.
[159] Design Discharge Standard Cross-Option Study Volume2.page 20.
[160] Drinking Water Inspectorate Information Letter 01/2013.

efficiency requirements. Thames Water should reconsider the treatment proposed for the Beckton reuse system.

5.3 Water level impact on the Tideway

The water levels in the Tideway are driven by the tidal height and meteorological conditions, and, in the Middle Tideway, to a comparatively small extent, by the freshwater inflows. The assessment report in the dWRMP acknowledges the minor role of abstraction: *"The effect of any changes in water level from abstraction is considered likely to be offset by tidal inflow, resulting in no material impact on associated intertidal habitats."*[161]

Water quality impacts on the Tideway ecology

Historical situation

The use of the Beckton reuse scheme would reduce the amount of water being discharged from the Beckton STW. This is considered below. However, it should be borne in mind that until about 1870 there was no discharge from this site, thus the modern situation is somewhat artificial anyway.

Salinity

With the reduction in freshwater discharges due to diversion of some of the STW effluent, parts of the Middle Tideway could change in salinity. It is known that salinity in the Tideway varies due to tidal heights and freshwater flows. Figure 5-1, taken from the Ricardo report on the cumulative Tideway effects[162] shows salinity in the Tideway under high and low flows. The text states "*The salinity range at Beckton is 0.09% to 0.93%."*[163] Tidal excursion is about 13km.

[161] Reuse Appendix L Ricardo report page 4.
[162] Ricardo Cumulative effects of re-use. desalination, and DRA WRMP19 Options page 16.
[163] Ricardo Cumulative effects of re-use, desalination and DRA WRMP 19 Options page 15.

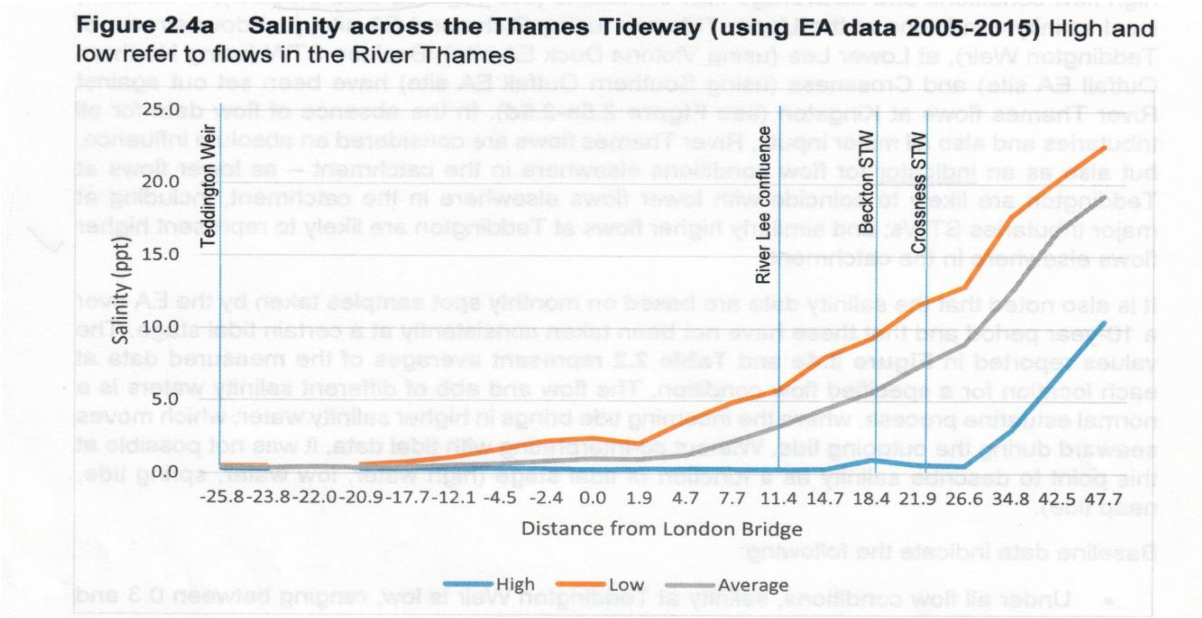

Figure 5-1: Salinity across the Thames Tideway

We note that:

1. There is already a significant change in salinity due to natural conditions. "*These initial studies suggest that more than a 15 to 20% reduction in freshwater inputs (275-366Ml/d) could result in salinity regime modification.*"[164]

2. However, "*The ecology of the Tideway is generally resilient to salinity change and consequently the options will have little influence on local biota.*"[165]

3. Consideration of individual species resulted in sea trout, bullhead and European smelt having a "*minor impact*". The proposed marine conservation zone could result in "*a minor impact in future.*"[166]

4. "*Further validation of the potential salinity changes is unlikely to amend these ecological conclusions*."[167]

5. *"climate change (sea level rise, drier summers and potentially lower summer freshwater inputs) may result in more routine and stronger saline ingress in the summer period and resilient communities would have to adapt to this regardless of the implementation of future water resources schemes."* [168] (but note that the flows over Teddington Weir are set by the Environment Agency and there is no reason to believe that the hands off freshwater flows will reduce in the future).

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[164] Ricardo Report, Conclusions, page 54
[165] Ricardo Report, Conclusion,s page 54.
[166] Ricardo Report, Conclusions, Page 55.
[167] Ricardo page 55.
[168] Ricardo report on Cumulative effects of re-use, desalination and DRA WRMP19 options summary page 3.

Net abstractions

As stated above these minor impacts are based on a reduction in freshwater discharges of 275 to 366 Ml/d. *"Initial evaluation suggests that more than a 15% to 20% reduction in total freshwater inputs (equivalent to 275-365 Ml/d) to the middle Tideway over a period of several months could see a noticeable change in the salinity regime of the middle Tideway. A prolonged period of salinity increases resulting from freshwater reductions above the level indicated could change community structure in biological elements including benthic macroinvertebrates and fish*."[169]

However this does not take account of the fact that much of the abstracted freshwater returns as effluent at the Beckton sewage treatment works. The effluent has already been treated at Beckton before leaving. It is then treated to potable standards at Coppermills WTW where the process losses are recirculated, so no overall loss there.

Some treated water will be lost within the water supply system. Thames Water research states *"between 5 and 30% of the water is 'lost'."*[170] On the conservative assumption that 20% is lost, then 80% would return to the sewage treatment works. The water from the Coppermills works would be delivered to householders generally in the WRZ served by the Beckton STW. Some effluent would return to the Deephams STW which discharges into the River Lee which in turn discharges into the Tideway upstream of the Beckton STW. In the future some potable water may be returned to the Crossness STW which discharges into the Tideway a short distance downstream of Beckton STW. Thus the returning freshwater would replace about 80% of the diverted freshwater.

Thus, were say 500 Ml/d of Beckton STW effluent to be abstracted, then the net loss of freshwater would be about 100 Ml/d, appreciably less than the amount considered by Ricardo as the potential freshwater upper limit of 275 Ml/d to 366 Ml/d.

5.4 Inter-connecting works and reuse issues

Beckton Conveyance system

This comprises Beckton STW to Lockwood Shaft, a distance of some 19 km[171], (implied in the Fine Screening Report as a pipeline but in a bored tunnel in the CDR) and thence via the Thames Lee Tunnel extension to the Lee upstream of KGV abstraction. There are different size schemes quoted in different reports with 3x 100 Ml/d in the Fine Screening Report – transfer capacity up to 278 Ml/d for 200 Ml/d DO. A minimum size tunnel would take several times this flow.

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[169] Technical Appendix BB Water Framework directive Appendix B page 33.
[170] Thames Water Review of effluent returns for the water resources management system. 2013 Effluent return water balance page 31.
[171] dWRMP reuse feasibility page 119.

Considering the capacity of Beckton is about 1,000 Ml/d, and the transfer tunnel to KGV would have a similar capacity, there should be no problem with transferring a similar amount to the KGV reservoir. The extra capital cost would be largely just the increased treatment works.

Available land for the Beckton plant

"Whilst land has been identified for the reuse plant on the Beckton STW site, Thames Water is now concerned that it may conflict with spatial requirements for the expansion of the sewage treatment works."[172] However, at the Water Resources Forum on 21st March 2018, Thames Water reported that they were reducing the overall population estimate for 2100 by 1.4 million (as discussed in Section 2.1 of this response). Although Thames Water have not yet released sub-area projections, we calculate the London figure might decrease by about over 1 million, making the spatial requirement for Beckton STW expansion less of an issue.

Further, the desalination study identified land in the Lee catchment suitable for both storage and treatment of 150 Ml/d. This would not require the large water storage area so may well be able to provide reuse treatment for the 300 Ml/d reuse scheme.

"*Further consideration of conflicting land requirements will be needed if the option is selected in the preferred programme*"[173] which it is.[174] Since three phases of 95 Ml/d is included in the published Preferred Plan,[175] 285 Ml/d, then it would be reasonable to assume that the land is available.

"Primarily for this reason options larger than 300 Ml/d have not been developed through conceptual design and included on the Constrained List."[176]

However, a major weakness in this consideration is that the diverted effluent is transported by tunnel for many km through East London. Thus, any extra treatment needed does not need to be at the Beckton STW site but anywhere along the tunnel route. Thus, the limit of land availability has not been properly considered and is likely to allow for a scheme greater than 300 Ml/d. Thames Water should consider whether extra treatment could be carried out away from the Beckton STW site.

Phasing of Beckton

"Given the cost of conveyance from Beckton to Lockwood, a minimum size for the development of reuse at Beckton of 100 Ml/d has been assumed. The 50 M/d Beckton Reuse option has therefore been screened out. It is envisaged that small scale initial development

[172] dWRMP Fine Screening Report update February 2018 page 72.
[173] dWRMP Fine Screening Report update February 2018 page 72. 8.5.2.
[174] dWRMP Table 11-3.
[175] dWRMP Table 11-3.
[176] dWRMP Fine Screening Report update February 2018 page 73.

of reuse would be at Deephams which minimises the conveyance requirements."[177] In the Preferred Programme, Beckton reuse is brought in in three 95 Ml/d phases from 2061 to 2072 with no mention of Deephams reuse.[178] However Deephams reuse does appear in the development programme shown to the Water Resources Forum on 21st March 2018,[179] but in a slide showing it taking part of the re-use portfolio following a *reduction* in the Beckton Output from about 2080. This has neither been justified nor explained, and is symptomatic of the 'on the hoof' nature of the progress of the dWRMP *during* the consultation period. ***Thames Water should resolve these inconsistencies in the next version of dWRMP.***

Hoddesdon style scheme

One scheme not yet considered would be a transfer similar to the existing Hoddesdon transfer. In this Beckton sewage could be transferred to the inlet of an enlarged Rye Meads works, or treated to a similar standard as the Rye Meads works nearby.

Conclusions

Thus there would appear to be scope for substantially reducing the costs of the Beckton reuse scheme by adopting realistic water quality parameters and also increasing the size of such a scheme by taking account of the about 80% effluent return to the sewage treatment works and its mitigation of the salinity changes in the Tideway.

[177] dWRMP Fine Screening Report update February 2018 page 73.
[178] dWRMP Table 11-3.
[179] Thames Water, Water Resources Forum, Reading, 21/4/18, slide 34.

6. Desalination options

Key Points

- Freshwater return flow should be included in the planning for these schemes since this would allow schemes to be 4 times larger than proposed without breaching precautionary salinity limits.
- Were the Teddington DRA to expand to its full potential, then a freshwater supply of 900 Ml/d could be produced, with capacity for blending increased to about 450 Ml/d.
- TW should consider a pipeline interconnection system since this would provide spare capacity in the long term
- If space at Beckton is limited, the Lee Valley site would be a viable alternative that could provide 150 Ml/d.
- The tunnel from the Waldrist Way, 2d, option could be aligned with either Beckton desalination site to allow use of one tunnel.
- The modular nature of desalination plants means that output from Crossness 2d could be diverted to support Riverside 3a when required.
- There is scope for 450 Ml/d of blended desalination schemes.

6.1 The potential for desalination generally

Thames Water looked at a number of desalination schemes based on desalination of Thames Estuary Water.[180]They carried forward a scheme based on Beckton STW and two schemes based on Crossness STW.[181]

The process to be used would be reverse osmosis using brackish water or sea water membranes[182].

Unjustified limitation on the overall potential for estuarine desalination

The Forward to the Desalination Feasibility Report considers the need for a limit on desalination in the Thames Estuary:

"The environmental assessment considered a precautionary approach of applying a 300Ml/d limit on additional desalination capacity in the middle Thames Tideway, based upon an initial high level assessment of the likely threshold for additional brine discharges to the Tideway in the area between Beckton and Crossness/Thamesmead."[183]

"The cumulative impact of developing multiple options could substantially affect normal salinity patterns if there is more than a 15-20% decrease (275-366 Ml/d) in freshwater inputs to the Middle Tideway."[184]

This assumes that there is no freshwater return flow. In reality about 20% of the water put into supply will be "lost", but about 80% will be returned to the STWs as freshwater. These return flows would be to Beckton STW which is close to the Beckton desalination intake. For the 300 Ml/d Crossness scheme the freshwater treated effluent returns would be to Beckton STW, about 6km upstream of the abstraction point. Thus, the limit based on increased salinity in the Tideway would mean that the desalination plants could be about four times the size of those proposed by TW without breaking the precautionary limit.

Further the brine returns are conveyed to the STWs to limit local impact.

Connection to the potable water network.

"*The nature of the desalination water will seem different to consumers when compared to the water normally supplied by Thames Water from traditional sources. In part this difference can be attributed to the alkalinity and hardness of the water....It is likely that if*

[180] Desalination feasibility report February 2018 Executive Summary page v
[181] Desalination feasibility report February 2018 page 59.
[182] Desalination feasibility report February 2018 page 22
[183] Desalination Feasibility Report February 2018 Foreword vii
[184] Fine Screening report update February 2018 3.5.7 page 18.

the source of water were to switch intermittently between surface water and desalinated water the consumer complaints would result." [185]

"It is therefore considered that this should be mitigated by either:

- *Having supply zones which are dedicated to receiving desalinated water. This would require that the desalination plant was operated continuously"* or with a limited proportion of normal potable water.
- *"Transfer the potable water to a large supply node where the desalinated water can be blended with water from surface water sources prior to supply."*[186]

"*When introducing desalinated water into a non-desalinated supply, it is usual practice to blend the water to mitigate consumer's perception of a difference in the taste of the water "*[187]

"*Because the water is of different quality to normal drinking water it is proposed that it be blended before being put into supply....a conservative blend ratio of one third desalinated water to two thirds potable water is considered."*[188] a blending ratio of 1:2.

Effectively that would mean blending at Honor Oak service reservoir or Coppermills WTW. From Coppermills WTW there might be a requirement to increase the capacity of the link to the London Water Ring Main. Coppermills size is not stated but it is believed to be about 500 Ml/d. Thus Coppermills could currently accept about 250 Ml/d of desalinated water. *"The demand from Coppermills is forecast to increase such that, in the future, there will be need to provide treatment capacity of blending up to 300 Ml/d of desalinated water."*[189] Were the DRA to expand as envisaged by GARD[190] then the freshwater supply could well become about 900 Ml/d and the capacity for blending would then reach about 450 Ml/d.

Interconnection system

Because of the size of the schemes, the major infrastructures to be crossed such as main roads and railway lines, and the potential disruption to London traffic if a pipeline solution was adopted, all the conveyances would be in tunnel. This is expensive in capital cost but would provide spare capacity for long term expansion of supply.

Available land

Available land for the reception of the abstracted brackish water and the RO plant was a significant constraint on the sites available.

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[185] Desalination Feasibility Report February 2018 Page 24
[186] Page 25
[187] Page 25
[188] Page 25 Desalination feasibility Report Feburary2018
[189] Page 25
[190] GARD section 4 DRA. April 2018.

6.2 Sites considered for desalination

Beckton STW new desalination scheme

"*A potential opportunity associated with this option is that the tunnel*" from Beckton STW to Coppermills WTW" *could also be used to convey water from the existing Gateway desalination plant to Coppermills WTW which would improve the blending and address concerns around change of water quality when the Gateway is operated at full capacity.*"[191]

*"There is space adjacent to the Beckton STW for a 150 Ml/d desalination plant. "*However, this is the area allocated for the Beckton reuse plant. *"Whilst land has been identified for the desalination plant on the Beckton STW site, Thames Water now consider that it may conflict with spatial requirements for the expansion of the sewage treatment works. Further consideration of conflicting land requirements will be needed if the option is selected in the preferred programme."*[192]

If the Beckton site is required for other uses, there is the alternative Lee Valley site, 1b *"For many of the criteria they are comparable*"[193]. The Beckton site was chosen as a better site than any of the Lee Valley sites, but the Lee Valley site is still a viable site for 150 Ml/d.

Crossness STW new desalination site

Two sites were considered for the Crossness based desalination scheme, both some 4km to the south east of Crossness STW, close to the Thamesmead Industrial Estate and both capable of providing sufficient space for 300Ml/d. The site chosen was the Waldrist Way site, 2d.

The Honor Oak service reservoir was considered for the discharge point but was rejected as the Coppermills site was marginally nearer. The tunnel from Waldrist Way, 2d, would pass close to either of the Beckton desalination sites so it could be aligned so that these could use one tunnel.

Riverside WRZ

"one potential water resource zone for receiving a dedicated desalination supply has been identified as Riverside WRZ...between Woolwich and Erith."[194]

This option, site 3a, would supply Riverside WRZ full time, through the Northumberland Heath Service Reservoir, with a peak capacity of 75 Ml/d.[195]

[191] Fine Screening Report update February 2018.page 74.
[192] Fine screening report Update February 2018 page 74.
[193] 5.3.1 page 45
[194] Page 25
[195] Page 56.

However this scheme was screened out at fine screening as "*Desalination plant outage events would result in changes in water quality as the supply would need to revert to water supplied from the ring main via Honor oak. TW's experience is that these changes in water quality would lead to a significant increase in customer water quality complaints*." [196]

However desalination plants are modular units, thus the risk of half the plant being shut down when needed would be low. The preferred Crossness site 2d is right alongside the Riverside site 3a. Thus were the desalination plant on site 2d to be developed, then spare desalinated water from the 300 Ml/d peak capacity plant on site 2d could be diverted to support the Riverside desalination plant 3a sufficiently to avoid customer complaints.

Conclusion

Thus, even if the Beckton reuse plant is built, there would appear to be scope for 450Ml/d of blended desalination schemes, plus probably the 75 Ml/d Riverside direct supply scheme.

[196] Fine Screening Report Update February 2018 page 71.

7. Inter-regional transfer options

Key points

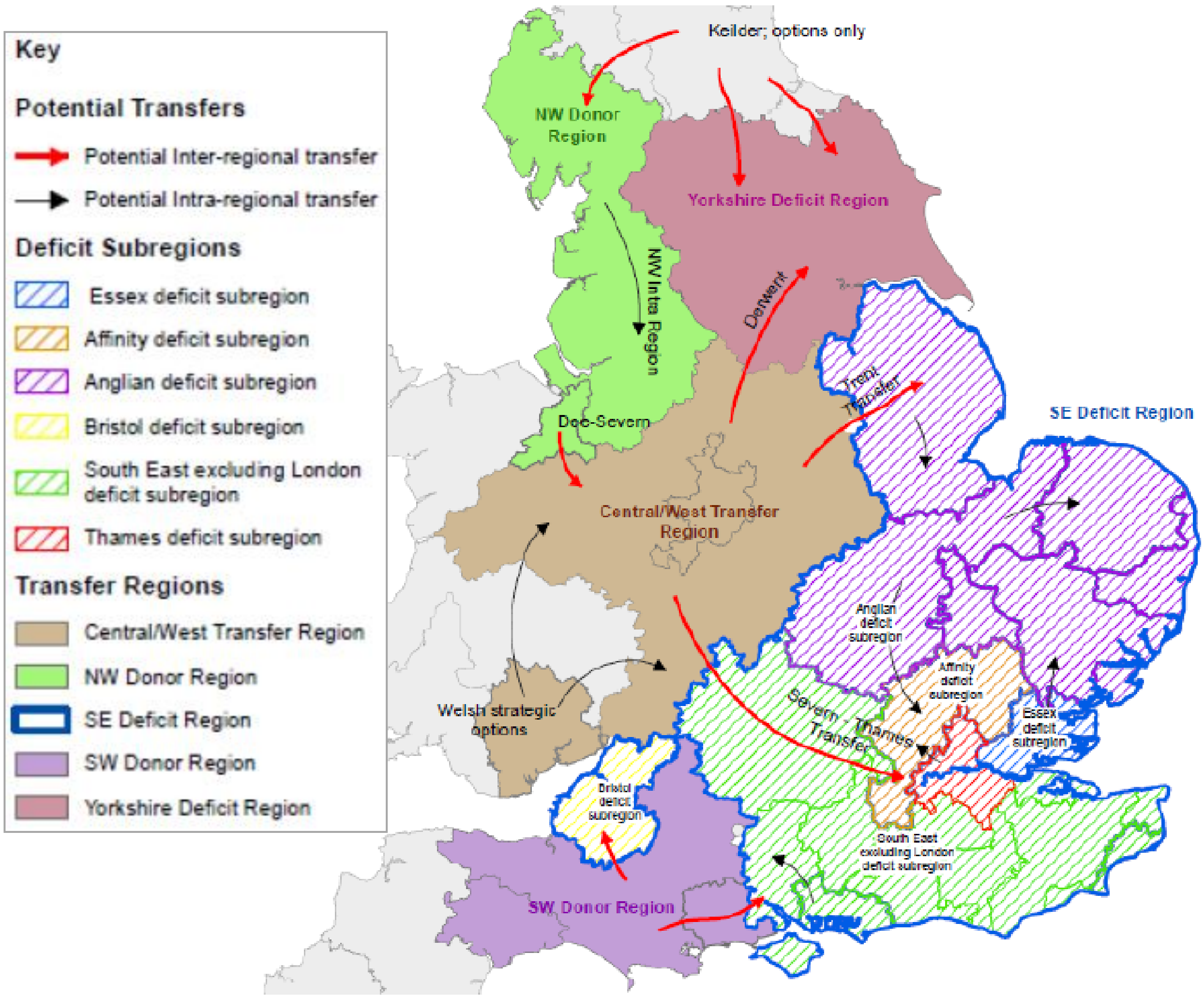
- The water resources of the River Thames basin are already over-developed and there is a strategic need to bring in "new water" for the South East of England.
- The development of strategically important transfers to the South East of England should not be dependent on horse-trading between water companies whose main allegiance is to their shareholders.
- The yield of the unsupported Severn-Thames transfer has been under-estimated by around 50% due to use of flawed river flow data generated by stochastic modelling.
- The unsupported transfer, yielding at least 120 Ml/d, is viable, requires almost no inter-company trading and should be the first stage of a phased development of inter-regional transfers from the North West to the South East of England.
- The yields of Vyrnwy support options have been underestimated through use of flawed stochastic data, failure to consider larger regulation releases to make better use of Vyrnwy storage and unjustified assumptions about climate change.
- With support from Vyrnwy, the Severn-Thames transfer could provide up to 400 Ml/d of yield for Thames Water and other water companies in the South East.
- There has been no transparency of cost estimates, but from the available NPV costings there appear to be huge inter-company trading costs included in the opex allowance, with no explanation provided.
- Since dWRMP14, the capex cost of the Deerhurst to Culham link appears to have increased by about 500% with no explanation.
- The report on River Severn transmission losses, only produced at the last minute, fails to address the fundamental water balance behind any losses, but makes vague and unjustified suggestions that they could be much higher than feasible from consideration of the water balance.
- The assessment of adverse effects for the SEA appears to be highly subjective and biased when compared with scoring of the same criteria for the Abingdon reservoir.

In GARD's opinion, Thames Water's assessment of the Severn-Thames transfer options has been heavily biased to make the schemes appear less favourable than the Abingdon reservoir. Noting the strategic importance of inter-regional transfers, the work should be independently reviewed by an organisation that is neither instructed nor paid by Thames Water or other water companies, taking proper account of GARD's views.

7.1 The strategic need to transfer water to the South East

The South East of England has a high and growing population and a shortage of water. The region is over-dependent on reservoirs filled from the River Thames and groundwater abstraction from storage in natural aquifers. The Thames reservoirs already have insufficient water to refill reliably in dry winters. The groundwater aquifers are over-developed with many cases of ecological damage, particularly to chalk-streams. The existing shortage of naturally available water in the Thames valley can only get worse as demands grow.

Fundamentally, the South East of England needs “new water” through inter-regional transfers from wetter and less populated parts of the country. This was recognised in Water UK’s report in 2016[197]which identified deficit regions and transfer regions as illustrated below:



From Water UK report Figure 4-4

Figure 7-1: Deficit and transfer regions in England and Wales

[197] ‘Water Resources Long Term Planning Framework’. Water UK. 2016.

As Water UK's summary report says (page 11 of Summary):

> *"Companies will need to develop new ways of working across their boundaries and with a wider range of stakeholders to optimise the use of scarce water resources, particularly through transfers."*

Thames Water appear to be ambivalent over the need for transfers as summed up in their CEO's introduction to the dWRMP (page 2 of the Summary):

> *"A number of significant raw water transfers have been provided to us as options. We see these as the first step in providing the pathway to a resilient and efficient nationwide water conveyance system. Each transfer option needs to be considered on both their economic and environmental merits relative to other potential options. For these reasons, at this stage, the options provided are not included in our plan. However, between the draft plan and revised draft plan we will reinforce our interest and continue to work closely with companies offering transfers. Taking this into account, any revised transfer offers from companies in Wales, the North West and the Midlands, or any change in the requirement of companies in the South East may have the effect of changing the supply-side options within our draft plan."*

Thus, having recognised the strategic need for raw water transfers into the region, Thames Water immediately view them in parochial terms and do not include them in their plan. However, there is hope of a more strategic vision in the statement "*between the draft plan and revised draft plan we will reinforce our interest and continue to work closely with companies offering transfers*".

The impression is created that strategically important inter-regional transfers will be left to horse-trading between water companies, perhaps more interested in shareholder returns than national interests. The regulators, Ofwat and the Environment Agency, appear to take no interest in this, seemingly content to leave the strategic planning to water companies whose main allegiance is shareholders. For example, why was it left to Water UK, a trade association, to undertake their strategic national study in a rapid time frame, probably with an inadequate budget? Why was it not a Government led initiative similar to those undertaken by the NRA in 1994 and the Water Resources Board in the early 1970s?

In GARD's opinion (and seemingly Water UK's, judging by Figure 7-1 above), a transfer from the Severn to the Thames lies at the heart of all inter-regional transfers to the South East. A link between the rivers provides the conduit for a range of potential donor regions and water companies – from the North West via redeployment of Vyrnwy reservoir, from the Midlands via redeployment of some of Severn Trent's sources (which take water from Wales) and from Wales itself, for example use of the Great Spring. In each case, river-to-river transfers can provide the links in what is in effect a national water grid, with rivers used as the main conduits rather than pipelines.

7.2 Unsupported Severn-Thames transfer

Introduction

In GARD's opinion, the unsupported Severn-Thames transfer should be the first step in bringing "new water" into the South East and introduced early in Thames Water's plan. Once the link is in place, transfers to the South East can be increased as the need arises. In the first instance, the unsupported transfer can bring in "new water" using only the existing water in the River Severn, without the need for any trading between water companies (aside from the provision of a small sweetening flow when the pipeline is not in use).

The yield and reliability of the unsupported Severn-Thames transfer has been the subject of a long-running dispute between GARD and Thames Water. This matter was covered in GARD's May 2017 response to Thames Water's 2nd draft Fine Screening Report (FSR)[198]. In our opinion, the unsupported transfer would provide a resilient yield of at least 120 Ml/d, even after allowing for climate change. It should be considered a viable first stage of a phased development of an incrementally supported Severn-Thames transfer with the potential to deliver ultimately up to 400 Ml/d, if eventually needed.

Unjustified Rejection on grounds of low stochastic yield

We do not accept the justification for rejection of the unsupported Severn-Thames transfer as stated on Table 5.5 of the latest FSR:

> *"Rejected at validation stage of feasibility report on cost grounds given low stochastic reliable yield for unsupported transfers"*

***In GARD's opinion, the "low stochastic reliable yields" are due to a flaw in Atkins' stochastic analysis which underestimates autumn flows in the River Severn*.** The underestimation of autumn flows also result in underestimation of stochastic yield for the *supported* Severn transfer options (see later).

GARD's modelling of the 300 Ml/d unsupported transfer using the historic flow data, assuming also 15 Ml/d of trickle support from Mythe, gives a yield of about 157 Ml/d, somewhat more than Thames Water's value of 142 Ml/d using historic data. Atkins' stochastic modelling gives a 1 in 100 year yield of only 100 Ml/d – much lower than the GARD or Thames Water assessments.

Atkins attempt to explain the differences in historic and stochastic yields in Section 7 of their report on the unsupported transfer resilience assessment[199]:

> *"The scheme is very sensitive to the exact patterns and behaviour of drought across the two catchments. The likely expected (statistical average) yield benefit of the scheme is*

[198] 'GARD response to Thames Water's draft Fine Screening Report on WRMP19 Resource Options', section 4.1, pp 8 -10, GARD, May 2017.
[199] 'Fine Screening Report', Appendix K. February 2018.

lower than suggested by a simple, historically based, Deployable Output (DO) analysis. Expected yield for the300Ml/d capacity pipeline is around 100 Ml/d, compared with 142 Ml/d gained from Thames Water's historically based DO analysis. This difference is simply caused by the fact that the 1921-22 and1933-34 droughts, which act as the crucial droughts in the historically based DO analysis, happened to have drought patterns and differences in rainfall between the Severn and Thames catchments that tend to result in a more favourable estimate of scheme yield. Other drought patterns such as those seen in 1975-76 would yield much less benefit, and this is reflected when the expected conditions are analysed."

In GARD's opinion, this attempt to explain the difference is irrational and wrong. Atkins are saying that the 90 year flow record from 1920 to 2010, on which the historic yield assessments were based, happened by chance not to contain a severe drought. The underlying principle in developing the stochastic data was that they should be representative of the climatic conditions of the historic period 1920 to 2010. Therefore, it is irrational to say that the droughts of 1921/22 and 1933/34 were, by chance, not representative of the climatic period on which the stochastic flow data are supposed to be based.

GARD's analysis of Atkins' stochastic data for the River Severn at Deerhurst shows that they under-estimate flow in September and October by about 300-600 Ml/d compared to the historic Deerhurst flows generated by HR Wallingford, which must be viewed as the best available source of historic flow data in the lower Severn. These are crucial months when the River Severn flows always recover faster from drought than flows in the Thames because of the much less permeable geology of the Severn catchment. In Figure 7-2, we compare the flow duration curves for September and October for the Thames at Teddington and the Severn at Deerhurst. In each case, the historic flows 1920 to 2010, as used in the WARMS2 model, are compared with the 15,600 years of stochastic flow data generated by Atkins and used in their stochastic yield assessments[200]:

[200] Data provided by Atkins to GARD by file transfer 8.8.2018

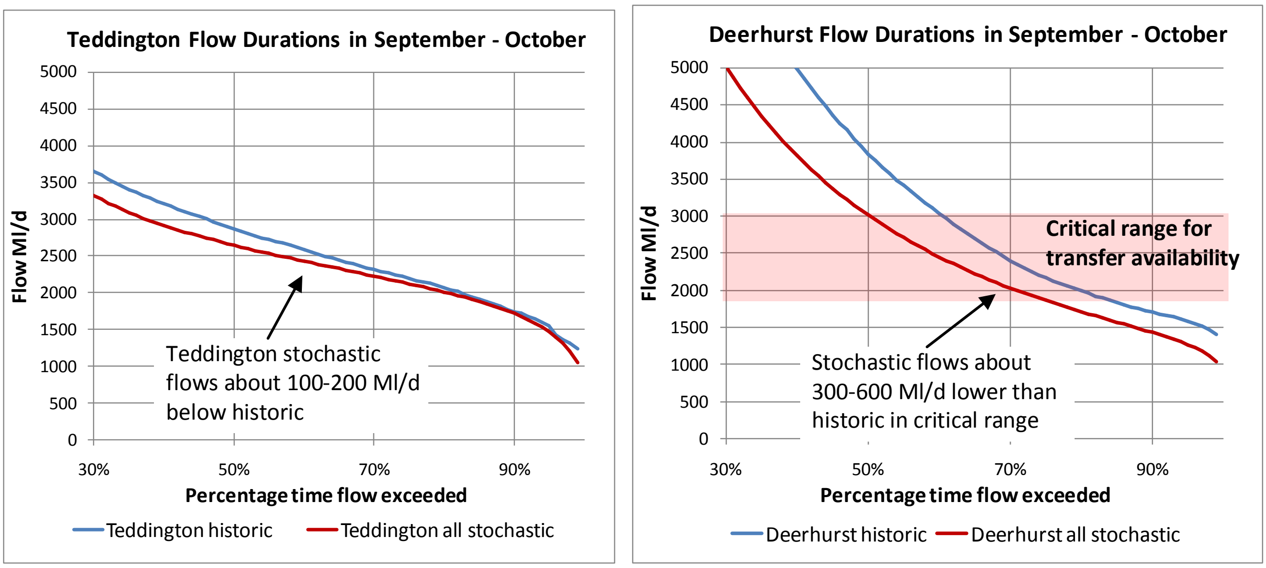


Figure 7-2: Stochastic and historic flow duration in Sep-Oct at Teddington and Deerhurst

Figure 7-2 shows that the stochastic flows at Deerhurst in September/October are about 300-600 Ml/d lower than historic flows in the critical range of flows which govern availability of water for transfer. In contrast, the Teddington stochastic flows are a better match for historic flows, although still about 100-200 Ml/d too low in the critical flow range below 3000 Ml/d. It is also noted that the comparison between historic and stochastic flow duration curves appears minimal when they are plotted for the full year at a reduced vertical scale as they are in Atkins' reports. It is only when they are plotted for September-October at an enlarged scale covering the critical flow range that the magnitude and significance of the stochastic flow discrepancies become apparent – see flow duration plots in Appendix B.

The large discrepancy between historic and stochastic flows in September-October explains the 50 Ml/discrepancy between historic and stochastic yields of the unsupported STT.

This flaw in the stochastic data has negated the primary benefit of the unsupported transfer – the faster autumn drought recovery of River Severn flows due to its more impermeable geology. The importance of geology and its effect on autumn flows in the Severn and Thames was recognised by the National Rivers Authority and water companies when the unsupported transfer was first proposed in the 1990s[201]. It is the reason why the unsupported transfer is able to deliver a reliable benefit. This has been pointed out repeatedly by GARD in numerous papers and in a presentation given to Thames Water Technical Stakeholder meeting on 26th March 2015.

In GARD's opinion, it is also wrong for Atkins to use the drought of 1975/76 as an illustration of a drought in which the unsupported transfer would fail to deliver a reliable supply. 1975/76 was <u>not</u> a critical drought for the London supply system and the unsupported

[201] 'Water – Nature's Precious Resource – Water Resources Development Strategy for England & Wales'. National Rivers Authority. March 1994. ISBN 0-11-886523-4.

transfer would have easily maintained a yield gain of about 150 Ml/d for the existing London supplies (confirmed by GARD and WARMS2 modelling). This is because the 1975/76 drought ended in September 1976. The droughts that severely test the existing London supplies are always those that extend well into the autumn. The unsupported Severn-Thames transfer always delivers its benefits in the autumn because the Severn always recovers from drought about 2 months earlier than the Thames, due to its much less permeable geology. The three most severe droughts in the past 100 years (from the perspective of drawdown of the London reservoirs), 1921/22, 1933/34 and 1943/44, are examples of this – see Appendix B for plots of historic flows at Deerhurst and Teddington in September-October in major droughts since 1920.

Allowance for climate change

We also do not accept that Atkins' finding that the yield of the unsupported transfer should be reduced by 40 Ml/d to allow for climate change and full use of licences by existing abstractors. Our reasons for this are given later in our assessment of supported transfer options.

Drought resilience of the unsupported transfer

However, we do agree with Atkins' statement that the ***yield of the unsupported transfer is resilient to a range of drought severities,*** as illustrated in Figure 4-2 of their report on the resilience of the unsupported transfer option[202], as replicated below:

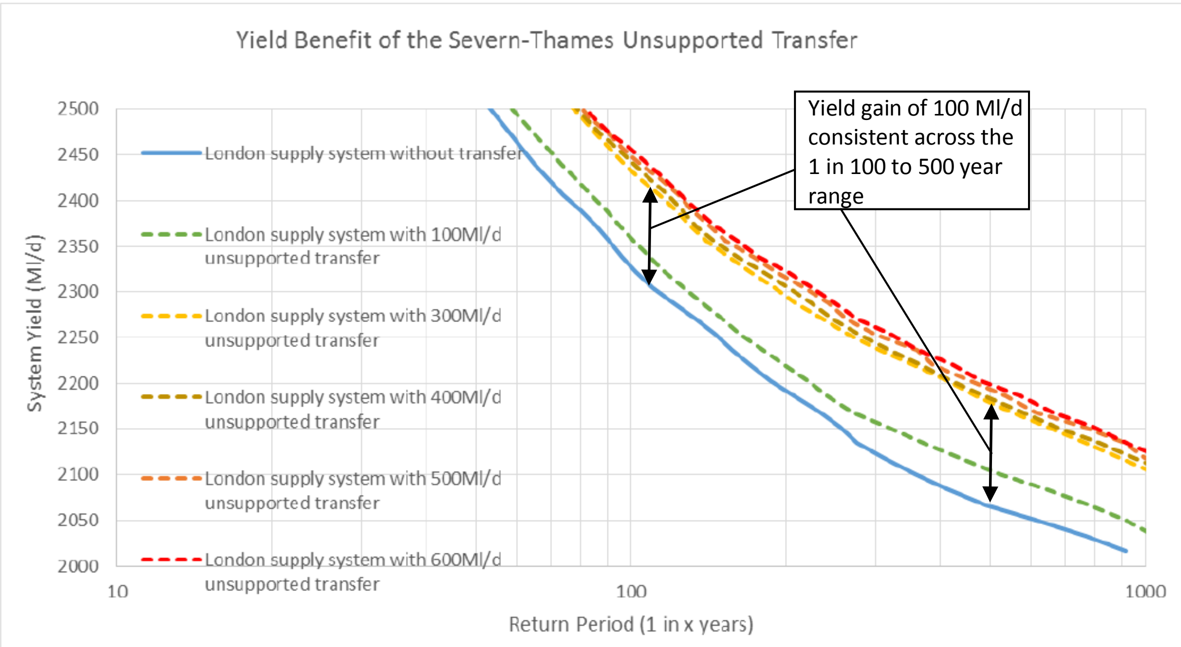


Figure 7-3: Stochastic yield v return period for Unsupported STT

[202] 'TW WRMP19 Stochastic Methods – Appendix Document for Unsupported Severn Thames Transfer', version 7 Appendix J to Updated FSR (Rev03), April 2017. ***Note that an earlier version (v4.0 – Jan 2017) of this report is included in the supposedly final Raw Water Transfer Feasibility Report***

This plot shows the 100 Ml/d yield increment, at 1 in 110 year return period (equivalent to the existing 2305 Ml/d London return period), for the unsupported transfer, obtained using Atkins' flawed stochastic data which underestimates Deerhurst flows in the crucial autumn months. It also shows that the 100 Ml/d yield is maintained up to the 1 in 500 year return period, demonstrating the resilience of the yield of the unsupported transfer to droughts more severe than those in the historic record. Quoting from Section 7 of Atkins' report[203]:

> *"the stochastic methods indicate that the scheme yield of 100 Ml/d [Atkins' value, not accepted by GARD] is reliable across a range of drought severities, if drought severity is expressed according to total system yield."*

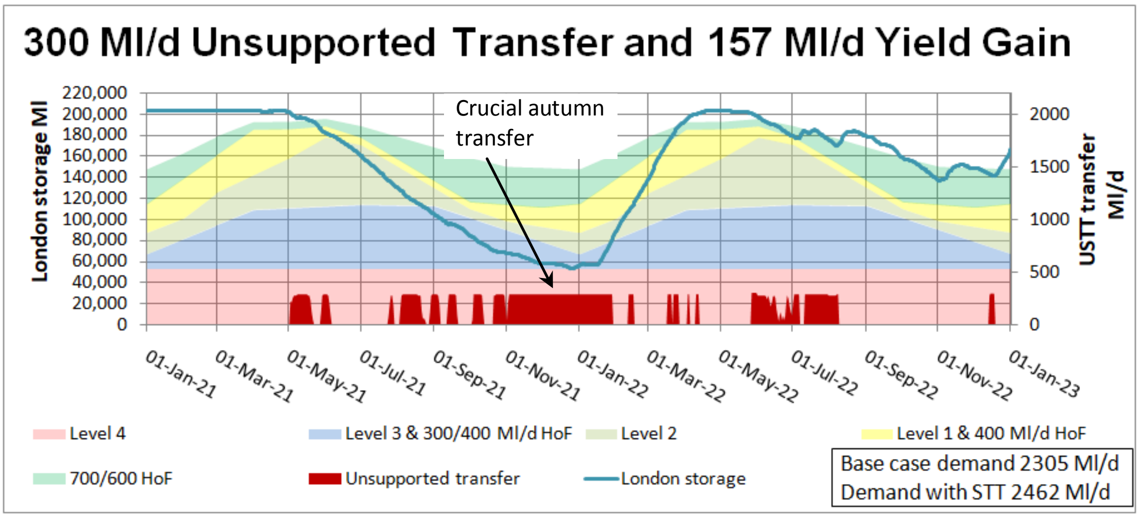
The Raw Water Transfer Feasibility Report[204] refers to a Severn and Thames drought coincidence study undertaken by HR Wallingford dated April 2016. This report is not on Thames Water's web-site, but has been summarised in the feasibility report:

> *"The study has assessed the likelihood of a coincident drought occurring between the River Severn and River Thames using evidence from the historical record and the new TWUL PR19 stochastic drought library. The evidence suggests that when the River Thames is in drought it is very likely that the River Severn is also in a drought. This is demonstrated by 95% of the stochastic droughts in the Thames experiencing more than 22 Deerhurst HOF transgressions per year, where 22 is the historical average. 50% of the drought events in the River Thames are associated with River Severn flows where the Deerhurst HOF is transgressed approximately 80 times in a single hydrological year.*
>
> *This work supports an assessment that a solely unsupported River Severn abstraction at Deerhurst would not be resilient to drought."*

This finding is not consistent with Atkins' resilience report and should be rejected. We also consider it to be simplistic and misleading to focus on the number of days that the unsupported transfer is not available. This displays an ignorance of the principle underlying the unsupported transfer which is that, with the London supply system only being vulnerable to droughts of over 12 months duration, any water available in the course of the drought, from start of reservoir draw-down to minimum storage, adds to the reliable yield of the system. This is illustrated in Figure 7-4 below showing the behaviour of the London supply system with the 300 Ml/d unsupported transfer (with 15 Ml/d of trickle from Mythe) delivering a yield of 157 Ml/d for London in the droughts of 1921/22 and 1933/34:

[203] Appendix J to Updated FSR (Rev03), section 7, April 2017

[204] 'TW dWRMP19 Resource Options – Raw Water Transfers Feasibility Report', page 20, February 2018.



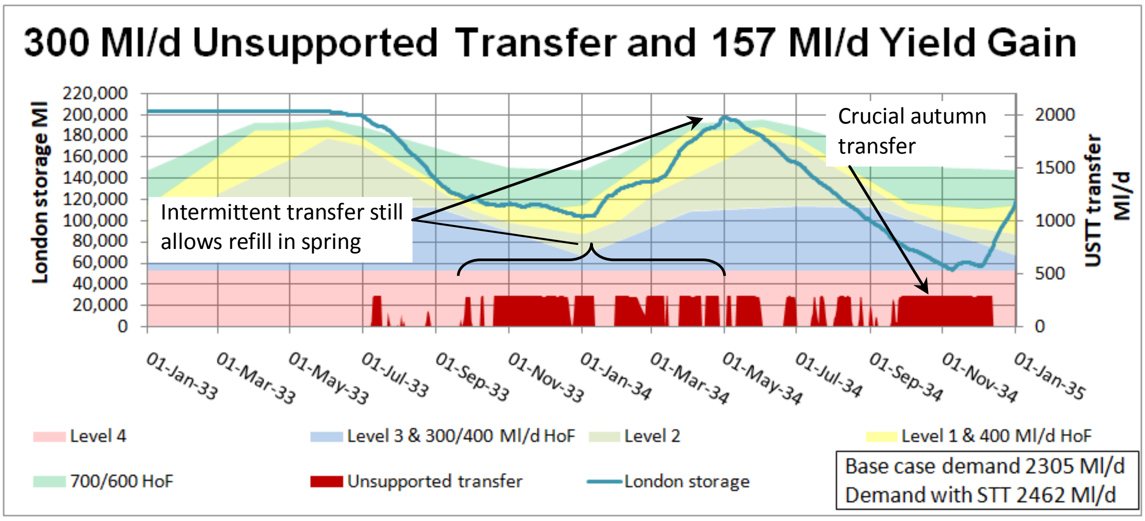


Figure 7-4: Performance of 300 Ml/d unsupported transfer in 1921/22 and 1933/34

As can be seen in these plots, the unsupported transfer is able to maintain a yield of 157 Ml/d in these droughts despite the numerous days when the transfer is not available. For both these droughts which were critical for London's supplies because they extended well into the autumn, the availability of Severn water in the autumn is crucial (also in the winter of 1933/34, helping the reservoirs to refill).

Unsupported transfer as first phase of Severn-Thames transfer development

This analysis shows that the unsupported STT still should be considered as the first phase in any development of the Severn-Thames transfer. Even without any flow support and allowing generously for climate change, it can provide a deployable output of at least 120 Ml/d (double Atkins' suggested yield), with the potential to meet deficits in SWOX and elsewhere in the Thames Valley, as well as in London. It can be developed without any trading agreement with other water companies (aside from provision of a small pipeline for sweetening flow via Mythe from Severn Trent), using Severn flows that are naturally available. If the deficit turns out to be less than forecast, there would be minimal residual impact from construction of the transfer facilities (compared to the Abingdon reservoir). It would fit with a ‘no regrets policy’.

7.3 The need for water treatment

The need for water treatment at Deerhurst was identified in the Water Quality and Ecology Assessment Report in October 2016[205]. Treatment was recommended to mitigate against occasional poor water quality in the Severn and the transfer of invasive non-native species (INNS). The need has been reinforced by the report of Dr Aldridge on INNS in Appendix B1 of the Raw Water Transfer Feasibility Report, which recommended coagulation and slow sand filtration for the pipeline transfer and strongly advised against the canal transfer option.

We are not aware of any precedent for the provision of water treatment for river-to-river transfer schemes in the UK. For example, there is no such provision in the Ely-Ouse to Essex scheme which has been operating successfully for 40 years, transferring similarly large quantities of lowland river water to smaller upland rivers.

GARD has repeatedly advocated that Thames Water’s team should look closely at lessons learned from the successful operation of the Ely-Ouse to Essex transfer scheme. For example, what difficulties have been experienced with INNS, poor lowland river water quality or ecological impacts due to the altered flow regimes in the smaller rivers receiving the transfers? What mitigation measures have been used? Have they been successful?

There is no reference in the Water Quality Ecology Report or the Raw Water Transfer Feasibility Report to any attempt to learn from the lessons of the Ely-Ouse to Essex transfer scheme or other existing river-to-river transfer schemes such as the Kielder reservoir supported transfers from the River Tyne into the Rivers Weir, Derwent and Tees. This seems an extraordinary omission, suggesting complacency in the investigating teams (or restrictions in their instructions from Thames Water).

That said, the provision of water treatment could be seen as a pragmatic solution to dealing with uncertain impacts of the transfer (and we recognise that treatment replaces the need for bank-side storage at Deerhurst which was proposed by earlier studies of the Severn-Thames transfer). However, the uncertainty over the need for treatment and the best treatment process could be addressed in a phased introduction of the transfer, starting with an unsupported transfer and, say, a 250 Ml/d first phase of aqueduct. The later need and type of treatment expansion could then be determined by operating experience.

[205] ‘Severn Thames Transfer: Water Quality and Ecology – Phase 2’. Cascade. October 2016.

7.4 Severn-Thames transfer supported by Vyrnwy reservoir

Introduction

Thames Water have assessed United Utilities' offer to provide regulation releases of up to 180 Ml/d from Vyrnwy reservoir to support the Severn to Thames transfer, combined with a continuous 15 Ml/d transfer of 15 Ml/d from Severn Trent's Mythe water treatment works (guaranteeing the availability of a sweetening flow in the transfer pipeline when it is not used for regulation).

GARD has the following concerns about the evaluation of the Vyrnwy support option:

1. The yields of the option used in the option appraisal have been underestimated by up to 50% (up to 200 Ml/d) due to:
    - Use of stochastic yields which are not consistent with historic yields
    - Not considering larger releases to use the full potential of Vyrnwy reservoir
    - Arbitrary and excessive reductions to allow for climate change
2. No consideration appears to have been given to the phasing of the scheme, making use of the potential for elements of support to be added as the need arises.
3. The allegedly huge and unexplained capital and operating costs attributed to the option – since WRMP14,Thames Water's estimated costs of the Severn-Thames transfer have roughly quadrupled.

Under-estimation of supported STT yield

The yield gain for London for the 180 Ml/d Vyrnwy support option with 300, 400 and 500 Ml/d Deerhurst to Culham transfer capacities is given in Table 7.3 of the Raw Water Transfer Feasibility Report and is compared with the values quoted in the dWRMP as follows:

All values in Ml/d

	Yield gain for London				
Transfer capacity	Regulation release	Using historic flows	Stochastic modelling	Stochastic modelling with climate change	WAFU in TW WRP Table 5
300	180	207	200	160	150
400	180	256	240	200	190
500	180	292	253	213	203

Table 7-1: TW values for London yield gain for STT supported by Vyrnwy reservoir

In GARD's opinion, the yield gains for the Vyrnwy support option, as used in dWRMP option evaluation, have been grossly underestimated for the following reasons:

i) Fixing the regulation release at a maximum of 180 Ml/d doesn't allow the full potential of Vyrnwy reservoir to be used for inter-regional transfer.

ii) The yields from the stochastic modelling are not consistent with yields from historic data and are demonstrably too low.

iii) The 40 Ml/d reduction in yield to allow for climate change is arbitrary and unjustified.

iv) The further 10 Ml/d reduction in the water available for use (WAFU), used in the dWRMP, is also arbitrary and unjustified.

These points have been made repeatedly by GARD in a number of evidence-based submissions in the course of development of the dWRMP:

- GARD letter to TW of 14.12.2015 and report "Modelling of Vyrnwy Support"
- GARD response to TW's draft Fine Screening Report, 31.10.2016, pages 13-21
- GARD response to TW's 2nd draft Fine Screening Report, 12.5.2017, pages 13-16

These submissions have not been acknowledged by Thames Water and appear to have been ignored in assessing the feasibility of this option. They are not referenced in the list of historic reports in Appendix A of the Raw Water Transfers Feasibility Report.

Yield assessment using historic flow records

Thames Water's yield assessment using historic droughts, as shown in Table 7-1 above, has only considered regulation releases of up to 180 Ml/d. GARD has confirmed the yields of the 180 Ml/d release options using its own model (with sample model output in Appendix B):

- with 300 Ml/d capacity transfer:209 Ml/d GARD v 207 Ml/d for TW
- with 400 Ml/d capacity transfer:255 Ml/d GARD v 256 Ml/d for TW
- with 500 Ml/d capacity transfer:292 Ml/d GARD v 292 Ml/d for TW

There is thus close agreement between GARD's yield assessment using their own model and Thames Water assessments using WARMS2. The critical drought for the London supply system in each case is 1921/22, although this is only marginally more severe than 1933/34 for London's supplies.

GARD's modelling of the operation of Vyrnwy reservoir in providing the regulation releases was described in earlier GARD reports which have previously been supplied to Thames Water and United Utilities[206] [207].

GARD's modelling included most of the existing operating rules for Vyrnwy reservoir as supplied by United Utilities[208], but made simplified assumptions about use of the Vyrnwy water bank. The yield of Vyrnwy in direct supply to United Utilities was determined by GARD's model as 199 Ml/d, which is understood to be similar to United Utilities' estimate. The Vyrnwy inflow records, which were only available from 1927, were extended back to 1920 by correlation with Claerwen reservoir inflow records to allow the drought of 1921/22 to be simulated in GARD's model.

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[206] 'Modelling of the use of Vyrnwy Reservoir to support the Severn-Thames transfer'. GARD. December 2015.

[207] 'User Notes for GARD's Thames Water Supply Simulation Model with Vyrnwy support option'. GARD. December 2015 with accompanying GARD model supplied to Thames Water and United Utilities.

[208] 'UU proposal for redeployment of Vyrnwy reservoir to supply TWS'. United Utilities. February 2015.

Simulation of Vyrnwy reservoir's operation supplying regulation releases of 180 Ml/d in support of a 500 Ml/d Severn-Thames transfer is shown in Figure 7-5, focusing on the 1933/34 drought, but also showing the modelled annual draw-downs of Vyrnwy reservoir since 1920:

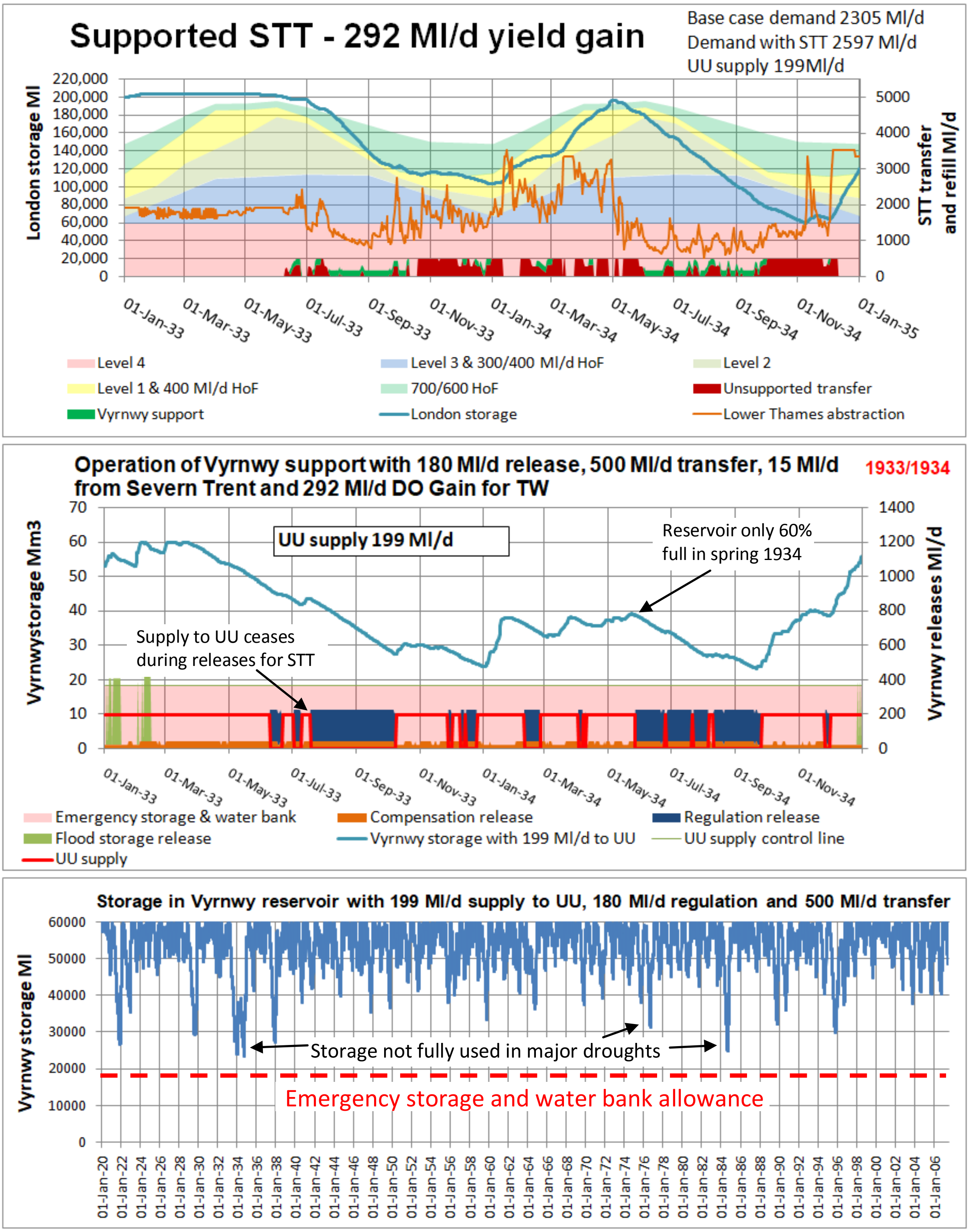


Figure 7-5: Operation of 500 Ml/d STT with 180 Ml/d Vyrnwy support & 15 Ml/d Myth

It is understood that the currently proposed operating rule is that United Utilities own supplies of 199 Ml/d from Vyrnwy would cease whenever the 180 Ml/d release is needed by Thames Water, as shown in the middle plot above.

United Utilities' draft WRMP shows an 81 Ml/d loss of yield from their own supplies with this option[209], allowing them to retain about 60% of the available Vyrnwy yield for their own supplies. No consideration appears to have been given to making regulation releases larger than 180 Ml/d from Vyrnwy reservoir, which would provide more yield for Thames Water but require United Utilities to give up more of their own yield. When questioned about this, Thames Water's response was that 180 Ml/d of regulation was the hydrological limit that could be provided by Vyrnwy reservoir.

In GARD's opinion, this is not correct – more yield could be made available to Thames Water, while still providing a smaller but guaranteed yield to United Utilities. Noting that the AIC costs per m^3 of United Utilities replacement sources are a lot less than Thames Water's, typically less than 60p/m^3 (from their Table WRP6) compared for with 110-250p/m^3 for TW, it seems likely that releasing more of Vyrnwy's yield for transfer to Thames Water would be a cost effective option. This has been repeatedly proposed by GARD and repeatedly ignored by Thames Water, with no justification provided.

GARD's proposal was described in our report of December 2015[210]. We have proposed that regulation releases of up to 400 Ml/d could be made with reduced yield to United Utilities which would be guaranteed by a Vyrnwy reservoir control line below which no regulation releases would be made. To illustrate this, GARD has modelled the following options:

	Yield gain for TW
• 300 Ml/d regulation with 100 Ml/d for UU and 500 Ml/d STT	336 Ml/d
• 350 Ml/d regulation with 50 Ml/d for UU and 500 Ml/d STT	376 Ml/d
• 350 Ml/d regulation with zero yield for UU and 500 Ml/d STT	416 Ml/d

The modelled operation with United Utilities' guaranteed yield reduced to 50 Ml/d and 350 Ml/d regulation, giving a Thames Water yield of 376 Ml/d, is shown in Figure 7-6:

[209] United Utilities dWRMP, Table WRP6 for Strategic Zone
[210] 'Modelling of the use of Vyrnwy Reservoir to support the Severn-Thames transfer'. GARD. December 2015

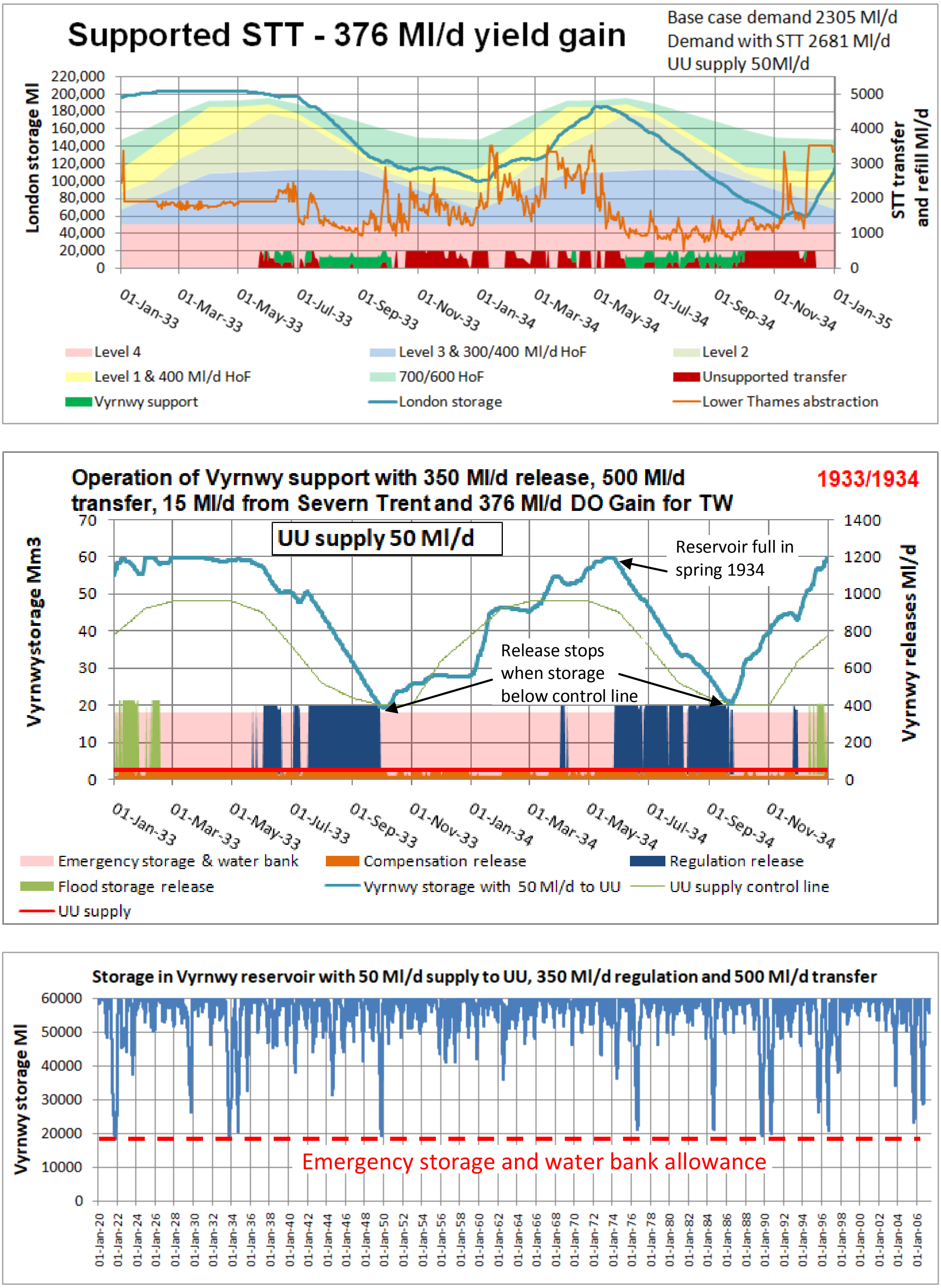


Figure 7-6: Operation of 500 Ml/d STT with 350 Ml/d Vyrnwy support & 15 Ml/d Myth

The 376 Ml/d yield for Thames Water is 84 Ml/d more than with the 180 Ml/d release option shown in earlier Figure 7-5. The 50 Ml/d yield still available to United Utilities is about 70 Ml/d less than for the 180 Ml/d release option.

It should be noted that, with the 350 Ml/d release option, Vyrnwy reservoir would completely re-fill in spring 1934, whereas with the 180 Ml/d release version the reservoir would only be 60% full in spring 1934 – winter refill of Vyrnwy reservoir would be much improved because there would only be a 50 Ml/d draw on the reservoir through much of the winter. Therefore, from Thames Water's perspective this option would be more resilient against longer duration droughts.

Effect of regulation releases on the River Vyrnwy

Concerns have been expressed that regulation release larger than 180 Ml/d would not be acceptable to Natural Resources Wales or the Environment Agency because of the possible impact of the higher releases on salmonid spawning and juveniles. In GARD's opinion, this is not a major concern, although it needs to be properly investigated. The impact of 350 Ml/d flows is shown on Figure 7-7. The upper plot shows flow duration curves for April to September, when most regulation takes place, and the lower plot compares flows in the drought of 1934 with the natural flows in 2007 and 2008, two naturally wet years:

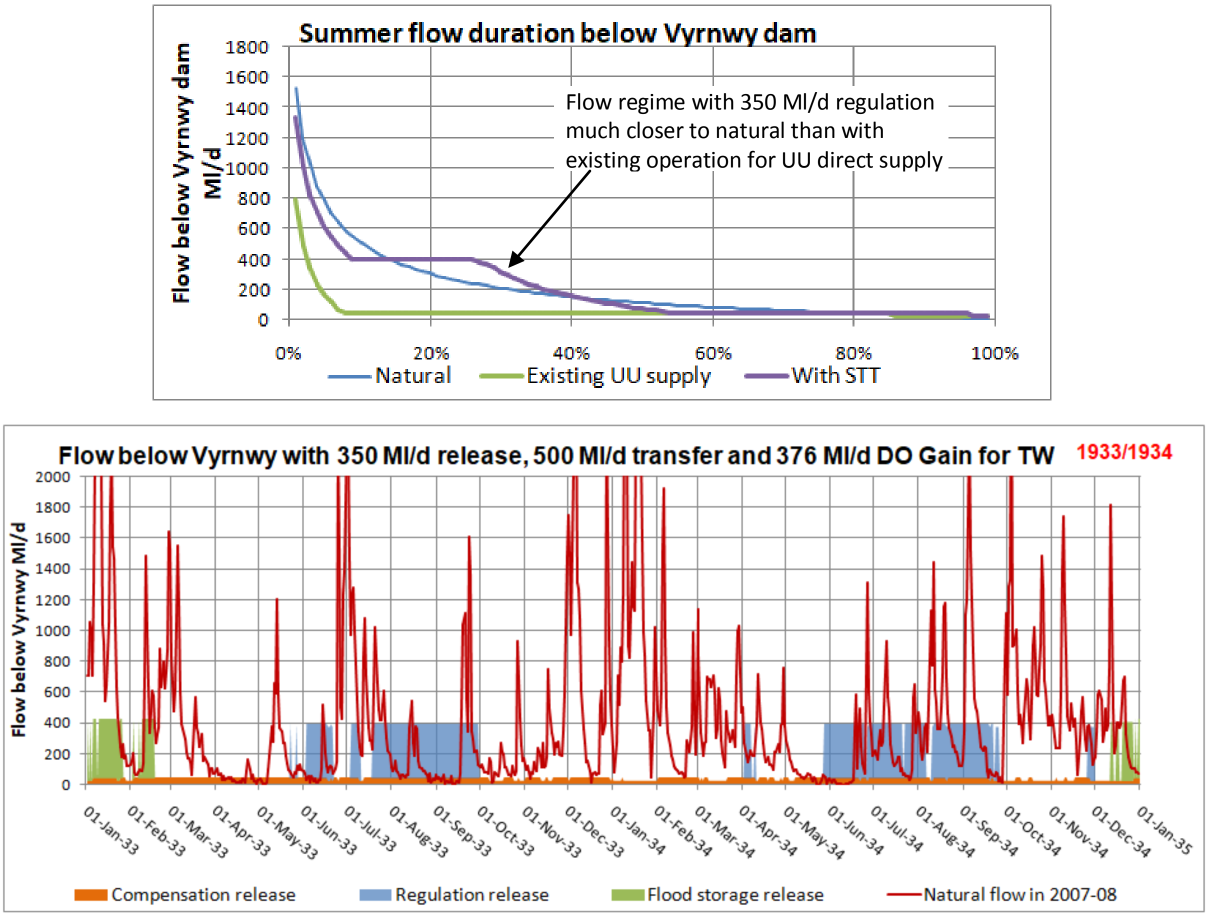


Figure 7-7: Impact of 350 Ml/d regulation on flows below Vyrnwy dam

The upper plot shows that the April to September flow regime would be much closer to natural than at present when flows are continuously at the 25-45 Ml/d compensation level. In geomorphological terms, this would be a marked improvement on the existing flow regime. The summer flow of nearly 400 Ml/d in a drought like 1934 would be unnaturally high as a continuous flow, but comparable to natural flows in wet summers like 2007 and 2008, albeit lacking the natural variation. Arguably, the flows in droughts would be better for juvenile salmonid productivity than protracted compensation flows of only 25-45 Ml/d. There would also be scope for varying the regulation releases, say from 200 to 500 Ml/d to give some flow variation more akin to natural.

The continuous regulation releases for several months would only occur in droughts and in most years there would far fewer days of release or none at all, as shown in Figure 7-8:

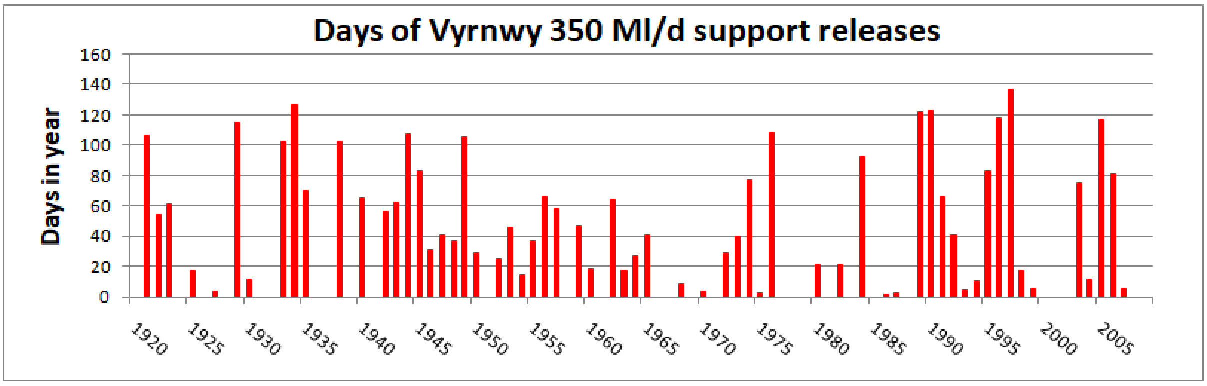


Figure 7-8: Frequency of regulation releases with supported STT

In GARD's opinion, the impact of 350 Ml/d regulation releases on the flow regime of the River Vyrnwy is not a show-stopper and could actually be beneficial for the long term productivity of salmonids. At a fundamental level, reducing the amount of water exported out of the Vyrnwy catchment is a benefit. The impact of higher summer releases needs to be properly investigated, including the potential for mitigation by varying the releases to mimic natural flow variation. Account should also be taken in the reduction of the need for autumn continuous releases of 400 Ml/d for flood alleviation which occur in most years at present.

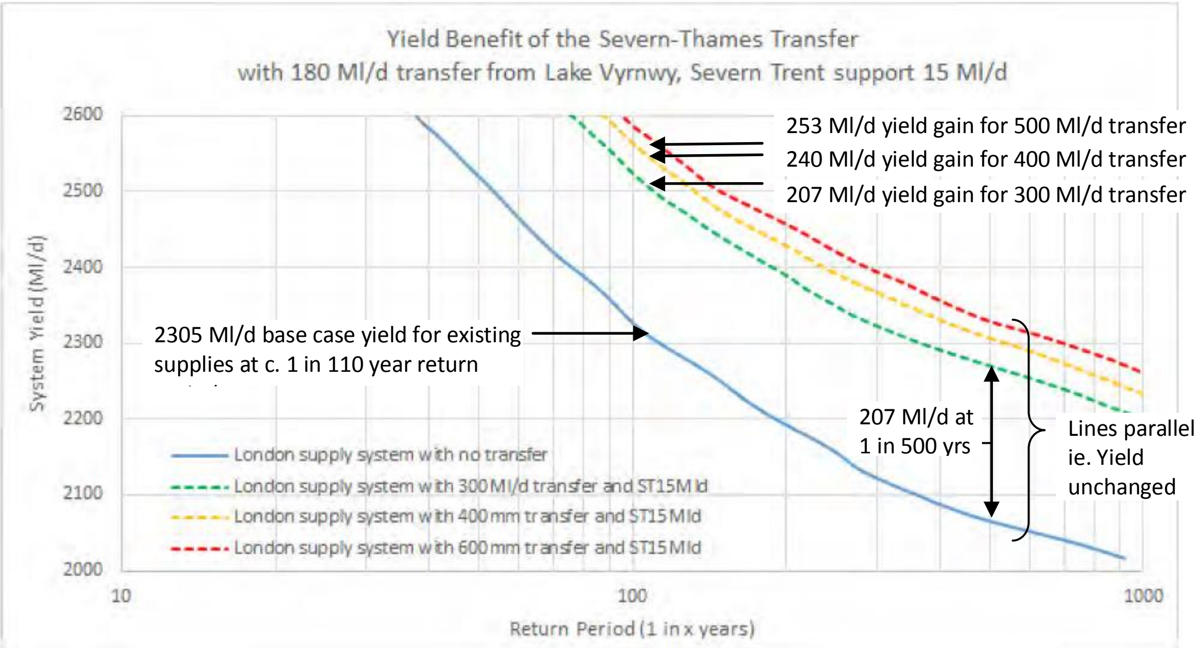
Stochastic yield assessment and resilience to droughts more severe than historic

The resilience to droughts more severe than historic has been investigated through analysis of performance of the 180 Ml/d release options in stochastically generated droughts as described in the Appendix J to the Fine Screening Report dated February 2018.

The stochastic yield analysis gives yields for the 180 Ml/d Vyrnwy support options that are substantially lower than the yields with the historic flows shown in earlier Table 7-1 and again below:

	Stochastic yield	Historic yield	Yield difference
• 300 Ml/d STT option	200 Ml/d	207 Ml/d	- 7 Ml/d
• 400 Ml/d STT option	240 Ml/d	256 Ml/d	- 16 Ml/d
• 500 Ml/d STT option	253 Ml/d	292 Ml/d	- 39 Ml/d

The stochastic yields above appear to have been taken from the analysis in Atkins' assessment of the resilience of the 180 Ml/d Vyrnwy support option in Appendix K of the latest Fine Screening Report. The diagram is reproduced below with GARD's annotation.



Source: Figure 3-2 in Atkins report on STT resilience in Appendix K of Fine Screening Report, with GARD annotations

Figure 7-9: Atkins' assessment of stochastic yield of 180 Ml/d Vyrnwy support option

This plot shows the 2305 Ml/d base case yield, assessed with historic flows, as about 1 in 110 year return period which seems reasonable. The diagram also shows that the yield lines for the three transfer options are almost exactly parallel to yield-probability line for the existing London system. On that basis, the stochastic yield gains for the Vyrnwy support options ought to match the historic yield gains, but they are significantly less, particularly the 39 Ml/d discrepancy for the 500 Ml/d transfer option.

As explained in earlier Section 7.2 on the unsupported transfer, the discrepancy between stochastic yields and historic yields appears to be due to a flaw in Atkins' stochastic modelling which has underestimated autumn flows by about 300-600 Ml/d compared to the historic flows. In GARD's opinion:

- Aside from the flaw in the stochastic flow data, the modelling of historic yield using WARMS2 is a lot more reliable than the stochastic yield using the much simplified IRAS model

- As the stochastic modelling has shown no change in yield across a wide range of return periods, the historic yield should be used in assessing the Vyrnwy support option and the stochastic yield should be rejected.

Thames Water appear to have made an arbitrary and unjustified decision to use the artificially generated stochastic yields rather than historic yields. This fundamentally unsound decision has been carried through into the AIC costings of the option, programme appraisal and option selection.

Reduction in yield due to climate change and "other" abstractors

As shown in Table 7-1 above, the yields for each scheme option have been reduced by 40 Ml/d to allow for climate change and other abstractors. The Raw Water Transfer feasibility report (footnote to Table 7-3) says this reduction has been taken from Atkins' stochastic analysis. However, Atkins stochastic analysis of the Vyrnwy support scheme did not make any allowance for climate change and the 40 Ml/d reduction appears to have been taken from their analysis of the unsupported option[211] as follows:

4. Both the historically based and stochastically based methods indicate that the *net* yield of the scheme reduces by around 20Ml/d under climate change, even though absolute flows in the Severn reduce by much more than this under climate change futures. This is because the *net* yield depends on the storage characteristics in the Thames-London reservoirs as well as the flows in the Severn. Lower flows and hence storage in the Thames lead to the transfer being called upon earlier in the season and for longer during a drought year than they are under the current climate. This means that the transfer is required when River Severn flows are closer to their winter maximum, so there is more opportunity for benefit from the scheme. Overall, when it comes to net yield, it appears that the lower flows associated with climate futures in the Severn are largely counter-balanced by the wider timing of need caused by lower flows in the River Thames.

5. The scheme is potentially vulnerable to third party abstractions within the Severn, and the drought abstraction patterns that would be expected under the current Severn Trent Water supply system tend to be well below their licensed capacity during the key spring and autumn periods. Risks from climate change, increasing demand and reductions in other licences are likely to increase pressure on the Severn Trent Water supply system, so there is a significant risk that abstraction will be increased towards maximum allowances in the future. Overall this places 10- 20 Ml/d of the net yield benefit at risk when future conditions (to 2040) are considered.

The allowance of 40 Ml/d is evidently a combination of "*around 20 Ml/d for climate change*" and "*10-20 Ml/d of the net yield benefit at risk*" from other abstractors. GARD's comments on this are:

- Making any allowance for climate change for the Severn-Thames transfer option is inconsistent with the approach used in assessing the Abingdon reservoir option, where no allowance has been made for climate change in the yield used in the economic evaluation of options.

- Logically, if climate change alters the natural flow regime of the River Severn, reducing low flows, the Deerhurst hands-off flow should be reduced to match the

[211] 'Fine Screening Report, Appendix K, Section 7'. February 2018

new “natural” flow regime, leaving the flow available for transfer at Deerhurst unchanged.

- The 10-20 Ml/d loss of yield to other abstractors is an exaggeration – Figure 6-2 of the Atkins report shows the loss as about 10 Ml/d. This small loss could be offset by Severn Trent giving up part of their unused licences and replacing them with available new groundwater abstractions with much lower AIC costs than Thames Water’s alternative. This would require no transfer infrastructure so would be a low cost trade between Thames Water and Severn Trent.

The further reduction of 10 Ml/d in yields used for option appraisal

The option yields quoted in the Table WRP5 for the London resource are all 10 Ml/d less than the stochastic with climate change yields. No explanation has been provided for this seemingly arbitrary reduction which appears to have been used in calculating option AIC costs and, presumably, in other option appraisals.

Cost of the Vyrnwy support options

The cost of the Vyrnwy support option has been dramatically increased in successive versions of the Fine Screening Report and then in Table WRP5:

	AIC + Carbon Cost p/m^3			
Option	FSR Oct ‘16	FSR April ‘17	FSR March ‘18	Table WRP 5
300 Ml/d Severn-Thames transfer supported by Vyrnwy and Mythe	85-145	100-165	170-210	265

No explanation has been provided for the increases, but they seems likely to be based on the huge Opex costs shown in Table WRP 5 for the London resource zone as extracted below:

Option name	WAFU (Ml/d)	NPV of WAFU (Ml)	CAPEX NPV (£000)	OPEX NPV (£000)	NPV of carbon (£000)	TOTAL NPV (£000)	AIC (p/m3)	AISC (p/m3)
STT 300 Ml/d - 180 + 15Mld	150.0	1,215,530	1,263,592	1,523,387	432,827	3,219,806	229	265
STT 400 Ml/d - 180 + 15Mld	190.0	1,539,672	1,411,508	1,678,175	512,145	3,601,829	201	234
STT 500 Ml/d - 180 + 15Mld	203.0	1,645,018	1,509,019	1,799,476	576,089	3,884,583	201	236

Table 7-2: NPV costs of STT options with Vyrnwy support

High Opex includes excessive UU trading costs?

In the absence of any breakdown of these costs, we have the following comments:

1. From discussion with United Utilities, we understand that the high Opex costs are due to them containing the full cost of United Utilities’ inter-company charges for the transfer. Noting that United Utilities dWRMP only allows for a loss of 81 Ml/d in their own yields for providing the transfer and the AIC costs of their replacement

sources are less than about 60 p/m^3, it is difficult to see how these costs can be justified.

2. In the equivalent Table WRP in WRMP14, the NPV Capex cost for the 300 Ml/d unsupported transfer supplying London was only £274 million. If all the costs for providing the support from Vyrnwy are included in the Opex, the capex NPV of the 300 Ml/d aqueduct has increased to £1264 million. No explanation has been offered for this extraordinary 500% increase in capital costs.

3. No consideration appears to have been given to phasing the development which would reduce NPV costs.

In GARD's opinion, the huge cost increases combined with total lack of transparency warrants a genuinely independent investigation of the costs by Ofwat and the Environment Agency. The results should be made public in a format that allows confidence that comparison with costs of the Abingdon reservoir have been undertaken even-handedly, without bias in favour of the reservoir option.

The potential for phasing the supported Severn-Thames transfer option

The supported Severn-Thames transfer option lends itself to phased development, with increments of support being added as demands increase, for example:

- Initially, the Deerhurst to Culham aqueduct only supported by 15 Ml/d from Mythe – the "unsupported transfer", which would provide a yield of about 120 Ml/d
- Increments of support from Vyrnwy releases, perhaps starting with only 60 Ml/d, with United Utilities' replacement sources also developed incrementally
- Addition of support from Severn Trent or Welsh Water sources, when and if the need arises

There is also potential for the Deerhurst to Culham aqueduct to be built in two phases, perhaps initially 250-300 Ml/d for the unsupported transfer and some later increments of support, followed by a twinning of the aqueduct to 500 Ml/d if the need arises.

The scope for phased development is one of the major benefits of the supported Severn-Thames transfer option, as GARD has repeatedly pointed out in previous response to dWRMP and versions of the Fine Screening Report. This benefit is particularly important in view of the large uncertainties in future deficit forecasts. Failure to investigate the potential for phasing is another big weakness in the assessment of this option.

7.5 Transfer losses in the River Severn

Losses assumed up until now

To date, modelling of the operation of the Vyrnwy support scheme by Thames Water, Atkins and GARD have assumed a transmission loss of 10% in the River Severn between Vyrnwy and Deerhurst. The Raw Water Transfer feasibility report, page 18, states that Thames Water have been asked by the Environment Agency to consider transmission losses in the River Severn of 20% and 30%. This has been followed up by Thames Water in a report commissioned from HR Wallingford. Before commenting on this report, we have some observations on the 20%-30% losses suggested by the Environment Agency:

- An addition of 180 Ml/d of regulation flows into the River Severn will add only a few centimetres of depth to the river, with minimal impact on the wetted perimeter of the river – why should water leak out of the river significantly more than it does at present?
- Where would the "leaking" water go? We are not aware of any part of the Severn valley being suspended above permeable strata with the capacity to absorb 40-50 Ml/d of flow throughout the many months when regulation would continuously take place. If such geological conditions exist, there would be existing substantial losses from the Severn channel – what evidence is there of this already happening?
- Whereas it can be imagined that, with a sudden increase in flow of 180 Ml/d, there could be a loss for a few days due to initial wetting of a slightly increased wetted perimeter, equilibrium would soon be reached. Thereafter, with the regulation releases continuing for about 6 months in a critical drought (see earlier Figure 7-6), further losses can be expected to be minimal.
- TW have assumed that regulation releases in the River Thames from the Abingdon reservoir would be only 2%. Why should losses be so much higher in the River Severn?

When developing earlier proposals for the Severn-Thames transfer option (Halcrow in 2006), contact was made with Richard Bailey, formerly a Severn River Authority and NRA manager with responsibility for the Severn regulation scheme. Correspondence with him and data supplied by the Environment Agency at that time are given in Appendix B. The same information was included in GARD's December 2015 report on the Vyrnwy support option. Richard Bailey's finding, based on many years of records of releases from Clywedog Dam was:

> *"These show that the actual releases made, which are subsequently not required for river regulation, are generally less than 10% of all releases during a regulation period - when more than half of Llyn Clywedog's storage (25,000 Ml) is required.*

When there are more intermittent periods of regulation during insignificant dry summers, the amounts can increase to 20% but this is not really relevant in the design or operation of the system.

I do recall calculations of similar figures for significant droughts in 1975, 1976 and 1984 and would be interested in following this up later."

On this basis, the 10% allowance for River Severn transmission losses seems reasonable.

HR Wallingford's report on losses

HR Wallingford have now produced their report on losses[212] which was provided to GARD on 9th April 2018, too late for a detailed review for this consultation response. We note that the report was dated February 2018, so it could and should have been made available to stakeholders earlier, particularly noting that GARD had raised the matter of losses in their report on modelling of the Vyrnwy support option in December 2015[213].

From a brief review of HR Wallingford's report, we have the following comments:

1. The summary to the report says that *"in general the river gains from groundwater ..... during low summer flows, during low summer flows, flows at Deerhurst are heavily supported by groundwater flows to the river".* This provides confirmation of our earlier point that water cannot "leak" out of the river
2. We agree that evaporation has minimal influence, as stated in the summary.
3. There is little reference in the report to the experience of regulation releases from Clywedog and Vyrnwy reservoirs or discussion with staff of Severn Trent Water or South Staffs Water as to whether these releases are effective in making water available for re-abstraction.
4. There is no reference to experience of the effectiveness of the Shropshire groundwater scheme which makes regulation releases of up to 450 Ml/d to the river.
5. There is no reference to the information and data on Clywedog from Richard Bailey, which we refer to earlier, despite this being provided to Thames Water by GARD in December 2015.
6. There is no recognition of the long duration of required regulation releases (see earlier Figure 7-6) and consequently the limitation on losses after, perhaps, higher start-up losses.

[212] 'River Severn Losses Estimation'. HR Wallingford. February 2018.
[213] GARD letter to Thames Water of 14.12.2015 and report "Modelling of Vyrnwy Support"

However, our main criticism of this report is its failure to consider the fundamental water balance in the Severn catchment and ask the question "where might losses go?". Noting that HR Wallingford agree that river channel losses and evaporation are minimal, the only other destination for "lost" water is consumptive abstraction by water companies or private abstractors. Why would the release of regulation water from Vyrnwy precipitate an increase in abstraction beyond what would be taking place without the regulation? If there are illegal abstractions taking place (eg by irrigators), they will occur regardless of whether regulation releases are being made. Why would the public water suppliers increase their consumptive abstractions beyond what they would take without the regulation releases, or beyond what has already been allowed for in the modelling of the Vyrnwy support option?

There is also a danger of double counting of losses, noting that Atkins have proposed an arbitrary deduction of 10-20 Ml/d (rounded up to 20 Ml/d) from the yield of the Vyrnwy support scheme to allow for unpredicted "other abstractor" (see earlier in Section 7.4).

GARD is also concerned by the suggestion that the Environment Agency will not allow a "put and take" arrangement for the re-abstraction of regulation releases, even after an allowance for losses. In our opinion, this would put an unjustified obstacle to developing a strategically important national scheme for bringing much-needed water to the South East of England.

We note that regulation releases of about 150 Ml/d to the River Wye from the Elan reservoirs to support the Wye-Usk transfer and Severn Trent supplies are re-abstracted on a put-and-take basis from the lower Wye. This is despite the Wye being a Habitats Directive protected river with a high hands-off flow, discharging to the Severn estuary. There is no allowance for transmission losses. The put-and-take abstractions frequently occur when the lower Wye flows are below the hands-off flow, with no known problems and no objections from local fishery interests. In our opinion, this has set a precedent that should be followed for re-abstraction of put-and-take regulation releases from Vyrnwy reservoir.

There needs to be a "can do" approach to finding ways to overcome any problems due to unauthorised abstractions from the River Severn, probably combining improved measurement of reservoir releases, river flows and abstraction, with carefully designed abstraction licence conditions.

7.6 Severn-Thames transfer supported by Severn Trent or DCWW

We note that no detail is provided in the dWRMP of transfers supported by water from Severn Trent (via Draycote or Minworth WTWW effluent), or by Welsh Water (DCWW) using water from the Great Spring in the Severn estuary rail tunnel. These options are said still to be under investigation.

GARD retains a keen interest in these options and would like to see details as soon as they are available.

In the case of the Welsh Water option for using the Great Spring, we still believe that the proposal previously put forward by GARD[214] has the potential for reducing impacts of Welsh Water's existing supplies on the River Usk as well as providing a low cost means of support to the Severn-Thames transfer. We note from the feasibility report that *"initial Information has been received but further clarification required to undertake assessment"* and that the transfer is to be made by a new pipeline from South East Wales.

The transfer via a new pipeline is a different scheme to that proposed by GARD which would allow water to be available to support by the Severn-Thames transfer indirectly via Great Spring water into South East Wales supplies, allowing:

- less need for the existing Wye-Usk transfer, in turn giving
- less need for regulation releases from the Elan Valley reservoirs, in turn
- increasing water available for Severn Trent via the Elan Valley Aqueduct in droughts
- thus reducing the need for direct supplies from the Severn
- and, finally, enabling more water to be available for the Severn-Thames transfer

We can see no reference to the scheme proposed by GARD in the Raw Water Transfer Feasibility Report, nor have Thames Water responded to our letter of 10th April 2016 (copy in Appendix A). In our opinion, GARD's proposal should be properly investigated – it is likely to be a low cost and environmentally beneficial means of making more water available to support the Severn-Thames transfer.

7.7 Use of the Cotswold Canal

We note the rejection of this option in the Fine Screening Report on the grounds of cost, construction complexity, pollution risk, water quality and vulnerability to invasive non-native species. Whilst being disappointed that this seemingly attractive and beneficial scheme is not deemed feasible, we leave it to the Cotswold Canal Trust to argue the case for this option.

From the perspective of GARD, it is immaterial whether a 300 Ml/d transfer is by pipeline or by canal.

7.8 Transfers by the Oxford Canal

We are pleased to see the Oxford Canal transfer scheme delivering 15 Ml/d for London via the River Cherwell, as previously proposed by GARD, is now on the list of options that could

[214] Letter from GARD to Thames Water dated 10th April 2016 and accompanying schematic diagram. Copy included in Appendix B.

become part of the preferred programme, if higher demands materialise in the middle of this century.

We note that the AIC cost of this option in Table WRP5 for London is less than the AIC cost for the Abingdon reservoir (86 p/m^3 v 106 p/m^3). The Strategic Environmental Assessment describes this scheme as having *"mostly negligible to minor adverse effects"*. That being the case, why is this option not always selected ahead of the Abingdon reservoir or any other more costly, larger and more disruptive option?

Also, as this scheme brings much needed "new water" into the Thames catchment, bringing the ability to supply the Thames Valley zones and reduce damaging chalkstream abstractions, why is this scheme not developed immediately and ahead of the Teddington DRA scheme?

The transfer via the Oxford canal and River Cherwell also can supply SWOX zone, with water transferred to Farmoor by a new pipeline from Culham to the River Thames upstream of Farmoor. This is discussed further in Section 11 of this response.

7.9 Environmental assessment

Referring to Figure 9-7 of the dWRMP, showing adverse effects of options, we have the following critical comments, particularly with regard to the comparative scoring of the Severn-Thames transfer and Abingdon reservoir options:

SEA Objective and rating			**GARD comment**
1.2	Protect and enhance natural capital		STT should not get an 'amber' score – the same as Abingdon reservoir. Temporary construction impacts of the pipeline cannot be comparable to loss of 10 km^2 of agricultural land and natural habitat with the reservoir
2.1	Protect health, raise awareness of water environment		STT should not get a 'red' adverse score? No aspect of health is adversely affected by the construction or operation of the STT
4.5	Reduce or manage flood risk		STT should not have even a 'yellow' score for flood risk, the same as Abingdon reservoir which has a substantial flood risk through loss of flood plain. The STT has zero flood risk
5.1	Protect geology and soils		STT should not be 'amber', the same as the reservoir – the pipeline has a minor, temporary construction impact. The reservoir has huge impact on geology and soils
7.1 8.1	Enhance heritage, landscape and countryside access		STT should not be red for these, the same as the reservoir. The pipeline will have minor, temporary construction impact, compared with the major impact of the reservoir

Table 7-3: GARD review of SEA impact scoring

In our opinion, the SEA scorings, which are highly subjective, have been heavily biased against the Severn-Thames transfer option and in favour of the Abingdon reservoir. Our issues with the SEA methodology and content are dealt with in more detail in Section 11.

8. Abingdon reservoir

Key Points

- Thames Water has not addressed the findings of the 2010 Public Inquiry or shown the need for a reservoir.
- Close examination of Thames Water's alternative proposals (including water transfers) and their SEAs show false assumptions and widespread error.
- Thames Water appear to have selected the Abingdon site because it is a large flat area devoid of settlement, ignoring other facts: it is a floodplain, has gravel and greensand seams, is close to heritage assets and in a non-industrialised area. These factors are grounds for rejection at other sites.
- Thames Water have never constructed a reservoir. This plan is for an experimental, high risk project of unprecedented size. The risk is not reflected in the dWRMP.
- Thames Water have misdirected public sentiment, playing on people's feelings about housing development, pretty reservoirs in valleys, leisure amenities, while playing down unnatural bunded design, flood issues, industrial scale, and disruptive construction and operation.
- The minimum average water depth in the reservoir should be assumed to be 5m to give acceptable water quality.
- Thames Water's allowance of 15,000 Ml of dead storage for Abingdon reservoir only leaves an average usable water depth of 5m.
- Thames Water's allowance of only 6% of emergency storage is far below the industry norm of 12-25% and would be of unacceptable water quality, being never more than 4.2m average depth.
- The emergency storage allowance should be 15% of live storage, in addition to the revised allowance for dead storage.
- With these more realistic provisions for dead and emergency storage, the deployable output of the Abingdon reservoir option should be reduced to 245 Ml/d.
- TW should re-assess the division and weighting of assessment sections in the SEA for the reservoir, since the existing skewed assessment downplays adverse effects and over-emphasises beneficial effects
- TW should re-assess the effect on historic listed houses and the listed Causeway since it is greater than stated in the SEA.

- TW must understand that the proposed removal and rerouting of ancient waterways is unacceptable, as is the loss of ancient field systems and boundaries. They must realise that such things once lost cannot be retrieved.
- TW must acknowledge their obligation to conserve and enhance heritage assets and their settings.
- TW must acknowledge their obligation to protect archaeologically important sites, including unknown assets which are either known or suspected to be of high importance.The Thames region is rich in unexcavated archaeology, because of its early and uninterrupted settlement.
- The dWRMP lacks any detail on how the reservoir will affect the local floodplain
- TW should conduct a full flood risk assessment for the reservoir and any ancillary works.
- TW should demonstrate how its planned programme will support and comply with the Oxfordshire County Council flood risk management strategy.
- TW should demonstrate how it will meet the requirements of the Thames River Basin District Flood Risk Management Plan to 'enhance and extend the floodplain'.
- TW should provide evidence as to how the 150m tonnes of water will affect the underlying geology and local water levels.
- TW should explain how its plan to provide deep-shelf flood compensation will provide extra capacity, when local experience shows that such schemes will fill naturally with water due to the high-water table.
- Since 2009, considerable housing, approved by the local authority, has been built immediately adjacent to the planned reservoir site. TW should demonstrate how it intends to protect these properties and determine how much these have already reduced the space available for the reservoir.
- TW must acknowledge the geology of the area and the presence of sand and gravel seams. It must explain why these attributes were grounds for rejection of other sites, but not Abingdon.
- TW should provide convincing evidence as to how they will protect against leakage and seepage and protect local villages.

8.1 Introduction and overview

The outcome of the 2010 public inquiry

In March 2011, the Public Inquiry Inspector, Mrs Wendy Burden, found that the TW (TW) dWRMP09 was:

- Not fit for purpose.
- Was not compliant with the regulators' requirements.
- Had failed to investigate fully viable alternative water resources.
- Had failed to make certain essential environmental assessments.

As a result, the Inspector ruled out TW's proposal to build a 100 million cubic meter capacity Abingdon reservoir. It is clear that in the intervening 8-year period, and despite the ruling, TW has continued to maintain the construction of the Abingdon reservoir as a central element in its long-term plan. Given the outcome of the public inquiry, GARD would have expected, at the least, an acknowledgement of the result and a detailed forensic analysis of the findings that made clear the work required to now justify the reservoir. Instead we find the reservoir appears as a 'given', except 50% bigger than previously and with many unresolved questions. This is astonishing.

Work conducted since the Public Enquiry

Clearly, TW has tried to address some of the inquiry's criticisms by producing a SEA for a plethora of alternative water resources. Unfortunately, close examination shows that these contain a number of false assumptions and basic errors. Examples of these are given in Section 11.3 and throughout the document. The errors in the SEA, which are a fundamental investment decision support tool for the dWRMP, undermine the credibility of the whole dWRMP.

Despite the Inspector finding that TW had failed to investigate fully viable alternative water resources, we find in the dWRMP the following statement from the CEO, TW:

'*A number of significant raw water transfers have been provided to us as options. We see these as the first step in providing the pathway to a resilient and efficient nationwide water conveyance system. Each transfer option needs to be considered on both their economic and environmental merits relative to other potential options. For these reasons, at this stage, the options provided are not included in our plan'*.[215]

This is a most confusing statement. Firstly, it is not credible that in the 8 years since the Public Inquiry and given the public criticism of the company on this very issue, TW has not fully worked up a range of options. Either it has carried out the work and wishes to suppress the detail, or it has not carried out the work and is incompetent. Further, the

[215] dWRMP19, Section 0, Executive Summary, page 2.

statement acknowledges up-front the importance of establishing a resilient and efficient inter-regional water conveyance system, but the dWRMP subsequently fails to programme any significant measures that would support such a system. When challenged on the issue of transfers into the area at the TW, Water Resources Forum in March 2018, the response was that the Board preferred to keep its infrastructure under its own control. Throughout the dWRMP it is clear that TW is very keen to transfer water out of its own region to other water companies, but not transfer water in from outside areas. The repeated assertion by TW, other water companies and the Water Resources in the South East (WRSE) grouping that the South East is a very water stressed area, undermines this whole argument. TW is already contracted now, and plans more such deals in the future, to sell water that will leave it short of water for its own customers.[216]This can only be about making profit from selling water, rather than provisioning a supply programme that first and foremost meets the needs of TW customers.

The dWRMP, modelling and the reservoir

Apart from the flawed SEA, the dWRMP contains no new information on the reservoir, indeed the cost elements are even more sparse than in previous WRMPs. Conversations with TW staff during several drop-in sessions and public meetings have failed to elicit any information on new studies carried out since the public enquiry. Always, the response to request for detail is that these issues will be looked at later.

Despite the lack of further work, the reservoir now appears in some form in all variations of TW's plans. The modelling process behind it and other options' selection is detailed in *Appendix W: Programme appraisal methods*. We discuss the shortcomings and false assumptions behind this process in Section 11 of this response. Our conclusion is that the appraisal process is completely flawed: the main sources of error and lack of fitness-for-purpose come from:

- The unnecessarily-restrictive constraints to demand management programmes(DMP) which constrain the amount of DMP which is inputted as data at the very start of the programme appraisal.
- The errors in Deployable Output (DO) for the various major water resources used as programme elements, which feeds into normalised cost.
- The improper costing of Mains Replacement, which fails to take account of maintenance budgetary contributions.
- The flawed SEA method with double-counting of benefits and inclusion of *potential benefits* as actual benefits (dealt with in greater detail for the reservoir in Section 8.3 below).

[216] A significant proportion of the forecast shortfall in the TW area is due to its intention to sell additional water to other companies out of their own Water Resource Zones. It is unclear why TW customers would foot the bill for developing infrastructure that is for other regions customers.

- The incomplete and inconsistent Drought Resilience analysis for the major climate-dependent water resources (principally the Severn Thames Transfer (STT) and the reservoir).
- The lack of a proper Adaptability analysis for the last stage of programme selection.

Equally important, the complete abandonment of such fundamental items as the dWRMP population projections and leakage targets, at a very early stage of the consultation period, means that the entire set of modelled outputs and hence programme selection presented in the dWRMP is invalid. Once TW have settled on final figures for both these elements and subjected them to wider stakeholder scrutiny, the modelling process must be re-run to include the new starting assumptions, and the correction of the flaws listed above.

Issues with the area selected for the proposed reservoir

This area of approximately 10 square miles between Hanney, the railway, Steventon and the Childrey Brook seems to appeal to TW because of its flatness and lack of current settlement. The flatness relates to the geology – it is a clay vale, a historic wetland; the lack of settlement arises because it is a floodplain, where no development should occur that blocks this function. Flooding is a major issue for local towns as well as the villages in the area (Abingdon, Oxford, Hanney, Steventon, Garford). A significant criterion for this option to be selected appears to be simply because it would be an asset under TW control.

Throughout the dWRMP there is no consistent application of selection or rejection criteria regarding potential reservoir sites, as the SEA contained in sub-Appendix F to Appendix B of the dWRMP show. We have commented further on this in our additions to the UTR 150 SEA spreadsheet[217]. The presence of gravel and greensand have caused rejection in other potential reservoir sites at the Fine Screening Stage, but their presence on the Abingdon floodplain is judged to be manageable. Similarly, closeness to heritage sites and listed monuments has led to rejection elsewhere. It is possible that TW think that the extensive industrial development in the area makes more of the same acceptable. This is to ignore the A34 dividing line effect, *where landscape scale development (Milton Park, Didcot power station, JET Culham, mineral workings, landfill etc.) have occurred to the east, whilst the Vale landscape to the west of the A34 has remained relatively intact.*

Looking for precedents for the construction of such a reservoir, it was astonishing to find that TW have not actually built or supervised the building of any reservoir. Constructing an experimental 30-metre-deep reservoir created entirely from artificial bunds with a volume second only to Kielder Water in the UK is a cause of great concern. The magnitude and scale are unprecedented; if it were breached, or even developed significant leakage, it would devastate an area including at least four large villages. Further, the weight and extent of the

[217] The spreadsheet is too large to fit on a reasonable size page and is supplied separately as an electronic document as part of the GARD submission.

construction will have many unknown side-effects, including damage to the underlying geology and changes in the water table and levels.

'Water stress' is an emotive term and no one wishes to deprive others of water; it is easy to see how some have come to think that a reservoir might be the answer. This document has set out to explain why a reservoir that stores Thames water in order to replace it in the Thames is neither sensible, drought resilient nor the best option. It is certainly not noble, with the main motive being the largest investment return for its private shareholders.

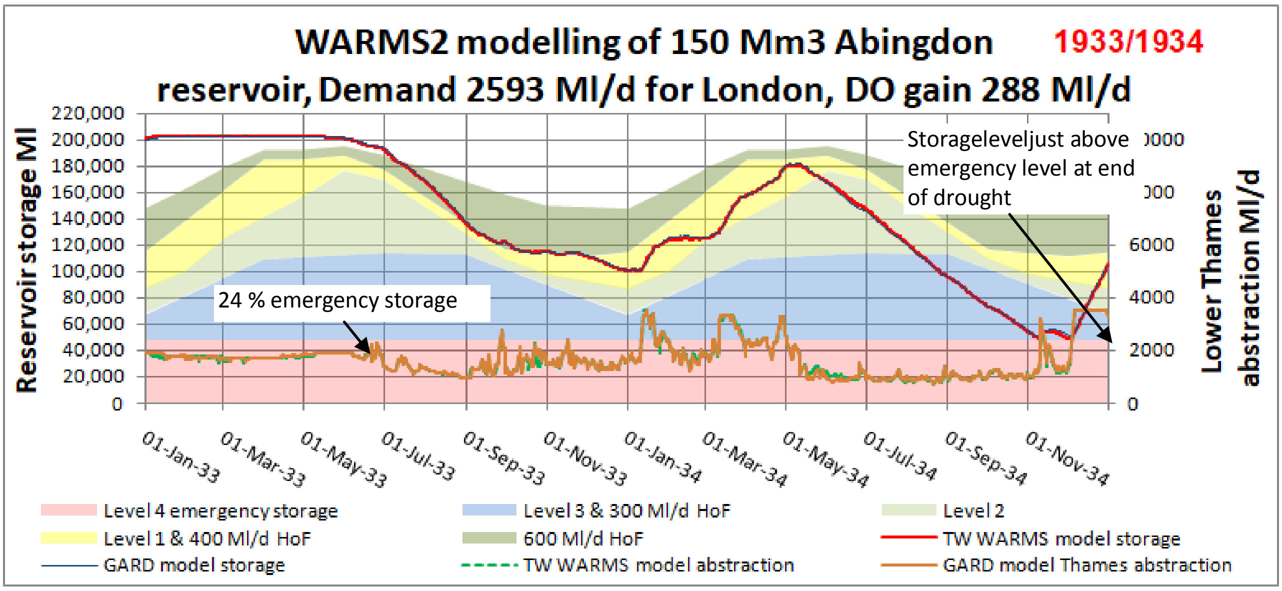
Misdirection of public sentiment

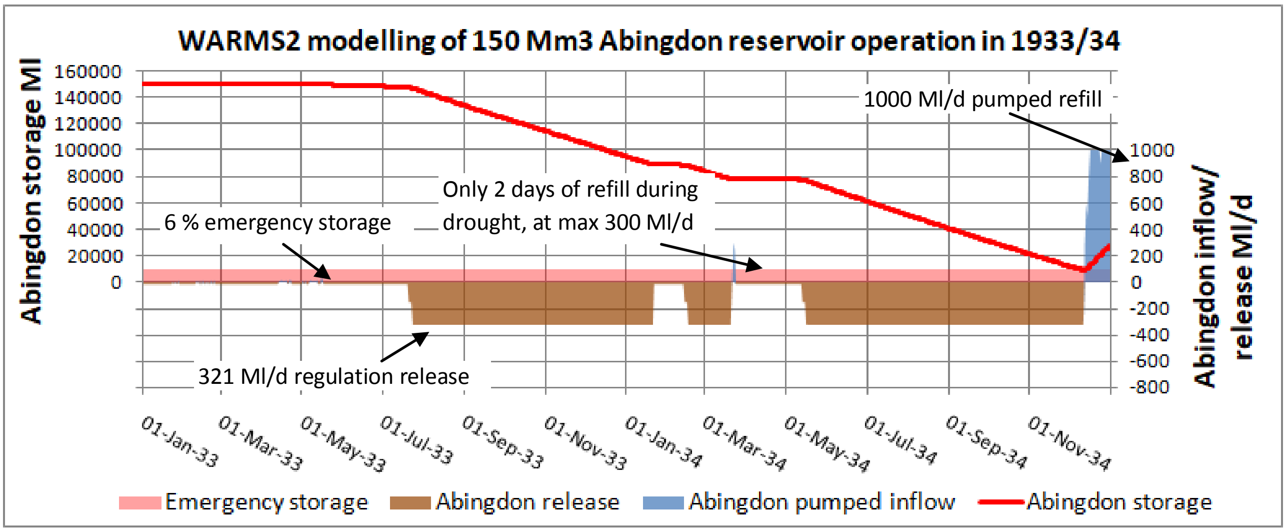
TW have become skilful at misdirecting the public sentiment around this project by such means as playing on the local population's fear of housing development. Historically, this has been the great enemy of floodplains and home owners in floodable areas still have a gut reaction to houses built on flood plain, even though modern building methods have resolved many previously associated issues. Developers would, in any case, face proper scrutiny by locally elected representatives. TW also capitalise on the way people visualise a reservoir – a valley or a lake, water lapping round the feet, wild life. People imagine water flowing into it from rivers, or rain filling it. By contrast, this reservoir would be 23m up in the air and pump-filled from the local river. Future amenities are proposed that may never happen and which anyway often only replace existing features: tranquillity, nature trails, nature reserve, boats, ponies, cycle tracks, education rooms for the young. The 'natural' quality of reservoir-sourced water is emphasised over, for example, chemicalised re-use-schemes and desalination-provided water. In reality, chemicals are used at every point of water processing and the reservoir water would require extensive treatment at various times, for example to deal with algal blooms or before reintroduction into the river system. The industrial nature of the proposal: water towers, lights, pumping stations, water treatment works, probable floating solar-panel arrays is deliberately down-played to make the project seem more attractive. Finally, the dWRMP significantly fails to properly describe the disruption and effect on local communities of 10 years of construction, 3 years of filling (assuming construction is followed by wet winters) and 15 years of tree and other vegetation and wildlife getting established.

8.2 Deployable output and emergency storage

Thames Water's assessment of deployable output

Thames Water have estimated the deployable output of the 150 Mm^3 Abingdon reservoir option to be 288 Ml/d for supplying London only (i.e. assuming no supply to SWOX zone or other water companies). WARMS2 model output has been supplied to GARD for the daily operation of Abingdon reservoir delivering a 288 Ml/d deployable output gain for London during the historic period 1920 to 2010. The critical drought which governs deployable output is 1933/34 and the modelled operation of the London and Abingdon reservoirs during this drought is shown on Figure 8-1 below:





Notes: 1. WARMS2 data from TW Excel file "GARD UTR investigation AR16 London DO 2593 Mld 2017-07 sent 260218"
2. Upper plot shows GARD modelling of the Abingdon option is almost identical to WARMS2 modelling

Figure 8-1: WARMS2 modelling of London and Abingdon reservoirs in 1933/34

Figure 8-1 illustrates the following aspects of operation of the London supply system when supported by regulation releases from Abingdon reservoir:

1. Deployable output of 288 Ml/d is determined by the demand that can be sustained without London reservoir storage dropping into the Level 4 emergency storage zone (24% of the 202,800 Ml live storage).
2. At the end of the drought Abingdon reservoir storage is also just above the 9000 Ml emergency storage (6% of the 150,000 Ml live storage).
3. There is virtually no refill of Abingdon reservoir from the start of the drought in July 1933 to the end of the drought in December 1934 – there is just 550 Ml total refill

during 2 days in March 1934 when there is sufficient flow in the River Thames at Culham to allow pumped refill of the reservoir. The absence of winter refill is invariably the case in the over-winter droughts that govern the deployable output of London's supplies, as discussed further in Section 9 of this response.

GARD's modelling confirms Thames Water's assessment of a 288 Ml/d yield gain for the Abingdon reservoir in the 1933/34 drought, if modelled using Thames Water's proposed 9000 Ml of emergency storage.

However, in GARD's opinion, the 9,000 Ml allowance for emergency storage is grossly inadequate, being only 6% of the Abingdon live storage of 150,000 Ml.

Emergency storage allowance and water quality

In GARD's response to the April 2017 Fine Screening Report, we pointed out that the average water depth in the reservoir, when full, would be 28 m, but it would reduce to only about 4m when the live storage is at the 6% emergency level. We suggested that the water quality in such a large shallow lake would probably be very poor and laden with algae. In our opinion, this would make the water unacceptable for discharge into the River Thames and re-abstraction for supply and we understand the Environment Agency share our concerns.

In the Reservoir Feasibility Study[218] Thames Water's response was as follows:

> *"The 28m water depth noted in the comment is the depth of the live storage (51m AOD to 79m AOD), there is a further 5m depth of dead storage in the central trench underneath (46m AOD to 51m AOD). We agree that a water depth of less than 5m would likely lead to water quality issues, hence the definition of such water as dead storage.*
>
> *Details of measures to control water quality have been provided within the Abingdon CDR ...*" [summarised as a combination of water jets, mixers and multi-level draw-off]

We are pleased that Thames Water agree that a water depth of less than 5m would lead to water quality problems, as we understand have already been experienced by Thames Water with shallow water depths in Farmoor reservoir.

However, Thames Water's response implies that the *"central trench"* (presumably referring to the fill borrow area which covers the whole base of the reservoir) provides a minimum depth of at least 5m, thereby avoiding poor water quality. This is misleading and factually incorrect as demonstrated by the following simple calculation:

- Reservoir area 675ha when full, c.550ha at embankment base
- Average depth at 15 Mm^3 dead storage, $15{,}000{,}000m^3 \div 5{,}500{,}000m^2$ = 2.7m
- Average depth at 6% live storage ($9Mm^3$, live storage) = (9+15) ÷ c.5.7 = 4.2m

[218] Reservoir Feasibility Report, Appendix V, July 2017, Thames Water Utilities Ltd

Thus, the dead storage only provides an average depth of 2.7m and, even at 6% live storage, the average water depth would be well below 5m. Water quality is likely to be poor even before the emergency storage level is reached. In our opinion, storage giving an average depth of less than 5m should be deemed dead storage. This would equate to about 27.5 Mm^3 out of the 165 Mm^3 gross storage (550ha at 5m depth = 27.5 Mm^3), ***giving 137.5 Mm^3 of live storage (as compared to 150 Mm^3 assumed by Thames Water).***

Allowance for emergency storage in other large reservoirs

As discussed, in later Section 9 on resilience, raw water storage reservoirs are usually designed to have an emergency storage allowance of 12-25% of live storage, for example:

- Clywedog reservoir 13%[219]
- Llyn Brianne reservoir 14%[220]
- Bristol Water (Chew, Blagdon) 18%[221]
- Welsh Dee system 20% (of gross storage)[222]
- TW London reservoirs 24%[223]
- TW Farmoor reservoir 33%[6]

Yorkshire Water's policy is for *"30 days supply at the reservoir or group yield, or 12.5 per cent of reservoir stocks, whichever is greater"*.[224]

Bearing in mind the poor winter refill of Abingdon reservoir and the vulnerability of the London supply system to longer duration droughts, when relying on releases from Abingdon reservoir, GARD proposes that the Abingdon reservoir emergency storage should be 15% of the 137.5 Mm^3 of live storage, i.e. 20.6 Mm^3 of emergency storage.

This would give 116.9 Mm^3 of live storage above the emergency level, as compared with 141 Mm^3 assumed by Thames Water in assessing the deployable output of the Abingdon reservoir option.

Reassessment of Abingdon reservoir deployable output with historic flows

We have used the GARD model to reassess the deployable output of the Abingdon reservoir, assuming allowances for dead and emergency storage as above:

	GARD proposal	TW proposal
Gross storage	165,000 Ml	165,000 Ml
Dead storage	27,500 Ml	15,000 Ml
Live storage	137,500 Ml	150,000 Ml
Emergency storage	20,600 Ml (15%)	9,000 Ml (6%)
Storage available in normal operation	116,900 Ml	141,000 Ml

219 South Staffs Water Draft Drought plan, Figure 2, August 2017.
220 DCWW Welsh Water Drought Plan, Figure 20, July 2015.
221 Bristol Water Draft Final Drought Plan, Figure 2, July 2017.
222 United Utilities Revised Draft Drought Plan, Figure A6.11, January 2017.
223 TW WARMS2 modelling of London and Farmoor systems, as provided to GARD.
224 Yorkshire Water Draft Drought Plan, Section 2.1, January 2018.

With these realistic assumptions for dead and emergency storage, the deployable output of the Abingdon reservoir drops from 288 Ml/d to 245 Ml/d, a 15% reduction. The modelled operation of the London and Abingdon reservoirs is shown in Figure 8-2:

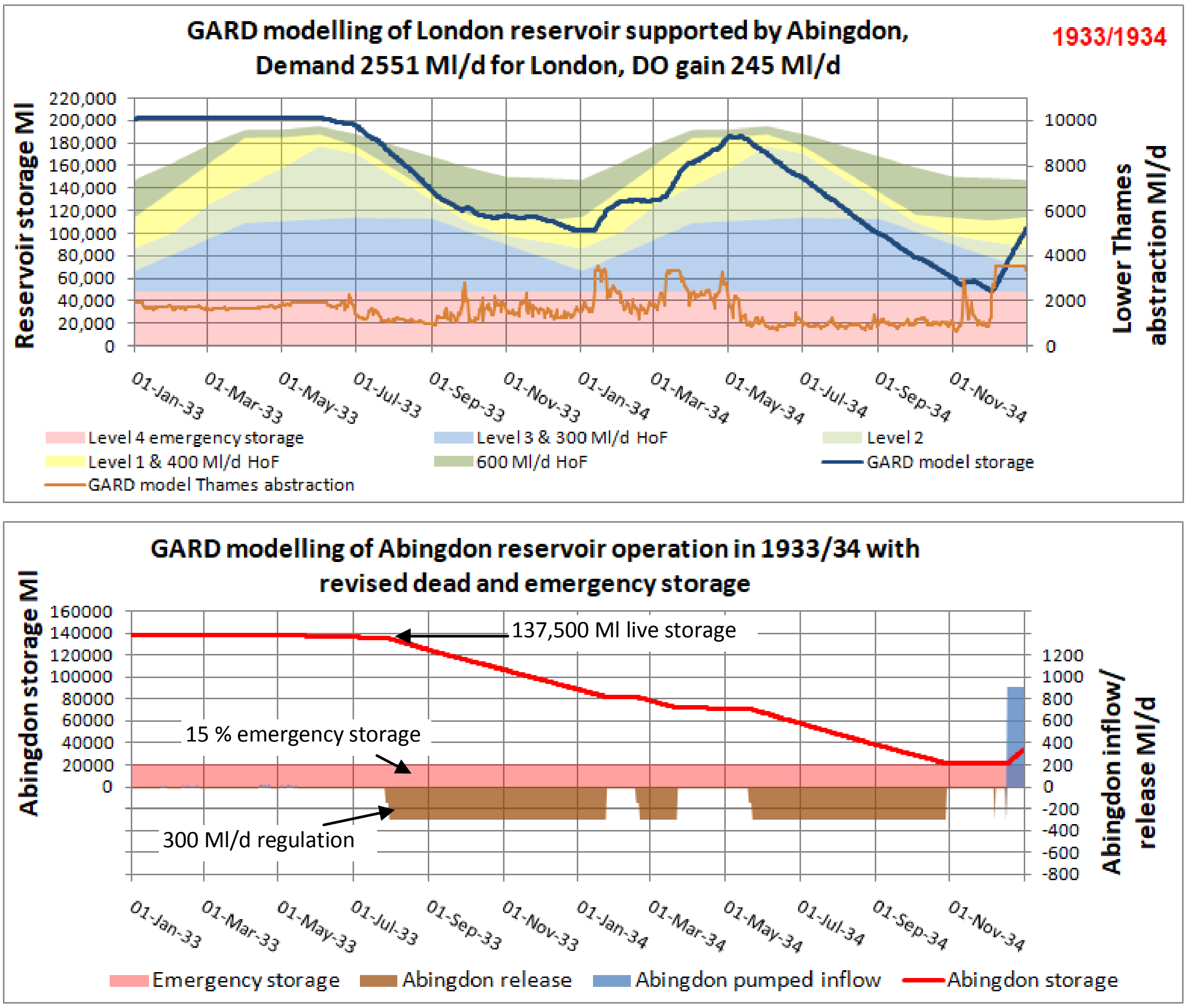


Figure 8-2: Operation of London and Abingdon reservoirs with revised dead and emergency storage – deployable output reduced to 245 Ml/d

In our opinion, the deployable output in the WRMP should be reduced to 245 Ml/d

8.3 Environmental Assessment

We have independently reviewed the reservoir SEA spreadsheet[225] and re-assessed the individual objective scores. Our comments and revised scores, for both benefits and adverse effects are attached separately ina modified version of the UTR 150 option spreadsheet presented in sub-appendix F to Appendix B. Most of our comments on, and criticisms of, the SEA are contained in the 'GARD Comments' column that we have added to the spreadsheet. Apart from the issuesalready discussed, a significant criticism is that while the majority of issues that have been marked highly on the adverse scale will definitely

[225] Abingdon A 150 contained in sub appendix F to Technical Appendix B: Strategic Environmental Assessment - Environmental Report

happen, most of the issues that have been marked positively on the benefits scale may or may not happen. For example, provision of a solar farm on the reservoir, possible provision of an equestrian centre and water-based amenities are all marked as beneficial, ignoring the fact that solar farms and an equestrian centre are already in the area and would have to be removed. There are already many water-based amenities nearby on the Thames and canal network. It seems as if the SEA has been conducted assuming that the reservoir is an independent entity in its own right, placed into a blank landscape, rather than within the context of the actual area that already exists. Additionally, the plan makes no firm commitments to providing these amenities, especially as TW would likely have to rely on third-parties to provide them. Awarding positive beneficial scores to aspects that may not be provided, or that already exist and would have to be removed before construction and then replaced, is unacceptable. The dWRMP in general, and the SEA in particular, make no mention of the fact that the proposed reservoir design, comprising bunded walls up to 30m in height would have unique access issues that would restrict some of the activities proposed.

Overall, we assess the adverse effects of the reservoir proposal to be more correctly scored as -8 overall and the benefits as either a 2 or a 3. This places the reservoir as the 84th worst option out of 85 options under consideration for adverse benefits and only better than 2 of the other 85 options in terms of benefits. Even by the original dWRMP scoring, it is hard to see how the reservoir option has not already been screened out. As discussed elsewhere, this is a classic example of the early screening out of other options leaving only one of the worst overall options available to be considered.

Issues around the weighting of each aspect/section of the Strategic Environmental Assessment, and divergence from Environmental Impact Assessment criteria.

Examining the permanent environmental effects for archaeology in the construction of the reservoir, compared with effects that are limited or transient in for example laying a pipe-line, we see that the SEA criteria lead to the stating of a single adverse 'perceptible effect' rather than the 'series of major impacts' that the EIA criteria would generate.[226] The SEA criteria attempt to belittle the significance of the heritage impacts to make the reservoir option have a less significant overall environmental impact, and hence score better in comparison with other options. As a strategic assessment of relative impact this is fundamentally unsound. From the terminology used throughout the dWRMP, TW seem to be either unaware or uncaring that the proposed construction of this massive reservoir would have very significant detrimental effects on the environment, including extensive obliteration of important landscapes rich in history, and the archaeology and heritage of this area. They appear "*to be treating what is a massive, hugely significant multi-period*

[226] See G. Lambrick's Report for the CPRE at the 2010 Public Inquiry: PROOF OF EVIDENCE ON HERITAGE AND ARCHAEOLOGY ISSUES: G H LAMBRICK MA (OXON), FSA MIFA ON BEHALF OF THE CAMPAIGN TO PROTECT RURAL ENGLAND (CPRE) SOUTH EAST.

archaeological landscape as if it were just any other single site."[227] On the basis of TW's own EIA criteria for judging the effects of the reservoir on the heritage, its construction would entail over 20 'major' effects of significant sites or features being destroyed together with many more significant losses from this massive development.[228]

Criticism of the SEA methodology with regard to the reservoir

The SEA methodology uses a subjective assessment of each objective where assigning a colour (shades of red for adverse, green for beneficial), establishes the overall viability of each option. The different topics have a varying number of objectives, thus affecting the overall colour assessment.

- By dividing Topic 1, 'Biodiversity, flora and fauna' into four objectives, TW achieve several smaller adverse effects rather than a cumulative moderate or major adverse.
- By dividing Topic 2 'Population and human health' into three objectives, TW achieve three major beneficials, repeating the provision of water as a major positive. This is, in effect, double accounting.
- Topics 7 'Archaeology and Cultural Heritage' and 8 'Landscape and Visual Amenity' have no sub-objectives, even though there are several that could be made. The effect on this occasion is that there is one major adverse for each of Topic 7 and 8, rather than several dark red major adverse assessments.

  Objective selection equivalent to those used in e.g. Topic 1, where three of the objectives began 'to conserve and enhance' different things could have been as follows:

  Topic 7, Archaeology and Cultural Heritage:
  Objective 1. To conserve and enhance the historic environment
  Objective 2. To conserve and enhance heritage assets and their settings
  Objective 3. To protect archaeologically important sites.

  This division into three objectives would generate three dark red major adverse panels with no mitigating green beneficials. This would have significantly altered the overall assessment of the adverse benefits of the scheme. Likewise, Topic 8, Landscape and Visual Amenity, which at the moment has one objective: 'To protect, enhance the quality of and improve access to designated and undesignated landscapes, townscapes and the countryside', could be better explored like this:

  Topic 8: Landscape and Visual Amenity:
  Objective 1. To protect and enhance the quality of designated and undesignated landscapes, townscapes and the countryside.

  Objective 2. To improve access to designated and undesignated landscapes, townscapes and the countryside.

[227] G Lambrick, recent communication.
[228] G Lambrick Report sic.

This again generates two rather than one dark red major adverse panels, with no mitigating dark green beneficials which would, again change the position of the scheme in the adverse benefits ranking table.

While the assessment method has been consulted on as detailed in the SEA Scoping Report, the questions chosen and objectives within topics are particular to TW's plan. These differ in detail from the questions asked in the SEA of other water companies. The lack of sub-division given to the heritage and landscape questions leads to a skewing of the assessment results, a major weakness in the chosen system. It would work better if each topic was assessed to a single colour result for adverse / beneficial, before combining the results into one column, thus enabling each section to carry the same weight. For the Environmental Assessment to represent a serious view of the environmental impact, it must take the cultural and heritage aspects as seriously as other hydrological and scientific aspects. The result in the TW SEA for the reservoir has been to inflate the positive aspects and reduce the impact of the negatives.

The SEA methodology was put out to consultation, in 2016, and the objectives chosen were agreed.[229]In the Responses to the SEA Scoping Report, concerning Section 6.1, where it states that *"options which are found by the SEA to have unacceptable adverse effects will be rejected from the options pool and will not reach the constrained list of options,"* the Environment Agency requested clarification on the definition of 'unacceptable'. TW replied that 'unacceptable' adverse effects are those where the effects are difficult or unlikely to be mitigatable. The impact of the proposed reservoir on the archaeology and landscape is shown in the assessment to be just such an 'unacceptable' adverse effect[230], indeed to be the *"extensive obliteration of important landscapes rich in history"*.[231]

Moreover, a notable fact, which has come to light whilst preparing this response is that, in the scoping document put out for consultation, the topic 7 was indeed split into ***two*** objectives (see page 101 of the Scoping Report). These did not correspond exactly to our definitions above, but nevertheless the intent was clear. There were no comments from consultees on these objectives, yet one of them has been removed from the SEA as carried out in the dWRMP. This removes a clear 'red' rating for the Reservoir, and is a highly suspicious finding. ***TW should account for the omission of this SEA objective.***

Finally, we contend that at that early stage, pre-population of the spreadsheet, it would have been impossible to fully appreciate the eventual skewing effect that such choices would have. TW should rework the SEA, giving equal weight to each topic or consult further on an agreed relative weighting for each topic.

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[229]https://corporate.thameswater.co.uk/-/media/Site-Content/Corporate/Media/SEA-Scoping-Report.pdf

[230] See para 11.10 at https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/Water-resources/Document-library/Consultation-on-the-SEA/TW-WRMP19-SEA-Scoping-Responses-Final-June17.pdf

[231] G Lambrick Report sic.

8.4 Archaeology and Cultural Heritage

Conservation of historic environment: houses and Causeway.

Both Steventon and Hanney are historic villages with large conservation areas and many listed buildings, noted by TW. In particular the Causeway sets Steventon apart, crowded with listed buildings close to the railway line. The intention to use the railway for transportation of aggregate offers a significant adverse effect for these historic structures, with the increased vibration and emissions. This is however scored by TW as a benefit (Objective 3.1 the use of existing infrastructure), whereas in fact it is simply a mitigation action to reduce HGV movements and their associated negative score. There are no circumstances under which increased rail traffic could be considered a benefit to the local community.

Conservation of historic environment: watercourses, and field systems & boundaries.

The removal of ancient watercourses is an important issue: in Objective 4.1, TW state that the scheme will involve the removal and rerouting of several small watercourses, including the larger East Hanney and West Hanney Ditches and removal of the remnants of the Wilts and Berks Canal, including the remains of three brick-built locks. The two ditches are historic and ancient, part of the geography of this area since it was drained to grow crops. The Canal is more recently historic, including the remains of three brick-built locks.

Field systems and boundaries*: "This area represents a pristine subsoil landscape of how settlement and farming has developed since the prehistoric period with upstanding remains of ancient (Saxon) parish boundaries still extant in the landscape (hedges). Visible landscape elements include: a middle Bronze Age field system; 11 middle Iron Age complexes include four sub-rectangular settlement enclosures; 12 Roman farming settlements from the 1st to 4th/5th centuries AD and extensive Romano-British complexes, over 5 hectares in size."*[232]
The proposed reservoir site has significance as a water-heavy area where the undisturbed sub-soil contains the traces of continuous settlement and cultivation: *"in relation to unknown assets, there are a number of floodplains within the TW supply region which are either known or suspected to be of high importance for waterlogged archaeology. Such evidence includes both material (wooden artefacts and structures such as trackways) and evidence of past environmental change from the deposits themselves."*[233]

Conservation and enhancement of heritage assets and their settings.

The proposed reservoir area destroys about six square miles of the Clay Vale, turning it into a range of artificial hills holding water eighty feet up in the air. *The openness of the Clay Vale of the White Horse is key to the setting of the North Wessex Downs AONB, providing*

[232] Excerpt from G Lambrick, Report sic.
[233]TW Utilities Ltd Strategic Environmental Assessment of Water Resources Management Plan 2019 Scoping Report July 2016 Section 4.8 Archaeology and Cultural Heritage.

separation from the Corallian (Oxford to Faringdon) Ridge to the north and, creating locally distinctive landscape character. The importance of openness of the Vale, and the resulting long views is noted in VoWHDC supplementary landscape policy.[234] This Clay Vale is the setting of a major heritage asset, White Horse Hill, along with Wayland's Smithy and the whole Ridgeway. While the Vale of the White Horse is not itself an AONB or a SSSI, the area is the historic environment which gives context to the actual heritage monuments. North Wessex Downs AONB have already registered their view re the reservoir in their response to the VWHDC local plan.

In context, the Downs naturally rise up from the flat wetlands of the Clay Vale. This area has changed over thousands of years from sea to swamp to marsh to the wetland of today."*The cumulative significance of the historical remains in the area is much greater than their individual importance, and is of undoubted major importance in terms of the evolution of the landscape in the Thames Valley and its influence on the character of the environment and an area's sense of place*".[235]The evolution of the landscape is properly understood as part of the setting of several Conservation Areas and listed buildings for which the area was part-and-parcel of their parishes and history as farming communities. The villages were known as 'islands' (e.g. Hen Island = Hanney), there are historic raised paths (causeways) and houses designed to 'float' instead of having foundations. This is the character of the area; to wipe out this character is cultural vandalism.

Protection of archaeologically important sites.

Like TW, we are aware that there are extensive archaeological remains in the area proposed for the reservoir and that the construction of a reservoir will completely destroy them. In the Environmental Assessment,[236]Archaeology and Cultural Heritage is one of two categories where there is major, dark red, adverse effect and **no** alleviating benefit. Publications on the archaeology include Hearne's brief account commissioned by TW,[237] and researches before the Hanney Road solar farm was established.[238]Apart from a brief statement in the EIA Scoping Report[239] these studies have not been pulled together into an overall detailed statement of the archaeology and landscape history of the area.

Most of the material relates to complete landscapes of farms and settlements and their associated fields, copses and other land uses, many covering several hectares in as interconnected a manner as the present-day landscape.[240]This area has running across it the main route taken between Wantage and Abingdon in Roman and Saxon times. As well as

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[234] M. Habermehl Landscape consultant BA DipLA MA-UD CMLI, private communication, April 2018.
[235] The Setting of Heritage Assets (2nd Edition) published Dec 2017 Historic England.
[236] Appendix F to technical Appendix B, category 7.
[237] Hearne, C M, 2000 Archaeological evaluation in the Vale of the White Horse, near Abingdon, 1992–99, *Oxoniensia* 65, 7–12.
[238] Landmead Solar Farm. East Hanney. Oxfordshire. Archaeological Watching Brief. February 2015 for Belectric. Cotswold Archaeology A Project: 4562. CA Report: 14566.
[239] Cascade Consulting and Land Use Consultants 2008.
[240] Lambrick Report, sic.

the excavated Roman temple and villa near Marcham which are close by the reservoir area, there are extensive Bronze Age, Iron Age, Roman and Anglo Saxon remains and unexcavated settlements towards Hanney and Garford. Archaeological remains buried beneath the bunds will become inaccessible and may be damaged through the weight and pressure of the solid bunds[241]. All archaeological traces beneath the reservoir itself will be obliterated since the area will be dug out to a depth of more than ten metres. This is unacceptable. The archaeological attention needed to ensure that these irreplaceable heritage assets are not lost far exceeds the 'watching brief' proposed by TW; for comparison, consider the massive excavation for the expanded A14 road between Cambridge and Huntingdon,[242] where there have been 537 trenches, 800 hectares of archaeology, more than 200 archaeologists working on the scheme, more than 25 settlements uncovered, including: Iron Age, Roman, Saxon and Medieval villages.

8.5 Landscape and visual amenity

General Note.

Topic 8, Landscape and Visual Amenity, deals with the landscape itself rather than as a setting for monuments et al. There is overlap with Topic 7, where conservation and enhancement of 'heritage assets and their settings' are in question.

The clay wetland typical landscape

The landscape where the proposed reservoir is set, is typical of clay wetland with definite characteristics. The area of the proposed reservoir is described as 'not within a designated landscape area'. However, this landscape is as particular as the Somerset levels - land criss-crossed by water-courses lined with willows and rushes, while ditches run in parallel lines through the villages, characterising the place. As stated in SEA sections 5.1 (geomorphology) and 7.1 (setting for heritage assets), this area, the Clay Vale, is contextually significant for the White Horse Hill and is one of the oldest continuously settled areas in England. The reservoir would completely alter the landscape and would remove part of the geomorphic context of the Wessex Downs AONB.

National planning policies in England refer to the importance of landscape character and local character[243], while the TW SEA Scoping Report defines landscape character as *"a distinct, recognisable and consistent pattern of elements in the landscape that makes one*

[241] See para 11.10 at https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/Water-resources/Document-library/Consultation-on-the-SEA/TW-WRMP19-SEA-Scoping-Responses-Final-June17.pdf

[242] https://molaheadland.com/project/a14-cambridge-to-huntingdon-improvement-scheme/

[243] The National Planning Policy Framework can be found at https://www.gov.uk/government/publications/national-planning-policy-framework--2

landscape different from another, rather than better or worse"[244]The area designated for the reservoir has strong landscape character that the artificial hill and high-level water installation will destroy.

The A34 and positioning of industrial development

The reservoir plan crosses the A34 'dividing line', bringing industry to a place of tranquillity.**"***There is a 'dividing line' along the A34 corridor where landscape scale development (power station, JET Culham, mineral workings, landfill etc.), have occurred to the east, whilst the Vale landscape to the west of the A34 has remained relatively intact. Notwithstanding the general openness of the Vale, when viewed from the key viewpoints (White Horse Hill and others), large scale development is particularly apparent within the Vale wide panorama. The current panorama scans from the Honda factory at Swindon, to the JET Culham laboratory, and including the wind farm at Shrivenham."*[245]

Mitigation of landscape change.

GARD is concerned that the severe effects of construction on this scale cannot be mitigated. The reservoir would form a further major element in the view causing damaging *'cumulative effects'*, in addition to its own specific landscape/visual impact. From within the Vale, the huge proposed landform would dramatically change the open landscape character and close long views. TW state that sensitive landscaping would "aid integration of the reservoir into the landscape and the setting of the North Wessex Downs AONB."[246]The replacement of the water-course rich agricultural Clay Vale with six square miles of bunded reservoir, acknowledging that "the scheme would be a prominent new feature in the landscape with three towers",[247] is not a landscape shift that can be masked. The reservoir and towers, when completed, would be the tallest structures in the Vale of the White Horse with inconceivable visual effect. The towers are likely to be highly visible engineered structures contributing to visual impacts. Will they be lit at night (as per the Didcot towers) and how will lighting components in general impact upon rural views and character?[248]

The character of the area as Clay Vale giving context to the White Horse will be changed and lost for ever. We agree and confirm North Wessex AONB's registered concerns about the proposal and its effects on the setting of the AONB. We concur with Mike Habermehl that *"the elevated reservoir will be an exposed landform and, with highly engineered function, is unlikely to be seen as a tranquil setting by eventual recreational visitors. With a construction period approaching 10 years and an (optimistic) further 15 years to planting maturity, TW*

[244]TWSEA Scoping Report: 4.9.1 Baseline (Landscape) Thames River Basin: The landscape character network104; also The Landscape Institute: Landscape Character Assessment - Technical Information Note 08/2015 February 2015: Local Landscape Character Assessment
[245] M. Habermehl Landscape consultant BA DipLA MA-UD CMLI, private communication, April 2018
[246] dWRMP19, Appendix B: Strategic environmental assessment – environmental report, p111.
[247] dWRMP19, Sub Appendix F to Appendix B, Abingdon reservoir 150 option.
[248] M. Habermehl sic

are recognising generational landscape and visual impacts. The form, scale and function of the reservoir proposals are entirely alien to the Vale and whilst landscape integration measures can provide limited mitigation, the suggestion of long-term moderate landscape benefit over current baseline conditions is not credible."[249]

Damaging effects for Sensitive Receptors

There will be damaging effects for many groups of people (Sensitive Receptors).The recreational users of the Thames Path National Trail and river boat users will be affected by the construction and operational effects of the proposed Culham inlet and discharge pipelines. In addition, there are effects on highly sensitive visual receptors on the Thames Path and on paths and viewpoints within the setting of the North Wessex Downs. In addition, the Hanney Road is part of the Oxfordshire Cycle Route and is frequented by large numbers of recreational cyclists enjoying the countryside -these will also be categorised as sensitive receptors.[250]

Opportunities for access and amenity

The suggestion in the TW SEA of new opportunities for improved access and amenities is misleading. This suggests a lack of access and amenity currently, which is not the case. There are paths, the old canal way and bridle ways. There are already grasslands, mature trees, hedgerows, watercourses with reeds, bulrushes and willows. There is already a stables/riding school and potential for regenerating the canal. TW remarks on the 'tranquillity' that is to be found in parts of this area, characterising it thus: "*'Tranquillity' can be defined as the quality of calm that is experienced by people in places full of the sights and sounds of nature"*[251]. The landscape under examination has a definite character and quality of its own. Because the bunded walls are so high, they will necessarily be mostly steep, severely limiting access and amenity and walking space. The area for these that already exists within the proposed reservoir footprint will be lost forever.

TW has put considerable emphasis on the benefits which a reservoir could provide for recreational activities such as rowing, sailing and fishing. As this is a structure with the water surface perched 23 metres above the surrounding landscape it does not conform to normal scenic settings or weather conditions. Even if some scope is provided for recreation there will certainly be photovoltaic generating panels floating on a considerable proportion of the surface which would need secure protection, but no mention is made of these in the design. Some of the area would also be unusable due to chemical and aeration practices used to deal with algae and, should the reservoir be used it will not be full, leading to significant mud margins around the waterline. Nor is there consideration of the extra local infrastructure needed to access recreation. Against improved habitat for some birds and

[249] M. Habermehl sic
[250] M. Habermehl sic
[251] TW SEA Scoping Report

water creatures the loss of habitat for others over 4 square miles of good quality agricultural land is not mentioned as an adverse effect. There is clear bias in the presentation of the effects of the reservoir would have locally, which completely undermines the TW public surveys.

General access during construction

Construction access is generally problematic and this needs to be assessed and costed realistically. In the 2010 plan, road access to the site was proposed through Marcham. The road infrastructure there is currently inadequate to cope with such a project and would have to be improved before the start of reservoir construction. Materials brought in by rail would use the Steventon Storage depot sidings but with electrification of the main Paddington to Bristol line and the still single tracks in each direction of that section of the line a lot of additional railway work would be needed. This should all be included in the project costings in addition to the diversion of the Hanney to Steventon road. Without sight of any current cost breakdown (despite repeated requests to TW), we cannot be confident that these are included.

8.6 Flooding impacts

General Note.

Topic 9.3 of the SEA, Flooding Impacts, deals with the water-table, the flood-plain and consequent increased flood-risk issues arising from the proposed reservoir.

Introduction

The dWRMP proposes building the maximum size possible Abingdon reservoir, as part of the 'Preferred Plan', although some variants at 125 Mm^3 are included in plan variants as part of the optimisation. Both these proposals raise several issues and concerns regarding the local area flood plain and potentially increased flooding risk to local towns and villages. The document is very light on the detail of what studies TW has undertaken, and plans to undertake in the future, to determine the effect of such a construction on local area flooding. The proposed reservoir overlays a significant proportion of floodplain, significantly reducing the area available for water to collect clear of populated areas. As a matter of urgency, TW should create an additional appendix to the dWRMP, giving full details of all aspects relating to the reservoir.

- **Responsibility.** While it is clear who has responsibility for flooding from existing rivers, reservoirs, groundwater, ordinary water courses and sewers, it is not clear who is the lead for future reservoirs during any planning stages. The dWRMP must clearly state what planning application process would be followed should the reservoir be included in the WRMP post consultation. A recent enquiry about

Flood Risk Assessment to the Environment Agency has drawn the following response: *''The Local Planning Authority would make the decision on whether the proposal for a reservoir would require planning permission. If planning permission is required, the Environment Agency would be consulted in their role as a statutory consultee".*

- **Planning application.** This would need to be supported by a full flood risk assessment for the reservoir and any ancillary works, which would be produced by the applicant (TW). In conversation with a member of the Vale of the White Horse District Council Planning Policy Team, it emerged that there was expectation that the reservoir, if in the approved Plan, would 'be a Significant National Infrastructure Project'. If this reservoir project is even to be considered as a National Infrastructure Project, its viability, cost, resilience and need must first be established beyond all doubt and the detailed design must be approved by the Environment Agency and independently checked for its integrity by dam experts and geologists. Even higher-than-normal seepage through the base could have devastating and incurable effects on the surrounding, overshadowed population. The protocol for Flood Risk Assessment is a cause for concern: this states that the Flood Risk Assessment is carried out after the WRMP has been adopted rather than as part of the initial scrutiny of the dWRMP.[252]

- **Preventing Risk.** The Environment Agency's Flood Risk Management Plan[253] describes measure to be taken in the Thames river basin to prevent the risk of flooding. These include ensuring that new housing developments (and by implication, any development) take place in the areas with lowest risk of flooding, maintaining existing flood defences and ensuring that a programme of mapping and modelling is undertaken to ensure that flood risk information remains up to date and fit for purpose. If the proposal to build the reservoir remains, the final WRMP must be updated to show how TW has engaged with the Environment Agency to ensure that they comply with these measures. Currently, the plan for the reservoir incorporates cut-off channels at the base of the bund walls but these will not markedly alter the risk to nearby villages. When repeatedly asked about flooding risk at 'Drop In' events in the area local to the reservoir site, TW staff have either deflected the question, saying detailed plans are not available, or, contrarily, stated that there is enough land in the reservoir site to divert the flood zone water. There has also been talk of 'upper and lower-shelf' compensation, even though the water table in the area is well-known to be high, even outside flood zone designations. However, it is not broadcast by TW, but the statement that adequate area exists within the reservoir site for flood water diversion ***does***

[252] D Bedlington, Area Flood & Coastal Risk Manager (Thames) david.bedlington@environment-agency.gov.uk
[253] LIT 10228 Environment Agency Flood Risk Management Plan March 2016, Page 6.

not apply to the 125 Mm³ and 150Mm³ versions of the project. These are, in fact, rated 'Red' against the criterion 'Floodplain encroachment (loss of floodplain/need for compensation storage'[254] in the Reservoir Feasibility Report.[255]There is no overall flood risk analysis for the project as the Environment Agency has stated that this will not be looked at closely until a planning application is submitted. This should surely be a precursor to any serious consideration of a major infrastructure project which affects such a large area of flood plain and the south Abingdon flood relief scheme. David Bedlington (Environment Agency) has stated *"The Environment Agency is very aware of the flood risk in local communities, including Steventon, the Hanneys and Abingdon and would want to ensure this is properly considered as part of any future flood risk assessment,"*[256]making clear his view that assessment as part of the planning application process will be an adequate safeguard. We have grave misgivings about this.

- **The Oxfordshire County Council Local Flood Risk Management Strategy[257].** Under the Flood and Water Management Act (2010), Oxfordshire County Council became the Lead Local Flood Authority. The management strategy notes that Oxfordshire County Council, District Councils, The Environment Agency and TW have a duty to cooperate. The WRMP should state what specific activities TW intends to undertake to determine the potential effect of the reservoir on the Oxfordshire County Council Flood Risk Management Strategy.

- **The Vale Catchment.** The Flood Risk Management Plan, Part B[258] describes its key measures in preventing risk as being to *"encourage appropriate development….to safeguard natural floodplains to reduce the consequences of flooding"*, to *"steer development to the areas with the least risk of flooding"* and *"to enhance and expand the floodplain".* The reservoir is incompatible with all of these measures since the weight and volume of water will distort underlying geology and affect water levels. We believe that the Strategic Environmental Analysis (SEA) of the reservoir option, as presented in the dWRMP, markedly under-represents the potential for increasing the risk of flooding by removing a major part of the flood plain. Surface water caused by run-off from the mounded embankments and seep-age from the base of the reservoir would also contribute to flood risk, while the height of the water table in the area leaves little extra capacity. There is about

[254] This criterion denotes the Extent of impact on all flood risks in line with NPPF and national guidance for e.g. flood compensation storage.
[255]dWRMP19, Reservoir Feasibility Report, Appendix T, pages 418 and 425, (dated June 2017, but re-released February 2018).
[256]Email D Bedlington – D Bennett received 20 April 2018.
[257] Oxfordshire County Council Local Flood Risk Management Strategy, available at https://www.oxfordshirefloodtoolkit.com/wp-ontent/uploads/2016/04/OxfordshireFloodRiskManagementStrategy.pdf, accessed 17 Mar 18
[258] Thames River Basin District Flood Risk Management Plan 2015-2021, Part B – sub areas in the Thames river basin district

80 hectares of ‘upper- and lower- shelf’ flood compensation planned, but it is not clear how that works in an area where any hole dug immediately fills up with water. The SEA should be re-worked to more accurately reflect the major environmental risks noted above.

- **Housing development.** Since the 2009 reservoir proposal the number of houses in the four surrounding villages has greatly increased and continues to do so. Many of the new estates are on the front line, facing the proposed reservoir area. None of the purchasers canvassed by GARD have known about the renewed proposal for a reservoir; they knew that at the Public Inquiry in 2010 the reservoir plan was rejected as being among other things, “not fit for purpose” and they assumed that this dismissal of the plan would have lasting effect. The increased number of houses affects both traffic and the implications of flooding.

- **Geological Risk.** We were disappointed to find that the issue of surface seams of gravel and greensand across the proposed reservoir site were not explored in the Abingdon reservoir SEA and option selection process. Similar such conditions were quoted as rejection criteria for several other sites, but not mentioned in this case. We understand from TW briefings that only limited surveys have been conducted so far and none since the Public Enquiry in 2010/2011. Open studies must be conducted to determine the total extent and nature of these gravel and sand areas. In particular, the potential for a breach of the artificial clay layer to feed water into a gravel ‘lens’ that resurfaces at Steventon must be thoroughly examined and understood.

- **Secure design.** To our knowledge no reservoir of this scale, with the total perimeter consisting of 10 km of 25m high bund walls, has been constructed elsewhere, and contrary to statements by TW they have little experience in that field. With an excavation depth of 10m to provide the bund wall material there is heavy reliance on the integrity of the clay sub-strata which includes a significant seam of greensand stretching across the site, with the clay itself containing numerous porous gravel lenses. No mention is made of the metal munitions survey undertaken at the Hanney end of the site. Many design questions remain, which TW are unable to answer at the public displays. Sealing the reservoir securely is vital with a 25m hydrostatic head of water with bunds towering over the surrounding villages, so leakage and seepage must be prevented completely.

8.7 Cost estimates

The issue of being unable to access an appropriate level of cost detail has already been mentioned several times. What limited cost data is available is commented on in Section 1.2 of this document

9. Resilience to severe droughts

Key Points

- Thames Water's resilience design criteria have failed to draw the distinction between the return period of droughts to determine deployable output and the criteria for resilience to droughts worse than the deployable output design drought.
- Thames Water should not have slavishly adopted a 1 in 200 year design standard for deployable output contrary to the surveyed wishes of their customers and without a proper risk assessment.
- The adoption of the 1 in 200 year deployable output design standard, commits Thames Water's customers to pay for about 150 Ml/d of replacement sources at an NPV cost of roughly £1 billion (or an equivalent amount of Demand Management).
- In determining the resilience standard for London, Thames Water should take into account the allowance for droughts worse than historic that is already provided by the generous allowance for emergency storage in the London reservoirs and in headroom.
- The risk assessment needed for setting the resilience standard should take account of the probability of occurrence of droughts of different durations and intensities, and the availability of short-term emergency sources.
- There should be a focus on long duration droughts that would affect the output of the London Aquifer Recharge schemes and the West Berks Groundwater scheme
- ***Abingdon reservoir has only 30 days of resilience in droughts more severe than the deployable output design standard; after 30 days the reservoir would be empty.***
- The deployable outputs of Severn-Thames transfer options have been shown by Atkins analysis to be resilient to droughts worse than historic.
- In the event of a drought more severe than the deployable output design drought, the Severn-Thames transfer could always supply up to the capacity of the transfer via an Emergency Drought order, adding greatly to resilience of London's supplies.
- The Emergency Drought Order for such a use of the Severn-Thames transfer would be justifiable on grounds of over-riding public interest, if the alternative was standpipes and rota supply cuts in London.
- The Teddington DRA, effluent reuse and desalination options would be fully resilient in droughts more severe than the DO design standard, being able to continue supplying indefinitely.
- ***Thames Water's scoring of the severe drought resilience of the various option types has been grossly biased in favour of the Abingdon reservoir.***

9.1 Resilience design criteria

Frequency of Level 4 restrictions

Thames Water's approach to the drought resilience design criteria appears to GARD to be confused and inappropriate. There is no distinction made between:

- The design standard for deployable output (currently worst historic drought)
- The ability of the supply system to cope in the event of a drought worse than the drought for which the deployable output has been determined.

Thames Water have conflated these two very different criteria. They are proposing to adopt a 1 in 200 year design standard for assessment of deployable output, but have given no consideration to the effectiveness of the new supply source in the event of a drought worse than the deployable output design standard.

The regulators' guidance on the resilience design criteria is not clear, but it is not prescriptive either, for example:

- Environment Agency Water Resource Planning Guideline[259]: *"It is expected that when planning for historic drought within your baseline, you should not include the benefit of drought permits or orders. When planning for more extreme events (once an event reaches 1 in 200 years severity) you may decide to include the benefits of drought permits and orders in your baseline supply forecasts."*

- Ofwat Price Review Methodology[260]:*"the common performance commitments particularly focus on forward-looking resilience: the risk of severe water supply restrictions in a (1-in-200 year) drought"*

- And on page 83*:"Where appropriate, companies should consider a reduction in the long-term risk to water supply resilience from drought and other factors."*

In paragraph 0.15 of the dWRMP, Thames Water appear to have interpreted these guidelines as a rigid design standard, raising the Level 4 design criteria from historic worst drought (1933/34 and nominally 1 in 125 years) to 1 in 200 years.

- *"The WRPG set out Government and regulators' priorities for levels of service, with an aspiration to achieve a 1 in 200 annual probability of having to implement Level 4 restrictions"*

The Table 10-10 of the dWRMP shows results of a survey of customer support for a raised Level 4 design standard (with the survey probably phrased so that customers would think they were being asked about the deployable output design standard):

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[259]'Final Water Resource Planning Guideline'. Environment Agency. May 2016.
[260] 'Our Final Methodology for the 2019 Price Review'. Ofwat. December 2017.

Level 4 restriction	1:100	1:200	1:300	1:500
Preference %	88.3	10.4	0.8	0.5
Standby capacity (Ml/d)	0	140	187	280

Table 9-1: Results of customer preference for Level 4 restriction frequency

From this it appears that customers showed little support for reducing the frequency of Level 4 restrictions to 1 in 200 years.

In paragraph 0.63 of the dWRMP, Thames Water have stated the effect of adoption of different Level 4 design standards on loss of deployable output for London:

> *"1 in 200 year drought would reduce DO by up to 150 Ml/d and a 1 in 500 year drought would reduce DO by up to 300 Ml/d."*

Therefore, Thames Water have chosen to adopt a resilience design standard against the wishes of the great majority of their customers that will result in a need for 150 Ml/d of replacement sources or 150 Ml/d of demand savings[261]. The NPV cost of this decision is in the region £1 billion (roughly 60% of the cost of the Teddington DRA scheme in Table WRP 5 for the London zone). This will have to be paid for my customers against their surveyed wishes.

Provision of emergency storage and headroom

In previous supposedly less technologically "sophisticated" eras, water supplies in the UK were generally designed to cope with the worst drought on record and resilience to droughts worse than historic was made pragmatically through a combination of:

- Allowance for emergency storage in reservoirs, typically 20-25% of live storage
- Headroom, typically 5% of forecast demand
- A further safety factor in the additional headroom that exists because actual demands have in most years not yet risen to those that the supply is designed for.

Design criteria of this sort would no doubt have been the case as London's supplies were developed over the last century, including the development of the London reservoirs.

The legacy of this approach is in the current allowance of 24% of emergency storage in the London reservoirs (48.5 Mm^3 out of a live storage of 203 Mm^3) and a headroom allowance of about 4.3% for London in the current dWRMP (90 Ml/d target headroom with a base demand of about 2100 Ml/d).

[261] In Section 3, we estimated that 65Ml/d would be achieved by meeting the Ofwat target of 15% by 2020,a further potential 80 Ml/d by 2045 from reasonable pcc targets and 20 Ml/d from 80% meter penetration. This would achieve savings of approximately 165 Ml/d. We believe this would cost less than £1 billion NPV and in any case are likely to be activities required to satisfy Ofwat.

In previous eras, these allowances would have been considered to be appropriate as a buffer against a drought occurring that is worse than historic. Thames Water are now proposing to incur £1 billion of NPV costs to meet a new deployable output design standard against the wishes of their customers. Since the Ofwat and Environment Agency guidelines for this are not prescriptive, a discussion on how to achieve a compromise that aimed to protect customers to a sensible level, while maximising benefit versus spend, should be held to ensure that customers wishes are considered and customer costs minimised.

The need for consideration of consequences and proper risk assessment

In GARD's opinion, a shift away from the historic worst drought as the deployable output design standard would only be justified by a proper risk assessment that examines how London's water supplies would perform in droughts of different intensity and duration, including droughts substantially more severe than the deployable output design standard, with proper consideration of the economic consequences of supply restrictions. The risk assessment should take account of:

- The probability of occurrence of droughts of different intensity and duration.
- The performance of different available types of supply in different types of drought, for example:
    - How long would the reservoir emergency storage last and would it all be usable?
    - How long would the London aquifer recharge schemes last before they ran out of water?
    - How long would the West Berkshire Groundwater Scheme last before groundwater levels dropped too low?
- The effectiveness of emergency provisions including the adequacy of emergency storage, the effectiveness and impact of emergency drought orders and the feasibility and cost of emergency supplies that might include temporary desalination and water tankering.
- The economic consequences of emergency supply restrictions, particularly in London where the Environment Agency has estimated an economic cost of Level 4 restrictions as £7-10 billion per month[262].

In GARD's opinion, Thames Water have failed to carry out the risk assessment needed to justify a change from the tried and tested criteria of worst historic drought for setting deployable output, with 20-25% emergency storage and 5% headroom as the design criteria for drought resilience.

In particular, we consider that Thames Water have failed to consider to the long duration droughts in which London's supplies would appear particularly vulnerable.

[262] 'Water supply and resilience and infrastructure', page 3. Environment Agency advice to Defra. December 2015.

9.2 Abingdon reservoir

Thames Water's dWRMP claims that the Abingdon reservoir would improve the drought resilience of London's supplies. The Fine Screening Report allocates a high resilience rating to the Abingdon reservoir, scoring it the same as desalination and reuse options[263].In GARD's opinion, this rating is unjustified because of the scheme's poor resilience to droughts of longer duration than 17 months (from the start of draw-down of the London reservoirs to the time of minimum reservoir storage).

Since GARD's response to the Fine Screening Report in October 2016, we have repeatedly pointed out that the yield of Abingdon reservoir would be drastically reduced in droughts of longer duration than 17 months. A GARD report on the reservoir resilience was published in August 2017, and distributed to Thames Water, the Environment Agency, Ofwat and DEFRA.[264] Since then there have been a succession of reports and papers by GARD and Thames Water's consultants, Atkins, and a technical stakeholder meeting on 29th January specifically to discuss the drought resilience of Abingdon reservoir, particularly in droughts of longer duration than 17 months. These reports and papers are on record and not detailed here.

Thames Water's web-site shows the presentations from the meeting on 29th January, draft meeting notes and a revised proposal from Atkins for further investigation' However, GARD has written to Thames Water[265]requesting substantial changes to the meeting notes (which we consider inaccurate and biased), disagreeing with the revised Atkins methodology for further work and requesting a small technical meeting which would allow a proper discussion of the matter. There has been no reply from Thames Water.

There is some common ground between GARD and Thames Water's positions:

1. Although we agree with Thames Water's conclusion that the Abingdon reservoir yield of about 285 Ml/d, assessed for the droughts of the 20th Century, is resilient against more intense droughts (with even lower river flows), ***this only applies if their duration is less than 18 months.***

2. Thames Water agrees that the yield of Abingdon reservoir is ***not*** resilient to droughts of longer duration than those of the 20th Century and the yield can sometimes drop to only about 100 Ml/d. However, they have dismissed the risks as being extremely small.

Therefore, the main area of dispute is the likelihood and consequence of occurrence of droughts for which everyone agrees Abingdon reservoir would not be resilient. This question remains unresolved.

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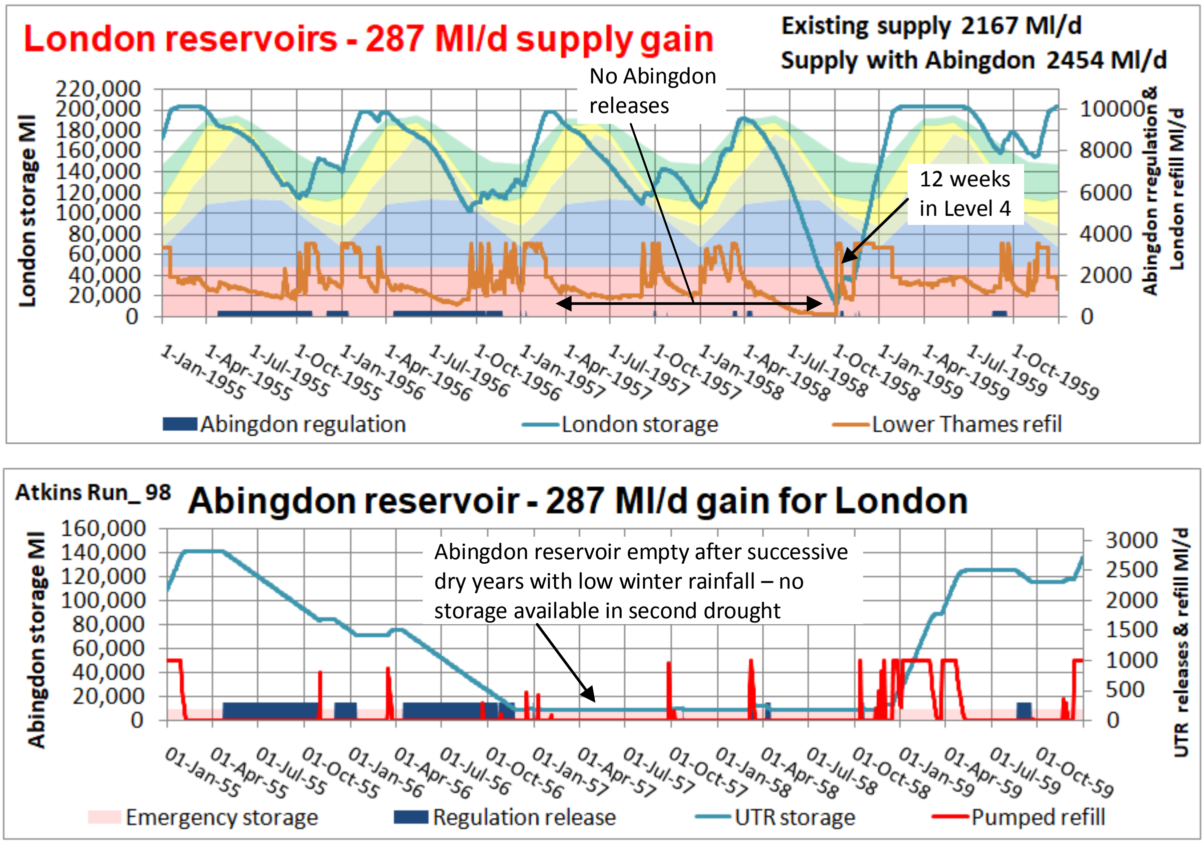
[263] Fine Screening Report, February 2018. Table 5.15.
[264]http://www.abingdonreservoir.org.uk/downloads/GARD%20review%20of%20UTR%20resilience%20final-21-08-17.pdf
[265] Email from Derek Stork (Chairman of GARD) to Lesley Tait (TW) on 8th March 2018.

Figure 9-1 below provides an illustration of the consequences of the type of drought in which the Abingdon reservoir has poor resilience.

In this drought, taken from Atkins' stochastic flow records, an only moderately severe drought in 1957-58[266] follows several years of dry winters in which no refill is available for Abingdon reservoir. Consequently, Abingdon reservoir is empty at the start of the main drought and no regulation releases are available. The consequence would be 12 weeks of Level 4 supply failure in London at an economic cost of about £20 billion according to the Environment Agency's estimate.



Note: dates shown are nominal dates from Atkins stochastic data, not actual 20th C dates

Figure 9-1: Example of long duration drought with poor Abingdon reservoir resilience

For this type of event, the Abingdon reservoir has minimal resilience in the event of a drought worse than the deployable output design standard – after use of emergency storage for 30 days, the reservoir would be empty throughout the remaining 8 weeks of the second drought.

There are a significant number of similar events in Atkins 15,600 years of stochastic data, but no estimate has been made of the probability of such an event occurring.

[266] Note: dates shown are nominal dates from Atkins stochastic data, not actual 20th C dates

In GARD's opinion, until the resilience of Abingdon reservoir has been properly assessed for the likelihood and consequence of droughts such as that shown in Figure 9-1, its drought resilience should be rated as poor.

9.3 Severn-Thames transfer options

Atkins has assessed the resilience of the Severn-Thames transfer, both unsupported and with support from Vyrnwy. In both cases, they found that the yield of the schemes at 1 in 1000 year return period was virtually the same as the yield at a 1 in 100 year return period. This is illustrated by the plots shown in earlier Figures 7-3 and 7-9 of this response. The conclusion reached is that the Severn-Thames transfer schemes have good resilience in droughts worse than the historic record. If this finding seems counter-intuitive (because flows in the River Severn reduce in droughts, like those in the Thames), the explanations are:

1. For the unsupported transfer, in droughts worse than the historic record, the need in the Thames for transfers from the Severn to keep the London reservoirs topped up starts earlier in the autumn and extends longer into the spring, times when flows in the Severn are generally available.
2. In the case of support from Vyrnwy, the reservoir has a large catchment in relation to reservoir storage which means that it fills reliably over-winter, making storage always available in the multi-year droughts in which the London supply system is vulnerable. Even in droughts a lot more severe than historic, the reservoir refills reliably. This would be particularly the case in the larger variants of the scheme proposed by GARD in which the winter draw on the reservoir would be a lot less than at present, when the reservoir is only used for a continuous direct supply to United Utilities.

Thames Water's analysis fails to recognize the additional resilience that the Severn-Thames transfer options offer in the event of a drought worse than deployable output design drought. The resilience comes from the availability of water in the Severn below the Deerhurst hands-off flow in the event of extreme drought. Atkins' stochastic flow records show the minimum flow at Deerhurst in the 15,600 years of stochastic as being 630 Ml/d. Thus in the event of an extreme drought, much more severe than the deployable output design standard, the Severn-Thames transfer scheme, supported or not, would always be able to supply London up to the capacity of the Deerhurst to Culham transfer pipeline – 500 Ml/d as proposed by GARD.

Obviously, this would only be possible with an Emergency Drought Order to abstract to below the Deerhurst hands-off flow. However, even though the lower Severn is protected by the Habitats Directive, it would seem unarguable that the Emergency Drought Order would be legally acceptable on the grounds of Over-riding Public Interest, the alternative being rota supply cuts in London. It is notable that the earlier cited Environment Agency advice on planning for droughts of 1 in 200 year severity includes the possibility to include Drought Permits or orders in a company's plans.

The 500 Ml/d of emergency supply available from all Severn-Thames transfer options contrasts with the zero availability of emergency supply because the reservoir would be empty in the event of a drought worse than the deployable output design drought.

9.4 Teddington DRA, effluent reuse and desalination options

These options will operate independently of the availability of river flows, so they are all fully resilient to droughts more severe than the historic record – regardless of drought they are always able to supply their design capacity in a drought emergency. This has not been recognised by Thames Water in their Fine Screening of options as shown below, extracted from Table 5.16 of the Fine Screening Report of February 2018:

Key to symbols:
- Substantial disbenefit
- Material disbenefit
- Neutral
- Material benefit
- Substantial benefit

	Raw Water Transfers				Water reuse						Desalination			River Regulat				DRA	
	STT Deerhurst to Culham pipeline with support from (Vyrnwy and Mythe)			Oxford Canal	Deephams	Beckton		Mogden	Mogden South Sewer	Crossness	Beckton	Crossness (blended)	Crossness (unblended)	Abingdon				Teddington	Lower Lee
	300 Ml/d	400 Ml/d	500 Ml/d	15 Ml/d	60 Ml/d	50 Ml/d	100-380 Ml/d	50-200 Ml/d	50 Ml/d	50-190 Ml/d	150 Ml/d	100-300 Ml/d	65 Ml/d	<125 Ml/d	125-225 Ml/d	>225 Ml/d	Phased	300 Ml/d	35 Ml/d
Resilience																			
Climate change	Material benefit	Material benefit	Material benefit	Material disbenefit (r)	Substantial benefit	Substantial benefit	Substantial benefit	Substantial benefit	Substantial benefit	Substantial benefit	Material benefit	Material benefit	Material benefit	Substantial benefit	Substantial benefit	Substantial benefit	Substantial benefit	Material benefit	Material benefit
Severe drought	Material benefit	Material benefit	Material benefit	Material disbenefit (r)	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit	Material benefit

Figure 9-2: Thames Water's assessment of resilience of major option types

In GARD's opinion, Thames Water's assessment of the drought resilience of the major options has been grossly distorted to favour the Abingdon reservoir:

- Teddington DRA, reuse and desalination options should be credited with "substantial benefit" for climate change and severe drought, not "material benefit".
- The Severn-Thames transfer options should also be assessed as having substantial material benefit – taking account of the availability of lower Severn flows under an emergency drought order, and the demonstration by modelling *across the entire data set* of independence of yield against drought severity.
- Abingdon reservoir should be assessed as having a substantial disbenefit for resilience to droughts worse than the deployable output design standard, ***because the reservoir would be empty***. It is hard to see how the further resilience assessment proposed by Thames Water for the Abingdon option can change this conclusion.

It is not clear how Thames Water's grossly distorted drought resilience assessments have been carried forward into the dWRMP programme appraisal, but they need to be corrected.

10. Thames Valley zones

Key points

- The forecast demands in SWA zone have been over-estimated through exaggeration of Thames Water's population growth estimates.
- The Final Plan peak week demands in SWOX zone have been over-estimated, with the peak week to annual average ratio forecast to increase over the planning period despite the introduction of universal water metering.
- The planned Teddington DRA scheme will enable the forecast needs of SWA zone, Affinity and South East Water to be met by reallocation of some of Thames Water's lower Thames abstraction licences through trading agreements.
- Thames Water should inform the public of the ability of the Teddington DRA scheme to alleviate over-abstraction in Thames Valley chalkstreams, rather than saying that the Abingdon reservoir is the only solution.
- SWOX needs, when correctly forecast, can be met entirely by demand management.
- If eventually needed for SWOX zone, the Oxford canal transfer scheme can be combined the Culham DRA scheme and GARD's earlier SWOX reuse proposal to boost supplies from Farmoor.

10.1 Supply demand balance

Thames Water's needs

Thames Water's forecast deficits in the Average Day Peak Week for the Thames Valley zones are shown in Table 6-1 of the dWRMP and replicated below (Henley zone is in slight surplus throughout and not shown):

WRZ	Item	Volume (Ml/d)					
		2019/20	2024/25	2029/30	2039/40	2074/75	2099/00
SWOX (ADPW)	Demand	330	338	343	347	354	356
	Headroom	16	21	22	22	22	22
	Supply	355	353	351	350	346	343
	Balance	8	-6	-14	-20	-30	-34
	WRMP14	-1	-12	-21	-32		
SWA (ADPW)	Demand	170	172	174	179	215	239
	Headroom	9	8	8	7	7	7
	Supply	196	196	195	195	195	195
	Balance	19	16	13	9	-27	-51
	(WRMP14)	8	5	1	-6		
Kennet Valley (ADPW)	Demand	122	125	127	129	137	141
	Headroom	7	9	11	10	8	8
	Supply	153	151	150	148	145	142
	Balance	24	17	12	10	-0.3	-7.0
	(WRMP14)	22	16	11	5		
Guildford (ADPW)	Demand	62.7	64.5	66.7	70.2	72.6	71.1
	Headroom	3.0	3.2	2.9	2.3	2.0	2.0
	Supply	67.7	67.7	67.7	65.0	65.0	65.0
	Balance	2.0	0.1	-1.9	-7.5	-9.6	-8.0
	(WRMP14)	0.1	-1.1	-2.1	-3.8		

Table 10-1: Forecast deficits in TW's Thames Valley zones

The deficit forecasts shown above are based on the already discredited and abandoned Thames Water population projections. Although Thames Water have given a new projection for their whole supply area, they have yet to share any of the detail and we have been told that they will not provide any new figures until the revised WRMP is issued.

On the basis of our assessment of the original dWRMP population projections, we believe that Thames Water's estimates of the high demand growth in the SWA zone post 2040 is likely to be based on the University of Leeds model, overestimating the effects of ethnicity on fertility rates and cultural norms for water use, as well as over-estimating immigration levels. On that basis, the SWA deficit at the end of this century is likely to be well below Thames Water's figure of 51 Ml/d.

In the next 25 years (up to 2039/40), the normal planning period for WRMPs, there are only small deficits for the Average Day Peak Week (ADPW), and none for the Dry Year Annual Average (DYAA):

- 20 Ml/d deficit in SWOX, which can be met by demand management – see later
- 7.5 Ml/d in Guildford, which can also be met by demand management

Noting that these deficits are only for the peak week and the zones are in surplus for the dry year annual average to beyond 2040, these small deficits are relatively minor and can be dealt with by demand management.

Furthermore, in our opinion, the peak week demands for SWOX zone have been exaggerated by Thames Water, with its already high peak week to annual average ratio of 1.4 forecast to rise to 1.51 over the planning period despite the introduction of universal metering (see later Section 10.3).

Deficits for other Water Companies in the Thames Valley

Affinity's draft WRMP forecasts substantial deficits from the mid-2040s in their Thames Valley zones West of London, which are supplied by abstraction from the Thames. The deficits arise for these water companies despite their intensive programmes of water metering and demand reduction over the next 10 years. Affinity envisage imports from Thames Water of 50 Ml/d into their Pinn zone by 2049, and another 50 Ml/d into their Guildford zone by 2066[267]. They envisage these imports being achieved by increased abstraction at their existing River Thames sources, supported by regulation releases either from Abingdon reservoir or from the Severn-Thames transfer.

South East Water are forecasting smaller deficits than Affinity, but envisage a 9 Ml/d import from Thames Water's Kennet zone in 2045[268] and a new abstraction of 20 Ml/d from the River Thames West of Reading in 2069[269], supported by regulation releases from either the Abingdon reservoir or the Severn-Thames transfer.

Sustainability Reductions to reduce existing abstraction impacts

The existing water supplies in the Thames Valley, particularly groundwater abstractions from the chalk aquifer, have a long history of controversy about over-abstraction and ecological damage to chalkstreams. The needs of Affinity and South East Water include provision for Sustainability Reductions on rivers affected by over-abstraction. These Sustainability Reductions are strongly supported by local people, Rivers Trusts and other environmental NGOs.

[267] Affinity dWRMP, page 263
[268] South East Water dWRMP, page 150
[269] South East Water dWRMP, page 158

GARD is aware that, at meetings with the public, Thames Water have been “selling” the merits of the Abingdon reservoir, as the means of enabling Sustainability Reductions to alleviate ecological damage due to over-abstraction from chalkstreams. This appears to have been done to drum up public support for the reservoir, without adequately explaining that there is a range of options that could enable the Sustainability Reductions, as described below.

10.2 Options for Thames Valley zones

Options available

The primary needs in the Thames Valley zones are driven by demand growth in the SWA and SWOX resource zone, the needs of Affinity and South East Water and the need to alleviate ecological damage to chalkstreams. Together, these needs could require an additional continuous abstraction of in excess of 100 Ml/d from the River Thames between Abingdon and London.

In the draft WRMP, the main options for dealing with these needs are, in their order of Thames Water’s intended implementation in the preferred plan:

- Release of licensed Didcot power station cooling water
- Demand management through water metering and leakage reduction
- The Abingdon reservoir
- The Oxford canal transfer
- The Severn-Thames transfer

Reduction of Didcot cooling water and demand management (reduction committed at the moment for two AMPs), particularly water metering, will deal with immediate deficits in SWOX and in reducing the peak week demands that are generally driving needs in the Thames Valley. Although Didcot is currently allocated to London WRZ, if it is used first in SWOX then London will still receive 80% of that through effluent return. The Oxford canal transfer (15 Ml/d) would provide a small increase in flows in the Thames, if it is ever implemented, but will fall well short of the potential needs of SWA, the other water companies and Sustainability Reductions. That said, again if used in SWOX, 80% will be returned.

Thames Water appear to have dismissed the Severn-Thames transfer option from their preferred programme (although it is shown as a component of the ‘Least Environmental Impact’ programme of the Summary), leaving only the Abingdon reservoir as a possible option to meet the long term needs in the Thames Valley. Aside from our views of the importance of bringing in “new water” via the Severn-Thames transfer as described in Section 7 of this response, we think that Thames Water have completely over-looked the potential for the DRA scheme to make more water available in the Thames Valley.

Use of the Teddington DRA scheme to meet Thames Valley needs

From the perspective of Affinity and South East Water, dependence on Thames Water's successful implementation of either the Abingdon reservoir or the Severn-Thames transfer is a substantial risk. Both of these are large schemes that would take many years to promote and construct.

What has not been mentioned in any of the Thames Water, Affinity or South East Water dWRMPs, is that there is actually a solution without having to develop either of the major new upper Thames resources. Instead, use could be made of the additional water made available at Teddington by the Teddington DRA scheme, as described below.

Were Affinity or South East Water to have a new abstraction from the middle River Thames, then about 80% of the water abstracted would return to the River Thames as treated sewage effluent. Thus, Thames Water's abstraction from the lower Thames would only lose about 20% of the water abstracted, see Thames Water's review of effluent returns[270]. Affinity or South East Water would only need to pay Thames Water through a trading agreement for the lost 20% - say, for 20 Ml/d for 100 Ml/d of gross abstraction. With the Teddington DRA scheme providing a large increase in deployable output for London, Thames Water would be well able to relinquish the small amount needed to meet the needs of Affinity and South East Water (including allowance for their Sustainability Reductions), as well as for Thames Water's own supplies for SWA.

As the Teddington DRA scheme is being selected by Thames Water as the next major new source for London for implementation by 2030, the use of this scheme for meeting Thames Valley needs would happen much sooner than waiting for implementation of either Abingdon reservoir or the Severn-Thames transfer. This should be a substantial comfort to Affinity and South East Water, and to their customers.

The potentially quick implementation of the DRA scheme would be a major advantage from the perspective of the chalkstreams interests in the Thames Valley that have been campaigning for decades for solutions to over-abstraction. In GARD's opinion, this is the message that Thames Water should be giving to stakeholders in the Thames Valley, rather than the persistent over-selling of the case for the reservoir.

We also note that, not only would most of additional water abstracted for supplies in the Thames Valley be returned as sewage effluent, but the Sustainability Reductions would boost not just flows in the chalkstreams but in the main River Thames itself. Overall, there would be little change in the flow regime of the River Thames between the Thames Valley abstraction points and London.

[270] Review of Effluent Returns, July 2013, page 31. HR Wallingford

GARD would hope and expect that the Environment Agency would take all these environmental benefits into account in considering the acceptability of this scheme and its associated licence change requirements. There would be justification for considering the scheme to be unacceptable through rigid application of the Environment Agency's CAMS assessment of the River Thames as being 'over-abstracted'.

GARD will be making all these points in our responses to the consultations on the draft WRMPs of Affinity and South East Water.

10.3 The needs of SWOX zone

Savings from demand management

The needs of SWOX zone's peak week deficit can be met, at least until 2040, by Thames Water's proposed demand management proposals. GARD is fully supportive of this, but has concerns that the benefits of demand management have been under-estimated. In the plots below, we show the forecast the meter penetration, demand savings and peak week to annual average ratio in SWOX zone[271]:

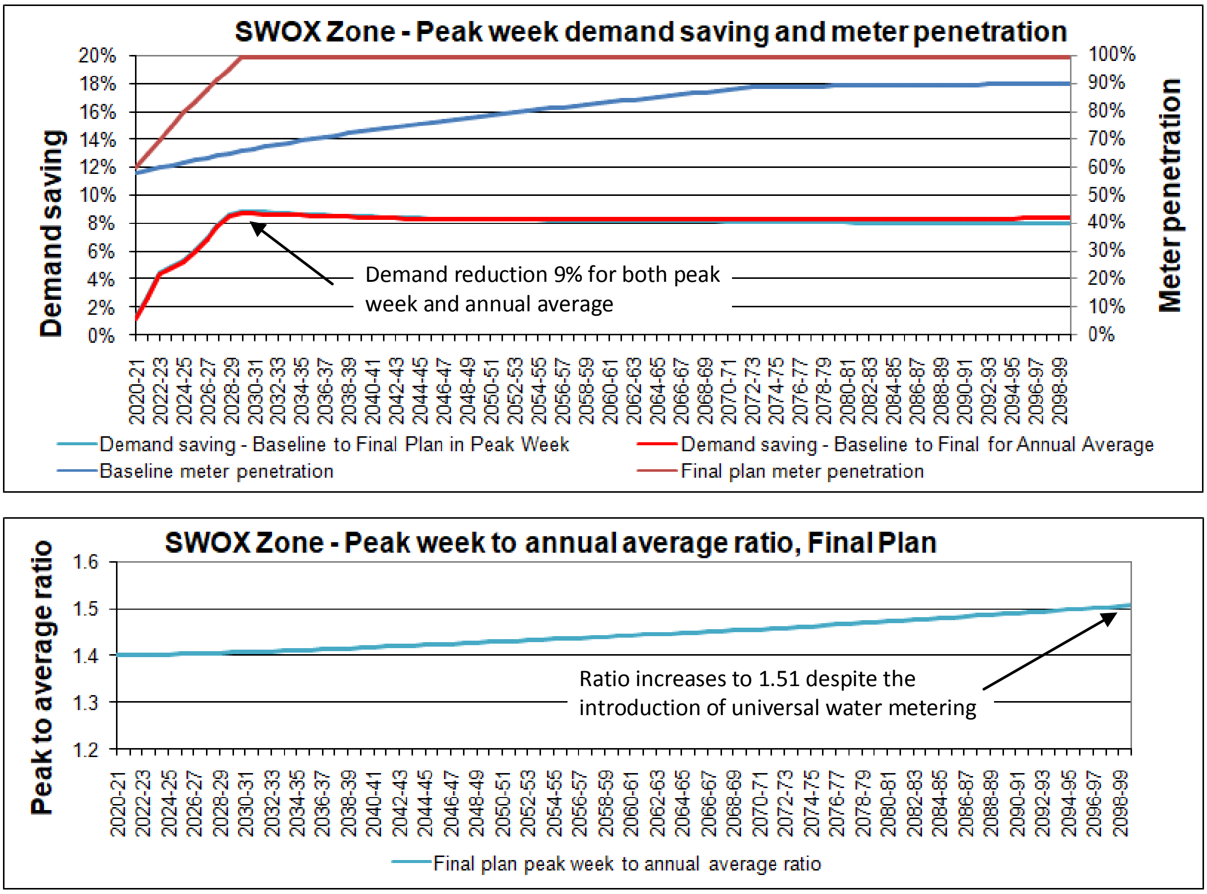


Figure 10-1: TW projections of meter penetration and demand savings in SWOX zone

[271] Data from dWRMP19 WRP Tables for peak week and average annual dry year in SWOX zone

Comparison of the annual average and peak demands in the SWOX zone WRP tables shows the peak week demands to be 40% higher than annual average for the base case and the final plan throughout the planning period. We have the following comments on this and the data shown on Figure 10-1 above:

1. The starting peak week to annual average ratio of 1.4 seems high and is forecast to increase to 1.51 in the final plan, despite the introduction of universal water metering. We would expect that it would be significantly reduced by the introduction of demand management and the high level of meter penetration proposed in the Final Plan. In our opinion, the ratio should reduce to around 1.33 in the Final Plan. In support of this we note that:

2. Looking at the WRP tables for Affinity's Wey zone, their peak week to annual average ratio is 1.31.

3. Southern Water achieved a 35% reduction in the peak week to annual average ratio on introduction of full metering[272]. Allowing only half of this, 17.5%, for SWOX zone would reduce the ratio to 1.33.

If the ratio is reduced to 1.33 and the annual average demand is 168 Ml/d, the peak demand at the end of the planning period would be reduced from Thames Water's figure of 253 Ml/d to 224 Ml/d, a reduction of 29 Ml/d.

In GARD's opinion, a realistic peak week ratio would leave SWOX zone still in surplus for the peak week in 2040. The peak week deficit would not arise until 2070 and would still only be 4 Ml/d at the end of the century.

Thames Water's own forecast for the annual average demands shows the SWOX region continually in surplus until the end of the century. We conclude that there is no need for any new sources in SWOX zone before the second half of this century and a only a minimal need beyond that.

New source for SWOX if eventually needed

If additional water is eventually needed for SWOX and the Severn-Thames transfer has not been implemented, the Oxford canal transfer, needed anyway for London, would also be available to increase SWOX resources by 15 Ml/d. We propose that this could be used to supply SWOX through a hybrid of Thames Water's earlier proposal for a small Direct River Abstraction at Culham and GARD's previous proposal for a SWOX reuse scheme[273]:

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[272]Southern Water Draft Drought Plan 2018.Annex 3 Demand interventions version 3 , 5 conclusions, page 38.
[273] GARD proposal for effluent reuse, submitted to Environment Agency, 3.3.2017

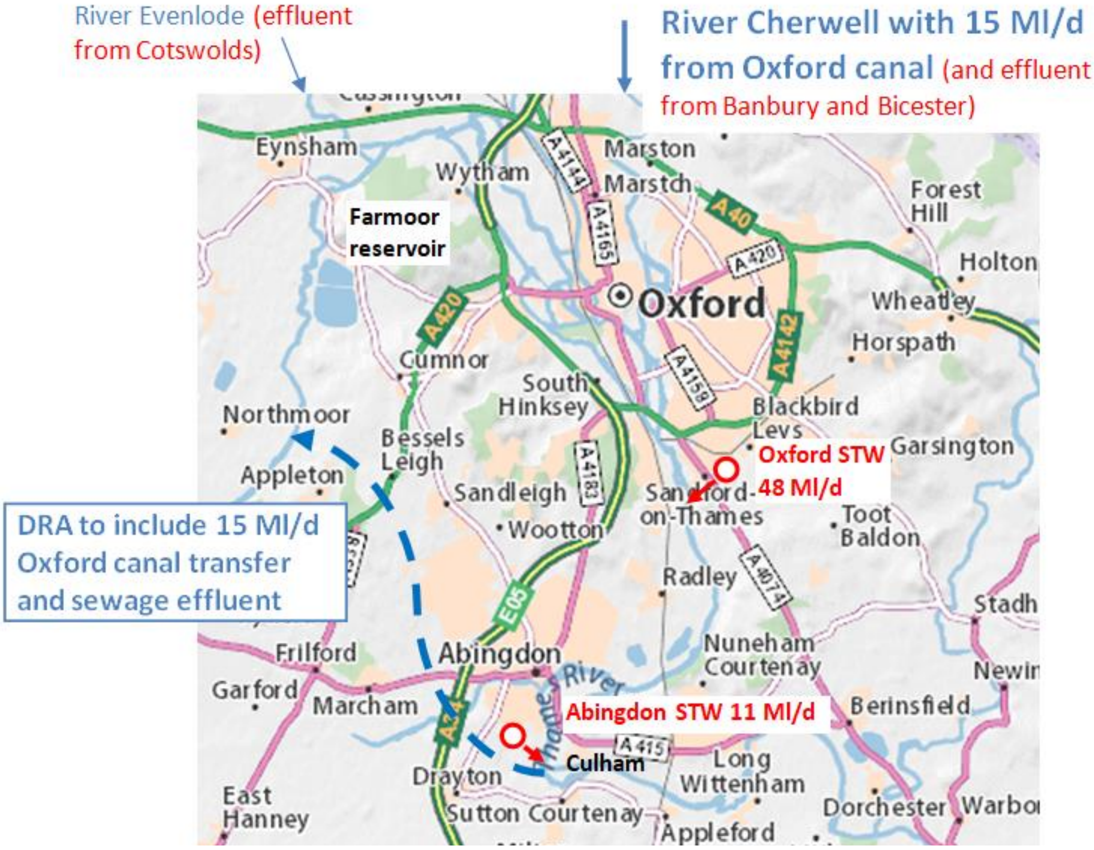

Figure 10-2: GARD proposed Culham DRA supported by Oxford canal

In GARD's opinion this would be a better way of feeding the Oxford canal transfer into the SWOX supply system, rather than Thames Water's proposal to transfer the water via a new pipeline from the River Cherwell around North Oxford to Farmoor Reservoir. The Oxford canal transfer water could be conveyed to Farmoor reservoir via a new Direct River Abstraction pipeline from Culham discharging into the River Thames upstream of Farmoor, as shown on Figure 12 above. If needed, the DRA abstraction could be considerably larger than 15 Ml/d, making use of the effluent from WWTWs for Oxford, Abingdon and various Cotswold towns. Operating rules and hands-off flows could use the same principles as those proposed in GARD's previous proposal for SWOX effluent reuse. These principles, which include the concept of improving dry weather flows in the Thames through Oxford, have been accepted by the Environment Agency[274] as a possible basis for a viable scheme which could be investigated by Thames Water.

We understand that the Environment Agency have informed Thames Water of their view on this, but, as far as GARD knows, Thames Water have not taken this any further to date.

[274] Notes of GARD EA meeting, 24th July 2017. Sarah Goode. Environment Agency.

11. Programme Appraisal

Key Points

- GARD welcomes the adoption of long term perspectives, and multi-parameter decision making in the dWRMP. However, we do not believe metrics have been applied in an unbiased way.
- Adaptability scenarios have yet to be agreed and were not available for the dWRMP. This is unacceptable: the revised draft which we are told will include this metric must be put out to a second circulation.
- GARD does not agree that the SWOX zone is 'highly complex' and Thames Water should revisit its strategic risk assessment.
- Costs cannot be analysed in any meaningful way from the current dWRMP. Thames Water should provide detailed costs so that programmes can be properly assessed.
- Since WRMP14, costs of various programmes have changed markedly in a way that does not make any sense. Thames Water should explain the basis for these changes.
- The Deployable Output described for many options in the dWRMP is wrong.
- The SEA treatment of different topics is inconsistent and at times subjective.
- The expansion of SEA Topics 1, 2 and 3 leads to a more favourable case for the reservoir than would otherwise be so.
- The expansion of Topics may have led to an element of double accounting of benefits that may not conform to best practice
- The expansion of certain SEA Topics has been at the expense of others, leading to an unbalanced weighting between topics.
- We do not consider the SEA assessments in the dWRMP to be 'clear and justified' as required by guidance.
- Thames Water should consider including the assessment 'uncertain' in its SEA and explain how this uncertainty will be resolved.
- Due to the substantial changes already made to the dWRMP underlying assumptions, we call for a revised environmental report to be issued for consultation.
- Treatment of similar issues between different options is inconsistent. This undermines the credibility of the dWRMP and we expect relevant sections of the SEA to be reworked using independent input.
- It is not clear how some assessment criteria such as permanence and magnitude have been used to significantly modify the assessment.
- Archaeology, cultural heritage and flooding have been downplayed in the SEA and these topics should be revisited to give more detail.

- Thames Water should provide a full set of stochastic drought simulations for the reservoir, as has been done for the STT.
- The attempt to account for intergenerational equity is compromised by constraints placed on the development model earlier in the process, especially relating to Leakage and Demand Management programmes.
- Programme selection models should include metrics that consider mounting debt and the effects of not paying a fair amount of Corporation tax.
- Increased debt accrued as part of unwisely sanctioned large capital programmes is of increasing concern to regulators. Thames Water should address this issue in their programme selection.
- Some of the customer preference data collected for this dWRMP runs counter to regulatory guidance. Thames Water should review its customer engagement programme.
- GARD analysis shows that programme selection is unduly skewed toward lowest cost – a particular concern, noting the unreliability and lack of transparency of Thames Water's cost estimates.
- The output of the PolyVis tool appears to have been blindly followed in the programme selection process, rather than being used to explore alternative approaches.
- Due to artificial constraints applied at an early stage of the programme selection process, Thames Water have failed to conduct a satisfactory optimisation process; this should be repeated with the constraints removed.
- Thames Water should repeat the entire programme selection process by using its new population and leakage figures, removing constraints, re-evaluating various SEA metrics, correcting errors in DO, and accounting for drought resilience.
- A true Adaptability analysis should take account of the errors and conservatism in the Demand Forecast to enable the production of a portfolio with true adaptability to changing futures. This will favour 'phaseable' projects.
- Of the supply side options, the potential for phasing and avoidance of unnecessary development places the Teddington DRA scheme as the best option, with London effluent reuse, desalination and the Severn-Thames transfer also well suited to phased development.
- The Abingdon reservoir option, with long lead-time and huge unit size, is by far the most likely option to become a 'white elephant' like Kielder reservoir.

11.1 Overview

Change of Methodology and Planning Horizon from dWRMP14

The dWRMP19 process involves a marked shift from previous practice for Thames Water (and the Water Companies in general). Whilst the statutory minimum planning period for WRMPs remains at 25 years, there is now strong government encouragement to adopt a longer planning period 'where appropriate'.[275,276] The appropriateness is judged on how 'complex' the problem of water supply is for the various Water Resource Zones (WRZs). The characterisation of complexity is dealt with below, but, Thames Water (TW) have characterised two of their main WRZs (London and SWOX) as 'highly complex' and chosen an 80-year planning horizon for these, and by association of common issues, for the 'moderate complexity' SWA zone.

The programmes for a highly complex zone are chosen by assessing a number of different metrics, not just the Economic Balance of Supply and Demand (EBSD) metric used in previous WRMPs.

At the outset, GARD would like to reiterate that, as a grouping, we have always argued for long-term strategy and planning, and not just 'lowest cost'-type approaches, and we have been consistent in advocating environmentally-responsible and resilient water resources, and in providing a legacy for future generations of a sustainable water-supply, not least by the tackling of leakage and demand management, and the adoption of climate-change-proof water resources. ***Thus GARD welcomes, in principle, the adoption of long-term perspectives and multi-parameter decision-making***. However, as always, the 'devil is in the detail' and consequently ***we do not believe that Thames Water have chosen or applied their metrics in an even-handed and un-biased manner***.

Programme Complexity characterisation

TW state[277] that they have followed the approach of the guidance for Decision Making in the UKWIR WRMP 2019 methods.[278] The first step is to define the strategic risk in a WRZ and by characterising the 'complexity' of the demand, supply and investment. TW shared this exercise with Stakeholders, as a table-top exercise at a Technical Stakeholders' forum in March 2016. The exercise was done on the London WRZ, and those Stakeholders present (including GARD) came to approximately the same conclusion as TW themselves had, i.e. that the London WRZ is 'Highly Complex'. However, the other zones were not assessed in this meeting, and TW produced a '*this is one we did earlier*' slide[279] to show the position of

[275]Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: interim Update, April 2017.
[276] DEFRA, Guiding Principles for water resources planning: For water companies operating wholly or mainly in England, May 2016.
[277]dWRMP19, section 10, Programme Appraisal, 10.8, February 2018.
[278] UKWIR WRMP 2019 Methods –Decision Making process : Guidance Report No 16/WR/02/10.
[279]https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Our-strategies-and-plans/Water-resources/Document-library/Past-meetings/presentation22march.pdf -slide 25.

the other zones in the Problem Characterisation[280] table (the equivalent of table 10.5 of section 10 of the dWRMP). It did not show SWOX as a 'high complexity 'zone, and did not show SWA as 'medium complexity'. See Figure 11-1 below, as presented on that day.

Problem characterisation for all the WRZs – Indicative results

Problem Characterisation		Strategic needs score			
		0-1	2-3	4-5	6
Complexity factors score	Low <7	Henley, Kennet Valley	Guildford SWA		
	Medium 7-11				SWOX
	High (11+)				London

Figure 11-1: WRZ complexity and strategic needs scores

No explanation was given as to how (in detail) these complexity changes took place, but they were already in the TW case by the time of the Fine Screening Report. There has never, in our view, been a justification for the movement of SWOX to a higher complexity rating. We note that to place a zone such as SWOX with a forecast deficit of around 35 Ml/d[281] into the same category as a capital city zone such as London with a forecast deficit (by any standards) of >400 Ml/d, and representing a major financial and strategic risk to the whole of the UK, is somewhat perverse. Moreover, as is shown in the 'Least cost' programme[282] (the nearest to the old EBSD appraisal), the SWOX deficit is 'solved' (in baseline) by just one action ('DMP_SWOX Metering') by 2030. A highly complex zone could not simply (even using the old method) be solved by such a straightforward measure. GARD suggests that the real reason for the move of SWOX to highly complex is to link it inextricably with London supply, and in particular as a host siting of the Abingdon reservoir. This is hinted at in the statement that: *"Optimising as a combined zone provides a solution of cost £51M NPV lower than the sum of three individual programmes for each of the zones."*[283]This may well be true, but on a NPV total (table10-11) of £3,159M, a 1.5% saving (on an 80-year programme) is hardly compelling. In any case, if it is all about cost, then at least TW should make an honest statement, and not try and hide behind the dubious markings given to the strategic risk and complexity sub-headings for SWOX in tables 10-1, 10-2, 10-3 and 10-4 of the dWRMP19 document. It is simply not credible to claim that: *"The solutions in these WRZs* [London,

[280] dWRMP19, Fine Screening Report, rev03, section 2.3, April 2017.
[281] dWRMP19, Executive Summary, figure 0-5, February 2018
[282] dWRMP19, section 10, table 10-11.
[283] dWRMP19, section 10-130

SWOX and SWA] *will be high cost, with long life spans."* [284]Table 10-11quotes the NPV for the SWOX programme as £172M, and SWA as £100M, against a London WRZ figure of £2,938M.

In short, GARD does not find the rating for the complexity of the SWOX zone given in the dWRMP to be justified. Thames Water should revisit this exercise.

Metric List

The list of Metrics chosen by TW in the dWRMP19 process given in Figure 11-2 below, copied from table 10-7 in the dWRMP19 document.

In general, the metrics form a development of those used in the dWRMP14, and the equivalence is demonstrated in Table W-14. [285]

Table 10-7: Draft WRMP19 Metrics

Performance metric	Description	Interpretation
Cost	NPV of the total cost of a proposed programme across the 80 year planning period.	Lower score is better
Adverse environmental impact	Numerical grading of SEA significance	Lower score is better
Environmental benefit	Numerical grading of SEA significance	Higher score is better
Deliverability	Probability that a proposed investment programme will deliver the volume of water within the timescale	Higher score is better
Resilience	The resilience of the proposed investment programme against a variety of hazards e.g. more severe droughts than in the historical record	Higher score is better
Intergenerational equity (IGEQ)	Evaluation of the impact of a proposed investment programme on current and future generations	Lower score is better
Customer preference	Evaluation of the programme in relation to customers' preferences and priorities	Higher score is better

Figure 11-2: dWRMP19 metrics (from table 10-7 in section 10)

'**Cost' –** is a straightforward use of the same metric as in dWRMP14;

'Adverse Environmental Impact' and **'Environmental Benefit' -** between them split the 'Environment' Appraisal of dWRMP14

'Deliverability' – is a development of the 'Risk' categorisation in dWRMP14

[284] dWRMP19, Section 10-26.
[285] dWRMP19, Appendix w, Table W-14, February 2018.

'Resilience' – is a development of the same metric name in dWRMP14

'Intergenerational Equity' – partially replaces the 'Government Priorities' in dWRMP14

'Preference' – combines aspects of 'Customer Preference' and 'Government Priorities' from dWRMP14.

An additional metric, **'Adaptability'** – accounts to Changing External Conditions and Future Pathways considered in dWRMP14.

In the basic descriptions given above, there can be little argument that this is a comprehensive set of largely appropriate metrics. However, as we have indicated above, the devil is in the detail of how these metrics are applied, and whether this process serves, ultimately, to elucidate or obscure the decision-making process.

Shortcomings in establishing values for the metrics

The manner in which the *values are assigned* to several of the metrics gives rise to significant shortcomings in the entire Programme Appraisal process and these shortcomings need to be addressed in order for the present consultation exercise to be valid. The *application* of the metrics listed below gives rise to concerns

'Costs'

The costs cannot be analysed in any meaningful way in the dWRMP19, because of TW's insistence on redacting all significant information because of 'commercial confidentiality'. There have been some marked shifts in cost indicators such as NPV, AIC etc. during this WRMP19 process (as indicated in Section 1.2 and other sections). As examples, for the Severn-Thames Transfer(STT) (this report, Section 7.5) there has been a 500% increase in capital costs since dWRMP14; the Teddington DRA AIC cost has trebled since October 2016. There have been sudden, unexplained shifts in other resource option costs: for example, in the updated Fine Screening Report (FSR)[286]there were sudden changes in: Abingdon Reservoir AIC - down by over 25%; supported-STT AIC - increased by 25%; and Thames Estuary Desalination plants AIC increased by 10%. In spite of the requests in the GARD response to this update,[287] there was never a satisfactory account of these changes.

Another cause of unreliable cost estimates which compromise the assessment of this metric, is the downplaying or miscalculating of deployable output (DO) for various options in the dWRMP19 proposals. This is most obvious for the Teddington DRA, where GARD has analysed and made a case for a DO of at least 316 Ml/d under present day circumstances, rising in future (post 2050) to over 470Ml/d (Section 4.5 of this document). Such a change, which needs analysis by TW to confirm, would make a large difference to the AIC of the DRA scheme. Section 7 also covers the under-estimation, in GARD's analysis, of the supported-

[286] dWRMP19, Fine Screening Report, Rev04, page 28, February 2018.
[287] http://www.abingdonreservoir.org.uk/downloads/GARD-response-to-up-dated-FSR-12.5.2017.pdf - section 7.1.

STT scheme, whilst Section 8.2 covers the dangers of over-estimating the DO of the Abingdon reservoir by assuming a dangerous level of Emergency and Dead storage.

Thus, due to a combination of lack of transparency, unexplained shifts in costs (which are in general in favour of options surviving in the 'Preferred Programme') and failure to estimate accurately the DO of various sources, ***we have a complete lack of confidence in the 'validity' of the Cost Metric.***

Deliverability

As this metric depends partly on costs being in-budget and partly on deployable outputs being realised, the metric is compromised by the issues related to these individual parameters.

Other metrics

For application of the *non-cost-based metrics,* we make comments in the sections following. The 'Adverse Environmental Impact' and 'Environmental Benefit' are dealt with in Section 11.3. The other metrics are covered in Section 11.4.

11.3 Review of application of Strategic Environmental Assessment

Issues with the methodology

The SEA methodology described provides a comprehensive environmental assessment that aims to create a single score for each option with regard to an 'Adverse effects metric grade' and a 'Beneficial effects metric grade'. Following discussion with the SEA study lead at the recent Water Resources Forum, it is understood that these final scores were determined by visually examining the different colours awarded for each SEA objective, as summarised in Fig 6.3 and 6.4 of Technical Appendix B[288]. Despite the WRMP implying that each individual SEA objective assessment was based on an individual score from -10 to +10, we believe that this scale only applies to the final overall score. The methodology for achieving the final score, therefore, is subjective, rather than being a calculated value.

The first issue we have is the expansion of certain SEA Topics into more than one objective. With each additional objective, and with the visual way in which the final score is calculated, the cumulative score of these topics is increased over those that don't have an expansion of objectives. For example, in the reservoir assessment, Topic 2 is divided into 3 separate categories each of which is awarded a dark green major beneficial score, whereas Topic 7, with only 1 objective can only register 1 major adverse. We note that the SEA process was put out to consultation and that this process was agreed, however we consider it unlikely that consultees were able to foresee the overall effect of adding objectives before these were considered and given a score. While increasing the number of objectives is a useful

[288]Technical Appendix B: Strategic environmental assessment – environmental report, page 100-103.

way of conducting a deeper investigation of a topic, we believe that at the end of the process, each topic should have a single score/assessment reflecting all of its constituent objectives. In this way, each topic would have equal weighting. If not, there should be a clear explanation as to how the relevant weight of each topic has been justified and discussion as to how the increase in the number of objectives has affected the overall assessment. In any case, we recommend that the SEA is re-marked using the methodology we have described of single scores for each topic, and subsequent ranking tables recalculated.

UK WIR Guidance

The dWRMP references a UKWIR document,[289,290] which provides SEA and HRA guidance for those preparing WRMP. We were provided a copy of this document by Thames Water and after reviewing it have the following comments:

- The SEA has followed the UK WIR methodology.
- However, the guidance notes that '*assessments must be clear and justified so consultees can follow decisions*'[291]. We do not consider that this is the case with the SEA for the UTR (and other) option(s).
- Further, '*a system which attempts to aggregate qualitatively assessed impacts runs the risk of implying that two environmental impacts are necessarily greater than one, and that beneficial impacts on one receptor can compensate for adverse impacts on another. In reality this is not the case'*[292]. This problem is exactly what we have seen with the reservoir SEA, where the benefits accrued under Topic 2 appear to have been used to over-rule all the other adverse effects.
- The SEA identifies a number of environmental impacts to which it is difficult to attach a value. When this happens, it is difficult to fully appraise the path to the optimum programme. This problem occurs in many of the dWRMP options considered under the SEA process. In each case, the respective SEA should highlight this issue and explain how it has been resolved; final programme selection should not take place until these options have been fully considered and explained.
- The UK WIR guidance notes that SEA outcomes can be used as a screening process to deselect schemes with unacceptable impacts. However, it then warns of the dangers of deselecting too early in the process as their rejection "*precludes any later*

[289] Strategic Environmental Assessment and Habitats Regulations Assessment - Guidance for Water Resources Management Plans and Drought Plans.
[290] The dWRMP should not reference documents that are not generally available to the public, particularly ones that cost £200. Although Thames Water were able to give us access to this document, it is unlikely that all organisations or individuals would have had the time or resource to obtain this.
[291] UKWIR WRMP & DP SEA-HRA Guidance 2012, Executive Summary.
[292] UKWIR WRMP & DP SEA-HRA Guidance 2012, p 21.

consideration as viable alternatives to other schemes which may cause other unacceptable impacts or risks"[293]. This appears to be the case in the dWRMP where alternatives to the UTR are progressively assessed as unsuitable and de-selected until only the reservoir (at the maximum possible size) is left - this in spite of the fact that many of the issues that caused other options to be de-selected are also present in this option. One example is the seam of greensand and gravel that crosses the reservoir footprint. As a result, the only option that is left at the end of the process is also the one with the greatest impact in many SEA Topic areas. This does not make any sense.

- It is clear from discussion with TW personnel that much of the detailed work on the reservoir scheme is still to be done, as it not considered cost effective to do it at this stage while considerable uncertainty over this scheme remains. It is therefore strange that the SEA assessment category of 'uncertain' has not been used at all. TW should review the SEA to determine where an objective should be assessed as uncertain and to explain what work will be required, and when it will be carried out, to remove uncertainty.

- The guidance notes that, in some cases, there will be substantial changes between draft and final WRMP. This is certainly the case with the TW dWRMP which has undergone major changes to the underlying assumptions even during the consultation period. In that case we expect, to maintain compliance with Article 5 of the SEA Directive, that the Environmental Report that forms part of the dWRMP will be either revised, or an addendum issued.[294]

Further SEA issues

We have reviewed the SEA assessment for the reservoir and other options and have found a number of anomalies. These include strong adverse scores where no adverse effects exist, for example the Severn Trent Transfer (STT) gets a red for 'protect health, raise awareness of water environment' even though no aspect of health is adversely affected by this option. Similarly, 'reduce or manage flood risk' gives the same yellow score to both the reservoir and STT, despite the former raising great concern about its effect on the local flood plain and the latter having no effect on flooding whatsoever. Further examples are contained in Table 8.9 of this report. We believe these examples, and others, undermine the credibility of the SEA as an independent review and that it should be reworked using greater stakeholder input. Discussion of the detailed Abingdon reservoir SEA assessment spreadsheet, alternative scoring and the potential implications of this are at Section 8.4

[293] UKWIR WRMP & DP SEA-HRA Guidance 2012, p 22.

[294] UKWIR WRMP & DP SEA-HRA Guidance 2012, p 22.

One element of the SEA methodology that is not clear is how the columns marked 'scale of effect', 'certainty of effect' 'permanence and magnitude of effect' etc. have been used to adjust the awarded score for each objective. It appears that the score is based loosely on the description in the commentary column, which seem largely disconnected from the assessment in the extra columns listed above. An example would be where the reservoir construction period lasts for 10 years with major disruption and permanent effect yet seems to be treated broadly similarly to the STT program which would last for only 5 years and have minimal permanent effect. The SEA should be re-scored placing more prominence on these issues.

We believe that the topics of archaeology and cultural heritage and in particular, flooding, have been seriously underplayed in the assessment. A comprehensive review of these issues is in the section on the Reservoir option (Section 8.4 and 8.5) and includes suggestions as to how these important topics could have additional objectives added.

11.4 Comparison of options other than cost and Environmental Impact

'Resilience'

GARD has devoted Section 9 of this report to the topic of Resilience to drought in general and also Section 7.2 to the resilience of the *Unsupported* STT, which we believe was dropped too early from the options. In our view, the resilience analysis performed by TW of manifestly climate-dependent sources (principally the Water Transfers and the Reservoir) has errors (discussed in the referenced sections) and has not been performed to an acceptably rigorous level for the reservoir. As said before, we would at least expect to see a full set of stochastic drought simulations for the reservoir, as has been done for the STT,[295] especially before allocating 'material benefit' to the reservoir as far as drought resilience is concerned. We have not had time to analyse TW's work on the other resilience parameters (flood, pollution etc), but the work on droughts gives great concern that this metric overall is compromised by the TW analyses.

'Intergenerational Equity' (IGEQ)

This is a complicated metric, and whilst attempts to describe it are made in the dWRMP Appendix W,[296] it would be helpful if terms in equations were defined. As reviewers, we have never seen so many equations with undefined terms. If we take at face value the IGEQ equation in para W.172 of Appendix W, then we see that IGEQ depends on the product of an *"affordable and equitable bill"* and figures of merit for the Leakage Reduction and Per capita consumption (PCC) reduction over the programme. Thus maximising IGEQ (a goal of the process) depends on strong progress of Leakage Reduction and PCC reduction. As we have seen in Sections 3.1 and 3.2 of this report, TW constrain the progress which can be

[295] See figure 7-9 in section 7.4.
[296] dWRMP19, Appendix W, W.172 et seq.

made on these topics, by constraints to the scenarios tested through the Integrated Demand Management (IDM) *before the Demand Management components of the programmes are put into this metric assessment process* (i.e. before the Least Cost optimisation). The decision to go in this direction is not well-justified in our view, and it constrains unnecessarily what can be done in maximising IGEQ. Even the use of only an '*affordable bill*' part to the metric omits the issue of mounting Water Company debt being passed on to future generations, and the lost Corporation Tax take, both of which result if companies over-extend their borrowing to finance huge 'vanity' capital projects to increase their capital asset base. Concerns of this type have been raised previously by regulators.[297] Ofwat reports have stated:[298]*"…should it* [Ofwat] *be concerned that some water companies are currently geared to a point substantially above the PR09 notional regulatory gearing assumption? There are two possible concerns. Firstly, Ofwat may be allowing companies to earn an excess (and unjustified) return by permanently exceeding the notional regulatory gearing assumption. Secondly, water industry companies may be introducing a higher risk of failure through their capital structure decisions, and such a level of failure risk could be to the detriment of customers."*Future generations of Customers, or Taxpayers, or both, could get saddled with the settling of debt unwisely sanctioned by large capital programmes. ***In GARD's view this needs taking into account in any real IGEQ maximisation.***

'Preference'

It is now mandatory, thanks to numerous regulatory guidance notes,[299,300] that Customer Preferences should be given prominence within the assessment of a dWRMP. TW have carried out 'customer research' to establish preferences for Option Types and Level 4 Restriction frequency (a measure of Drought Resilience). It is praiseworthy to consult customers, and especially if this includes an element of customer education about an important resource such as water. The material shown to customers has been criticised by various stakeholders (in a consultation in March 2017) as being frequently too simplistic, and in some cases, to contain 'leading' phrases. Not all of these criticisms were taken on board by TW.

The Customer preference results shown in Tables 10-9[301] for 'Option types' and 10-10[302] for 'Drought Resilience' point up the problem in allocating a weight to this metric. Table 10-9 clearly shows 100% of customers favouring 'Demand Management' options, with the next favourite option (DRA) well behind (55%) and Re-use (26%), Reservoir (15%), Water transfer, Desalination, Groundwater and Aquifer recharge (9-10% each) bringing up the rear (customers were given a choice of up to three options, so the figures add up to more than

[297] See e.g. Ofwat: Cost of capital for PR14, methodological considerations.(2016) https://www.ofwat.gov.uk/wp-content/uploads/2016/01/rpt_com201307pwccofc.pdf
[298] Ref 16 – op cit.
[299] DEFRA, Guiding Principles for water resources planning for water companies operating wholly or partly in England, May 2016.
[300] Ofwat, Customer Engagement and policy statement expectations for PR19, May 2016.
[301] dWRMP19, section 10, table 10-9, page 21.
[302] dWRMP19, section 1o, table 10-10, page 21.

200%). This is on the basis of being shown slides, which were highly simplistic, at one-day workshops or online surveys. The weight which should be attached to this sort of opinion is very controversial when set against all the other expert judgements on other metrics. However, it is clear that a meaningful optimisation with this metric cannot be achieved if the customer preferences are either unnecessarily restricted in early stages of the optimisation (in the process to obtain least cost), or if they conflict with regulatory guidance. Both these factors have played a role in TW's process, by their own admission. It has already been seen in Sections 3.1 and 3.2 of this report that TW in fact made conscious decisions, in the IDM optimisation, not to allow unrestrained programmes of Demand Management through to the next stage of optimisation. This has resulted in an unnecessarily-constrained Leakage Reduction programme that they have already been forced to abandon. Granted that the abandonment is in the direction that Customer Preference would welcome, but there is no sign that customers' instincts on this are going to be trusted in any meaningful way unless TW are forced to undertake the sort of action programme suggested by GARD in Section 3.

The situation on Drought Resilience is even more problematical. The customer preference (88.3%) is for the existing level of drought resilience (1 in 100 years Level 4 restriction), with only 10% opting for the new regulatory guidance level of 1 in 200 years. Clearly TW have a duty to follow guidance, this gives another reason why they may not be able to weight customer preference properly in an un-restricted manner.

'Adaptability'

Unlike the other metrics, Adaptability is not used in Programme Development of Programme Shortlisting, but is intended to be used to compare the shortlisted programmes as a *Programme Selection Tool.* This seems to be because of the *"..computationally-intense analysis …"*[303] involved, a rather strange limitation for a £Billion-valued company. Thus Adaptability is not really able to perform the role of establishing true 'Adaptive pathways' but is rather more akin to a sensitivity analysis or 'stress test' on an already-selected portfolio of options. Indeed, by TW's own admission, *"… the scenarios for Adaptability analysis have not yet been agreed and sensitivity testing* ***has therefore not been carried out for the draft WRMP19 submission*** *(Section 10: programme appraisal and scenario testing). Adaptability scenarios will be agreed and utilised in time to support the submission of a* ***revised draft****."*[304] [emphasis added by GARD]. ***This is an astonishing admission to make, and it is one more example of why the revised 'draft'***, as TW seem to be prepared to call it in sections tucked away from the main scrutiny, ***should be subjected to a second consultation period, a point we make in Section 1 of this response***.

[303] dWRMP19, Appendix W, W-118.
[304] dWRMP19, Appendix W, W-200.

11.5 Assessment of alternative programmes

The assessment of the alternative programmes for the 'highly complex' zones of London, SWOX and SWA is undertaken using a model known as 'EBSD+', a development of the EBSD model. TW were hoping to use a more sophisticated model capable of true multiple parameter, multi- criteria search, known as 'IRAS_MCS'. However, this latter model was not available for the dWRMP submission due to requirements for alterations to give more transparency, which came from the Expert Panel.[305] The revision of the IRAS_MCS model is ongoing, but TW do not say if it is to be applied to a 'revised draft'. In any case, we have not wasted time analysing the effects of any new model. In our view, unless the input constraints to the programme elements which we have highlighted above are radically changed, there will be no improvement to the assessment process.

According to TW: *"EBSD+ combines analysis of multiple parameters including cost, with single objective optimisation for each successive parameter. A second search uses a dual-objective search to find the best solution for each metric within a threshold increase of cost from the least cost solution (SCS). A third search finds near-optimal solutions for each parameter in relation to the SCS results, approach which is known as modelling to generate alternatives (MGA)."*[306]We can thus see that cost plays a key role in constraining any nominally '*multi-parameter*' search- the optimisation is not allowed to stray too far from SCS (TW state that a threshold default of 120% of least-cost is used as the limit in programme development).[307] This, as we indicate below, is manifest in the relationship between the 'Least Cost' optimised programme, and the 'Preferred Plan' programme.

The actual Assessment of Alternative Programmes

We give the bare outline of what actually has been done to assess the alternative programmes. This is quite difficult to establish, as so much time is spent in the relevant sections of the dWRMP in apologising for what is *not* there. For the individual steps we note, in the Table11. 1 below, we indicate where the 'pre-selection' process leads to shortcomings in the process.

The use of the 'PolyVis' tool to make final judgements as to 'acceptable' programmes raises concerns, as there really should be some alternative of weighting, at least as a validatory back-up to the final output to the 'what-if' testing of final programmes. Although PolyVis is an excellent visualisation and sharing tool and one which could undoubtedly aid understanding by generating debate on filtered output about trends etc., it has shortcomings if used as a final selection device unsupported. There are issues which emerge even from a limited consideration of PolyVis outputs shown in the documentation:

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[305] dWRMP19, section 10, 10-27.

[306] dWRMP19, Section 10, page 9, footnote 10.

[307] dWRMP19, Appendix W, W63.

- There is always a very tight range of the metric 'Customer Preference', e.g. in fig 10-7,[308]there is a range of only +/- 4% (from 4.2 to 4.5) over the whole programme portfolios shown. This prompts the question of whether a metric as vague as Customer Preference can be measured that accurately! The constrained range probably occurs from the IDM and regulatory restrictions to optimisation mentioned in the Table 11-1

- The other metric which appears highly constrained in optimisation outputs is IGEQ, an example is in fig W-13.[309] IGEQ varies by about +/- 15% (14 – 21) over the portfolio. This probably occurs because of the restricted DMP options (Table 11-1). Again, this indicates a possibly untenable claimed accuracy in evaluating this metric.

[308]dWRMP19, Section 10, page 22.
[309] dWRMP19, Appendix W, page 31

Step	Action	Problems
1. Collation and Validation of Input data	• Input baseline supply-demand balance (incl. headroom) • Input range of water resource options • Input range of Demand Management Plans (DMP) as optimized in IDM • Input uncertainty parameters for each DM and water resource option.	• Population statistics already known to be wrong and non-compliant[310]. • Several errors in DO for resource options[311] • IDM optimization over-constrained as to allowable Leakage and PCC reduction programmes.[312]
2. Develop Least cost programmes Development of programmes - metrics	• Optimise to find lowest cost (long-term NPV) • Dual-objective search to find optimum for ***each of*** Environmental score (+); Environmental score (-); Customer Pref. (type); Customer Pref.(service level); Resilience; Deliverability; IGEQ; ***around Least Cost point.*** • Search for near-optimal solutions for each parameter in relation to SCS-constrained results.	• Complete absence of cost transparency for stakeholder assessment. • Errors in DO ripple-through to this stage. • Unjustified constraints on (especially) OPEX[313] • Subjective SEA scoring; expansion of criteria leads to double-counting of benefits and unequal weighting[314] • Constraints on Customer Preference range due to restrictive IDM optimization and regulatory compliance. • Incomplete and error-prone drought resilience analysis[315] • Constraints on IGEQ from restrictive IDM optimization.
3. Validate outputs	Uses Polyvis tool	Obviously a good way of displaying, visualising, and sharing results. Beware 'rubbish out' possibility.
4. Shortlist and Test	• Use PolyVis to identify programmes for further testing/analysis. NO formal weighting used • Test against scenarios: **Baseline; Baseline+ incr Drought resilience (1:200; Baseline +1:200+WRSE transfer** • Output to 'what if' testing.	• Lack of formal weighting is a problem – 'select by eye' and 'judgement' are too crude.

Table 11-1: Steps in the EBSD+ programme optimisation process

[310]Section 2.1 of this response. Also Thames Water at WRF, March 20 2018.
[311]Sections 4.1, 7.4 and 8.2 of this response.
[312] Sections 3.1 and 3.2 of this response and various cited statements in dWRMP19, section 8.
[313] See, for example, section 4.1 of this response.
[314] See section 11.3.
[315] See sections 7.2, 7.4 and 8.2 of this response.

The ‘What-if’ analysis is carried out on the Programme Options selected, i.e. only on a small cohort. At this stage it is not intended to *change* the Preferred Programme in any way, but only to assess the impact of a limited number of future uncertainties:

- the effect of achievement of the Environment Agency’s Water Industry National Environment Programme (WINEP);
- the possibility that certain types of resource options become available (this is limited to ‘major’ options such as DRA, Abingdon Reservoir, Re-use at Beckton;
- the population and associated demand for water in the future being lower than expected.

The Shortlisted programmes, and the ‘What-if’ variants, are all subjected to a programme-level SEA, to *“…ensure that neither the quantification of effects for the environmental metric, nor the combination of impacts from multiple options, has skewed the assessment of the environmental impacts of the overall programmes.”*[316] If this is intended to be reassuring, it can hardly be, as the same dubious practices in the individual SEAs are perpetrated in the global SEA, and this test for the ‘What-if’ scenarios merely amounts to ‘impact trading’ between large resource options.

11.6 Programme option comparisons

Plans as presented to the Public

We start this section by referring to the figure presented in the Programme Summary (page 17) which is the General Public’s main interface to the dWRMP19. It is displayed in Figure 11-3. It is worth spending some time looking at this, and trying to imagine it in black and white. Without the colour, the ‘Least Cost’ programme is almost indistinguishable from the ‘Most Sustainable’ programme – the only difference being the early presence of Deephams Re-use in the former. The ‘Most Sustainable’ programme is to be identified with the ‘Preferred Programme’ listed in the table 0-10 of the Executive Summary,[317]probably the one to satisfy 1:200 drought resilience and WRSE transfers. ***What this figure shows clearly is that all the optimisation process is merely an exercise in perturbing around the Least Cost programme, and is not a true optimisation process at all.*** The fundamental reliance on Least Cost, detailed in many places above, is made manifest in this diagram.

The four programmes shown in Figure 11-3 can be identified as the four emerging from what TW term the ‘Stage 2c’ analysis (Baseline Demand + Increased Resilience + regional WRSE transfers). These are listed in section 10 of the dWRMP, on page 45 in table 10-17.

[316] dWRMP19, section 10, 10-40.
[317] dWRMP19, Executive Summary , page 36.

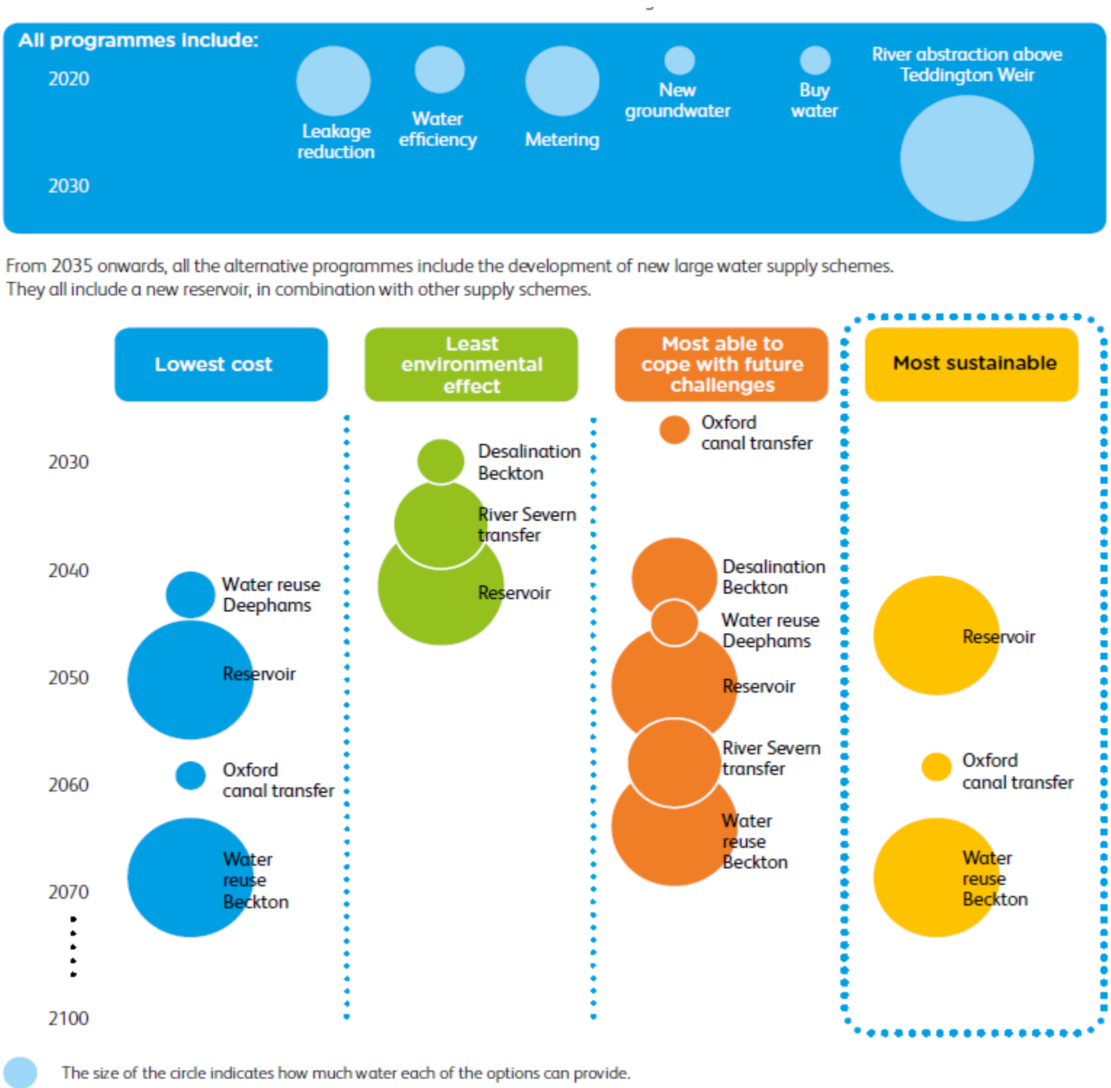


Figure 11-3: Programmes as displayed in Overview document of dWRMP19

'Least Environmental Effect' is programme 'Multi-obj_EnvC' in its stage 2c version, which is in fact nothing to do with least environmental effect in absolute terms, it is just an optimisation ***favouring*** the minimisation of environmental dis-benefit.

'Most able to cope with future challenges' is programme 'Multi-obj_FP' in its stage 2c version, which at least is labelled closer to its aim, that of ***favouring*** the resilience metric.

'Most Sustainable' is programme 'NearO_Sus' in its stage 2c version, ***favouring*** sustainability and IGEQ metric. This is classic splitting of a metric to make something look grander than it actually is. 'Sustainability' is in fact, as we have seen in Section 11.4 above, contained *within* IGEQ. The ability to optimise Sustainability is completely disabled by TW's artificially restrictive optimisation exercises of Leakage Reduction and Demand Management in IDM. There is almost literally nowhere for this optimisation to go. This is why the PolyVis plot of this optimisation[318] shows IGEQ almost untouched from the Least

[318] dWRMP19, Section 10, figure 10-13.

Cost programme (changes by 5 parts in 1000 according to table 10-17). The Customer Preference metric is actually untouched, and the cost difference from between Least Cost and NearO_Sus is only £78m in around £4.3bn. Thus we can see the 'man-in-the-street's' intuition, when faced with Figure 11-3 is actually sound.

GARD believes that the whole process of optimisation needs to be run again with:

- The implementation of the new population forecasting;
- Implementation of the Ofwat Leakage Reduction targets;
- Less constraints in IDM on the Leakage and Demand Management (this will lead to more ambitious Leakage and PCC reduction aims) ;
- Proper costing of Mains Replacement, which takes account of the capital assets maintenance budgetary contribution;
- A re-evaluation of the SEA metric for at least the major (>50 Ml/d) sources and demand management options;
- Errors of Deployable Output corrected;
- A complete Drought Resilience analysis for all the major Climate-dependent resources (essentially the STT and the Abingdon reservoir);
- A proper Adaptability analysis at the last stage.

We believe that all this is far more important than any attempt to get the IRAS_MCS model to work on these portfolios. Indeed, it is essential that TW repeat the EBSD+ analysis with this entirely new dataset. Only this will give an indication of the true sensitivity to proper optimisation of input data.

The comparative costs of selected programmes

Although we have no faith at all in the TW costings of various large projects, we note the quoted NPV for the various options of the Preferred Programme (as shown in table 0-10 of the Executive Summary):

Baseline programme	£3,709m
Baseline + Increased resilience in the Thames Water area	£4,082m
Baseline + Increased resilience in the TW area + regional (WRSE) transfers	£4,353m

A fit-for-purpose Adaptability analysis

As we show in Section 2 of this response, the Thames Water forecast of demand has too much pessimism and conservatism in the assumptions. Whilst some of this would be removed by improved population forecasts and more ambitious leakage and PCC targets, a more sophisticated Adaptability analysis with more potential scenarios considered would lead to a truly adaptable and flexible programme fit for an 80-year planning horizon.

Ability of option types to adapt to deficits lower than forecast

The ability of the main option types to adapt to uncertainties in the forecast deficit not materialising is very variable:

1. The Abingdon reservoir will become a “white elephant” if it is constructed in anticipation of a future deficit which does not materialise. The local environmental impacts of reservoir construction will be permanent and irreversible. This is a much bigger threat for the Abingdon reservoir than for the other major option types, where construction impacts will be a lot lower and less permanent. This is a large option which is not well suited to phased construction, because of repeated local construction impacts and loss of output capacity if built in two phases.

2. The Teddington DRA scheme is particularly well-suited to adjusting to different future deficits. The effluent available from Mogden will increase as demands rise. The main tunnel conduit will be over-sized for construction safety reasons, so will be able to accommodate higher flows if needed.

3. Effluent reuse and desalination schemes for London can be built in relatively small increments (say, 100 Ml/d phases).

4. With relatively short lead times and construction durations (particularly compared to the Abingdon reservoir), the Teddington DRA, effluent reuse and desalination options provide the opportunity for incremental development as the water supply deficit grows. The construction of these schemes would have relatively little permanent environmental impact (compared to the Abingdon reservoir). If the schemes turn out to be un-needed because the forecast deficit doesn’t materialise, they would simply be unused. Unlike the Abingdon reservoir, they would not be white elephants leaving an irreversible impact on the environment.

5. The Severn-Thames transfer can be built as an initial unsupported first phase and then be boosted by various support options as demands grow.

6. The demand management and leakage control options are best of all for flexibility and ‘no regrets’.

Appendix A - Teddington DRA deployable output calculations

Simulation with GARD's model of the effect of operating conditions on the Teddington DRA – present day baseline

As noted in section 4.1, GARD has run its model GARD to analyse the effects of relaxing two conditions which TW have placed on the operation of the Teddington DRA, which are considered to be unnecessary (the '30 days Emergency Storage' and the 'TW option trigger' (See section 4.1 for definitions and justifications). The analysis was run with the assumption that 300 Ml/d was available from Mogden STW.

Figures A.1 – A4 show that the scheme DO is enhanced by the omission of the unnecessary Emergency Storage and Continuous Transfer constraints. The GARD result for the existing TW operating conditions (265 Ml/d) benchmarks well with TW's analysis using WARMS2 (268 Ml/d)

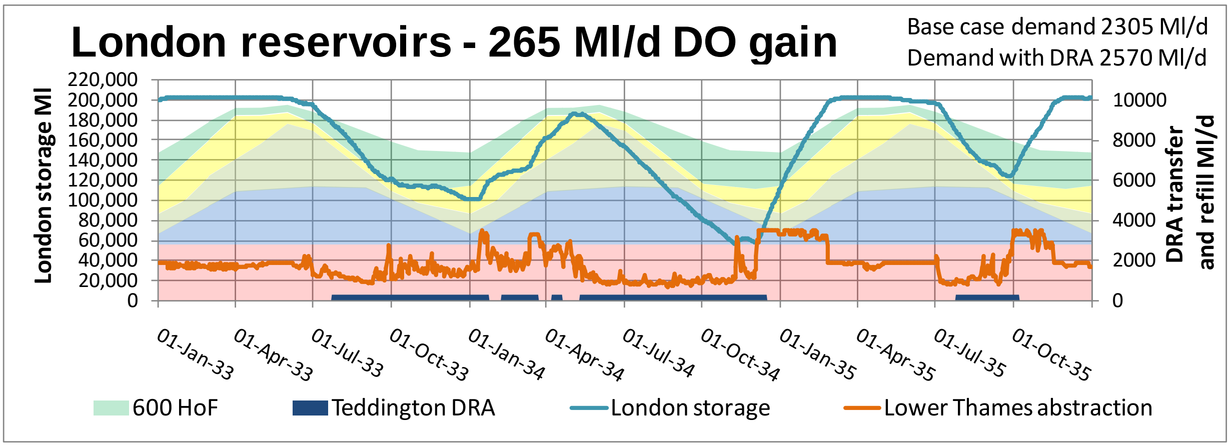


Figure A.1: TW trigger and 30 days extra emergency storage (7980 Ml)

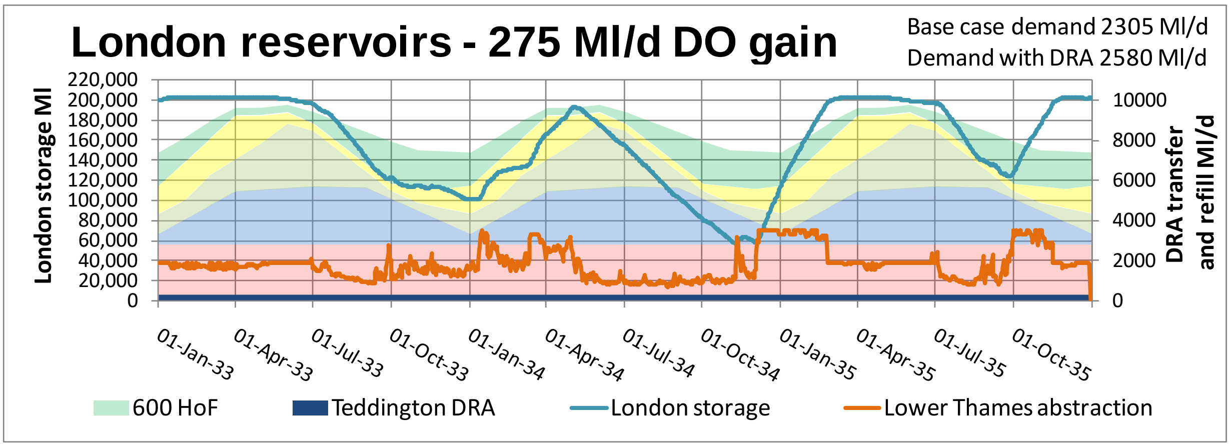


Figure A.2: Continuous transfer and 30 days extra emergency storage (8250 Ml)

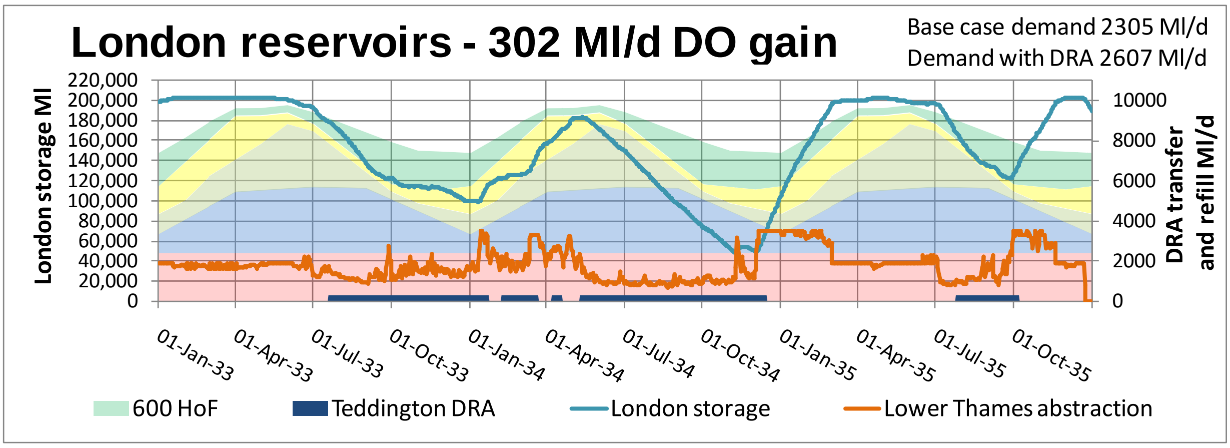


Figure A.3: TW trigger and existing emergency storage

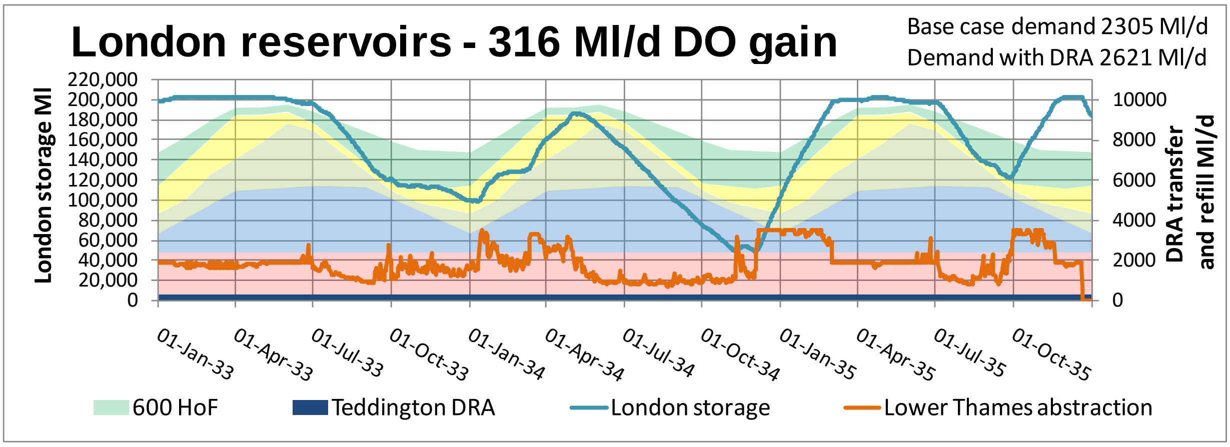


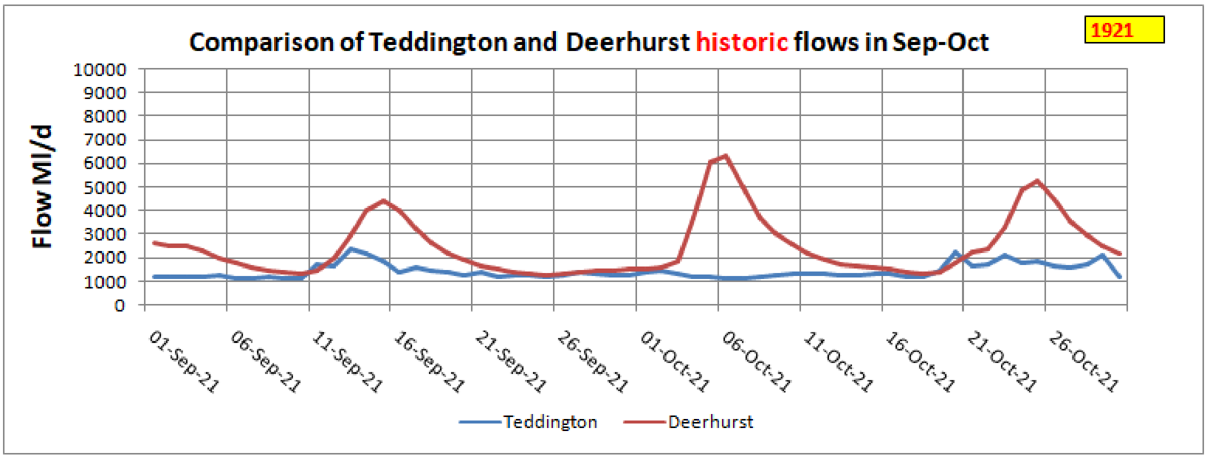
Figure A.4: Continuous transfer and existing emergency storage

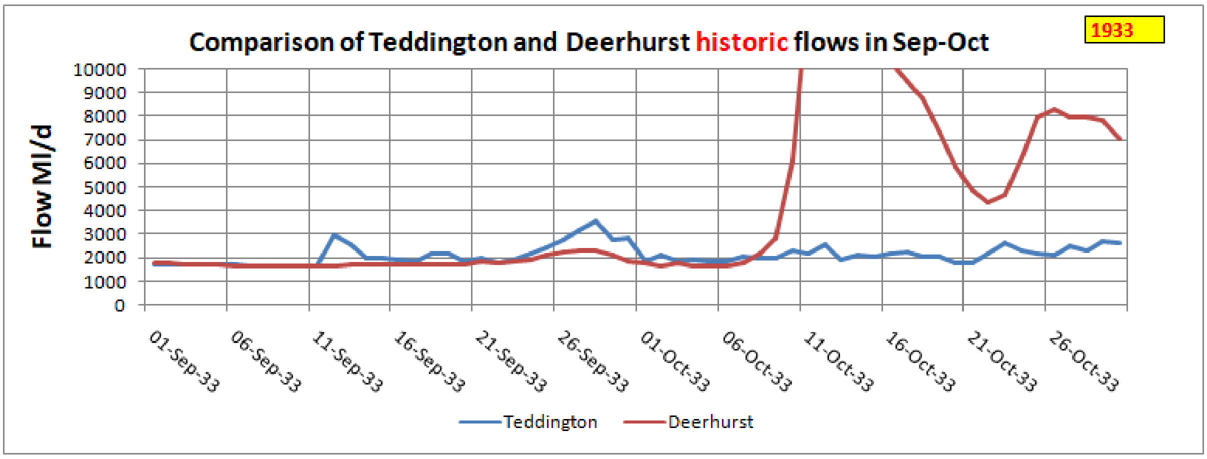
Discussion

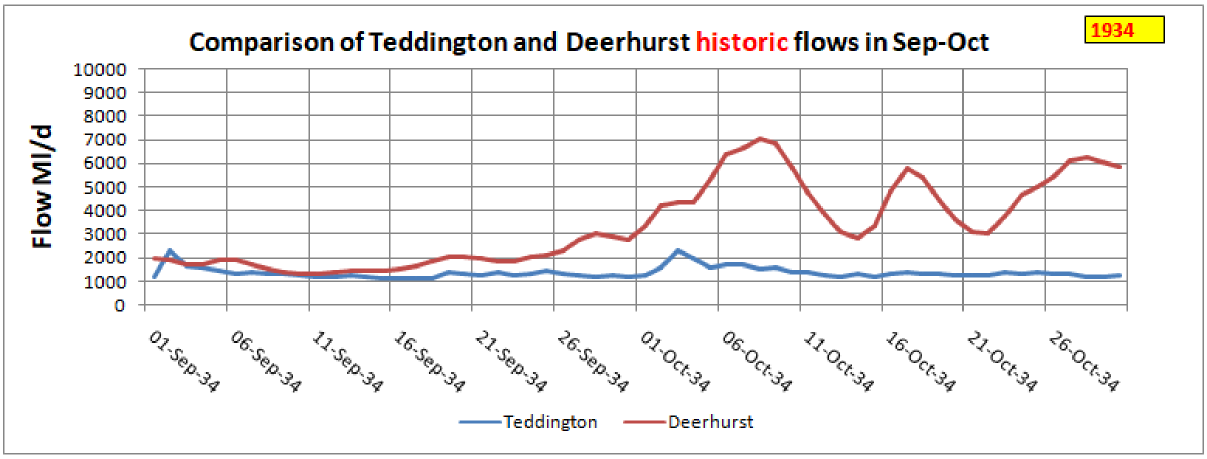
It is not obvious how a 300 Ml/d transfer of effluent can give a yield gain of more than 300 Ml/d. It is because, in droughts, the demand restrictions reduce a nominal demand by up to 14.5% (Service Level 3 TUBs in July), so in that month the 300 Ml/d at Mogden will meet a demand that would normally be 300/0.865 = 347 Ml/d, but which is reduced to 300 Ml/d by the 14.5% demand reduction. Averaged out over the drought the 316 Ml/d yield gain is 5.33% more than 300 Ml/d, so the average demand reduction over the drought was 5.33% Thus a 300Ml/d transfer flow would be able to cope with a nominal demand of 316 Ml/d. Thus, when the scheme was required to provide less than 300 Ml/d of DO it could be operated using the TW trigger. Once a higher DO is required it could be operated continuously.

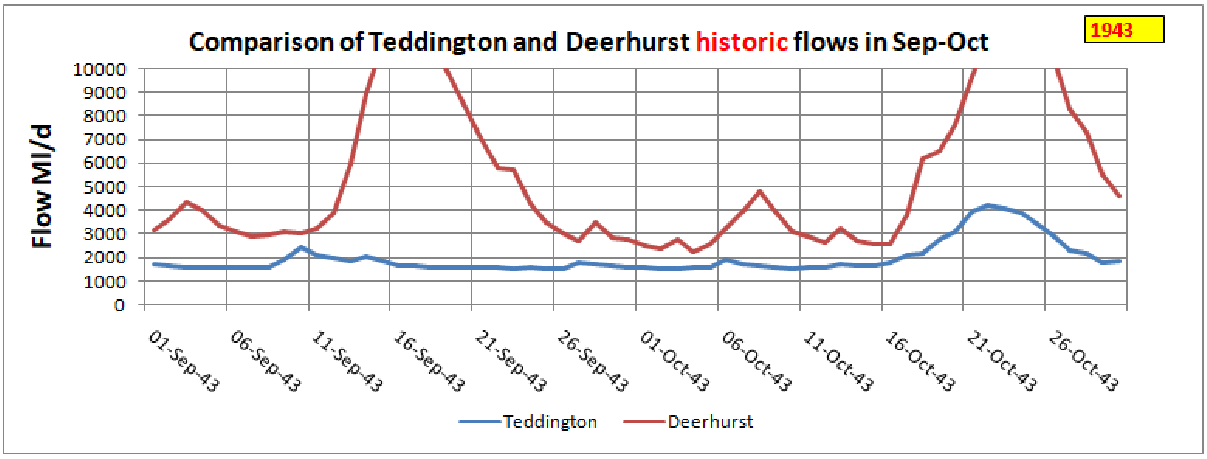
APPENDIX B – Inter-regional transfer support.documents

Contents

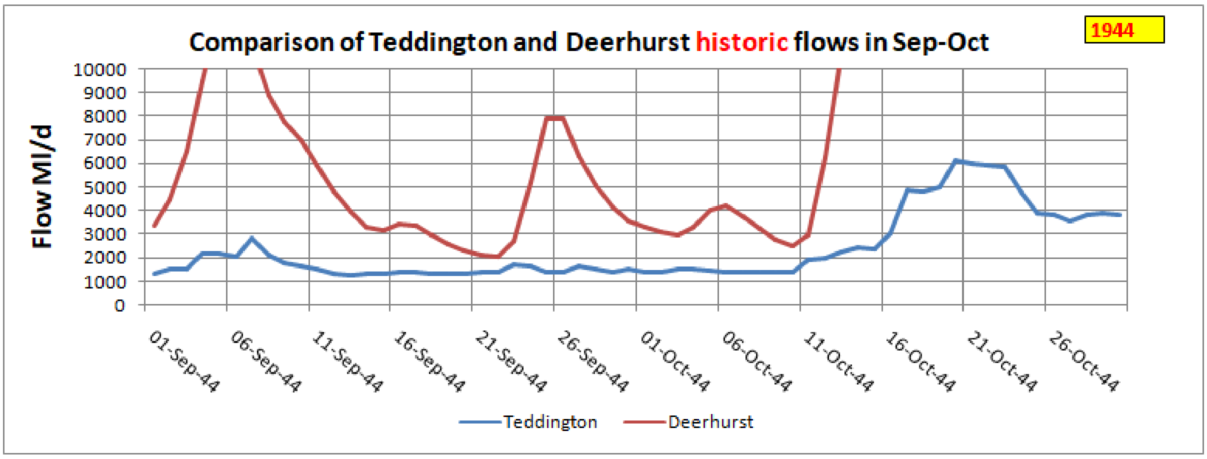


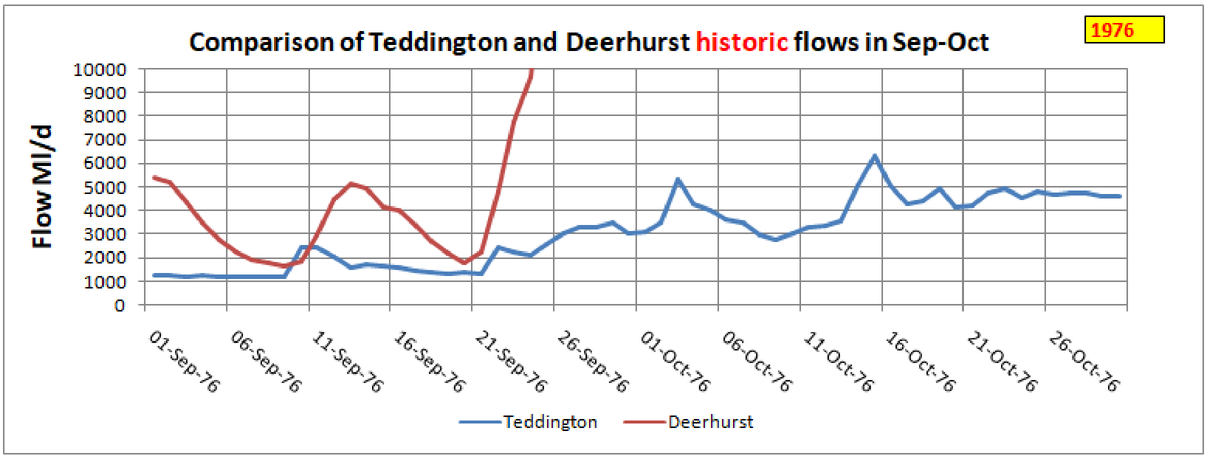


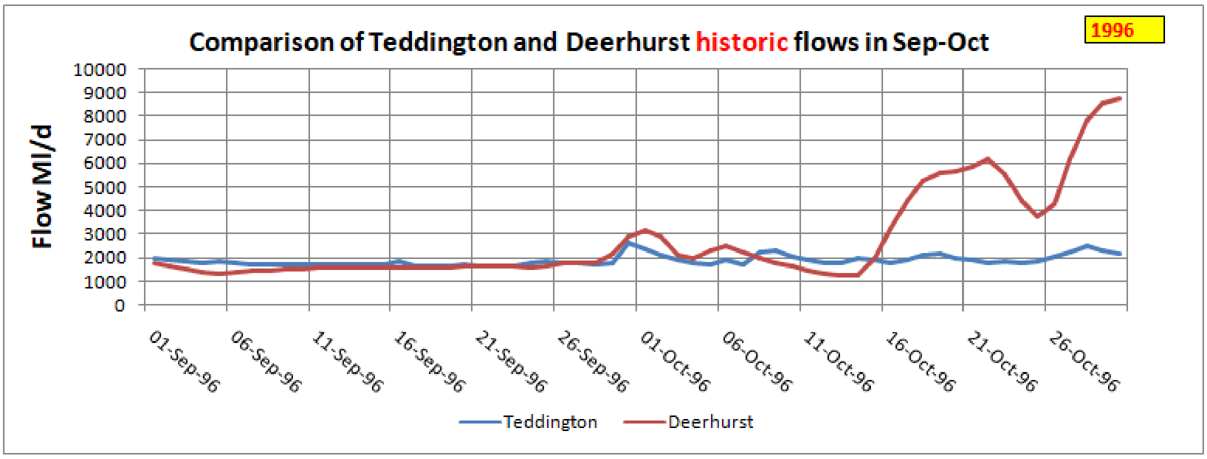


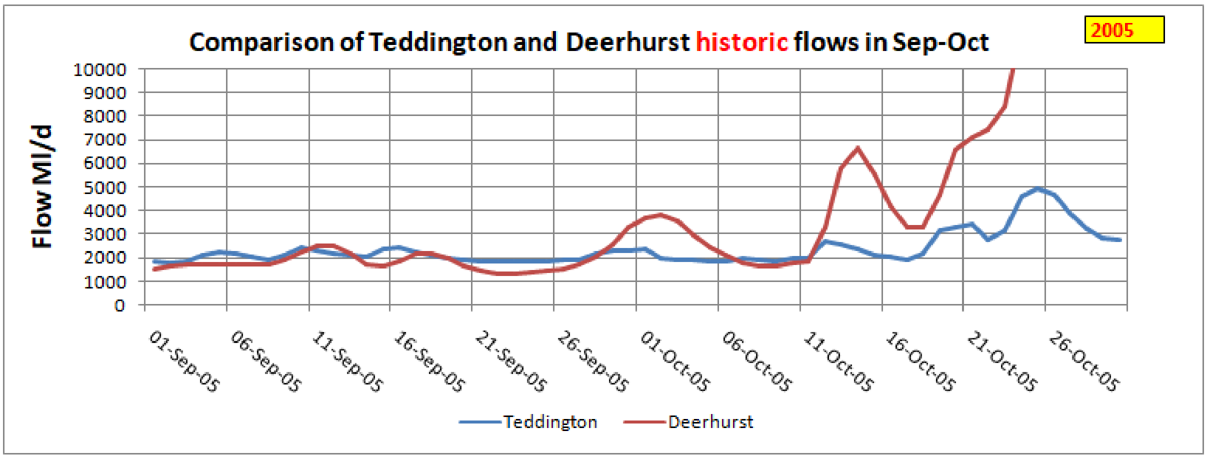


Examples of historic droughts when Severn flows recover faster than Thames in Autumn









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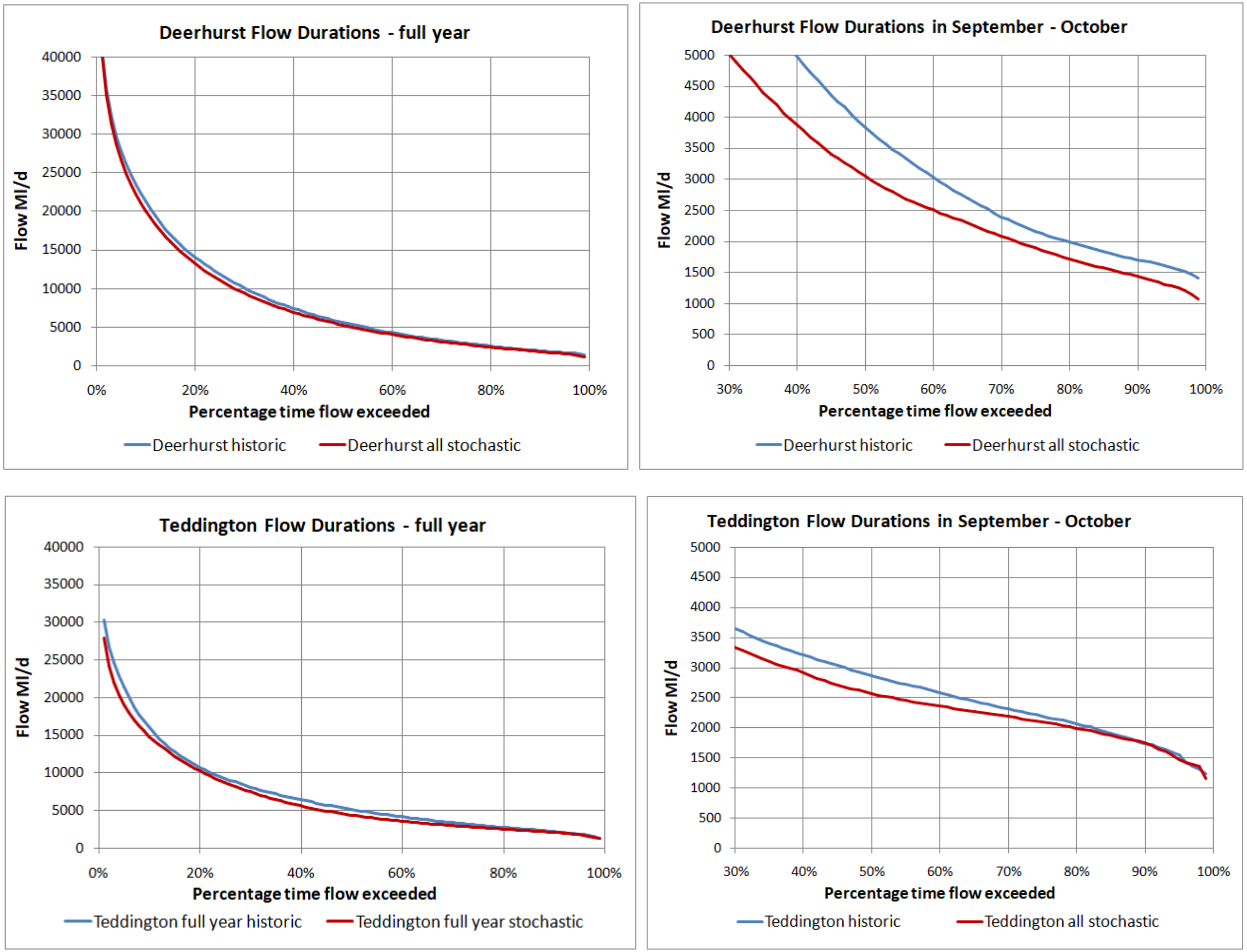


Historic v Stochastic flow durations for Deerhurst and Teddington – Full year and September-October

Brigadier NH Thompson CBE FICE
Hon. Chairman, GARD
Stock's Lane Farm
Steventon
Abingdon
OX13 6SS
Tel: 01235 832077

Mr Richard Aylard
Thames Water
Clearwater Court
Vastern Road
Reading
RG1 8DB

10th April 2016

Dear Mr Aylard

The "Columbus" scheme

At our meeting on 3rd March 2016, it was said that Natural Resources Wales were unlikely to support the "Columbus" scheme, making use of spring water pumped from the Severn rail tunnel. However, Thames Water were said to be working with NRW to confirm the position.

Please could you raise the possibility of Columbus supplying Thames Water indirectly by the arrangement shown on the attached schematic map and comprising:

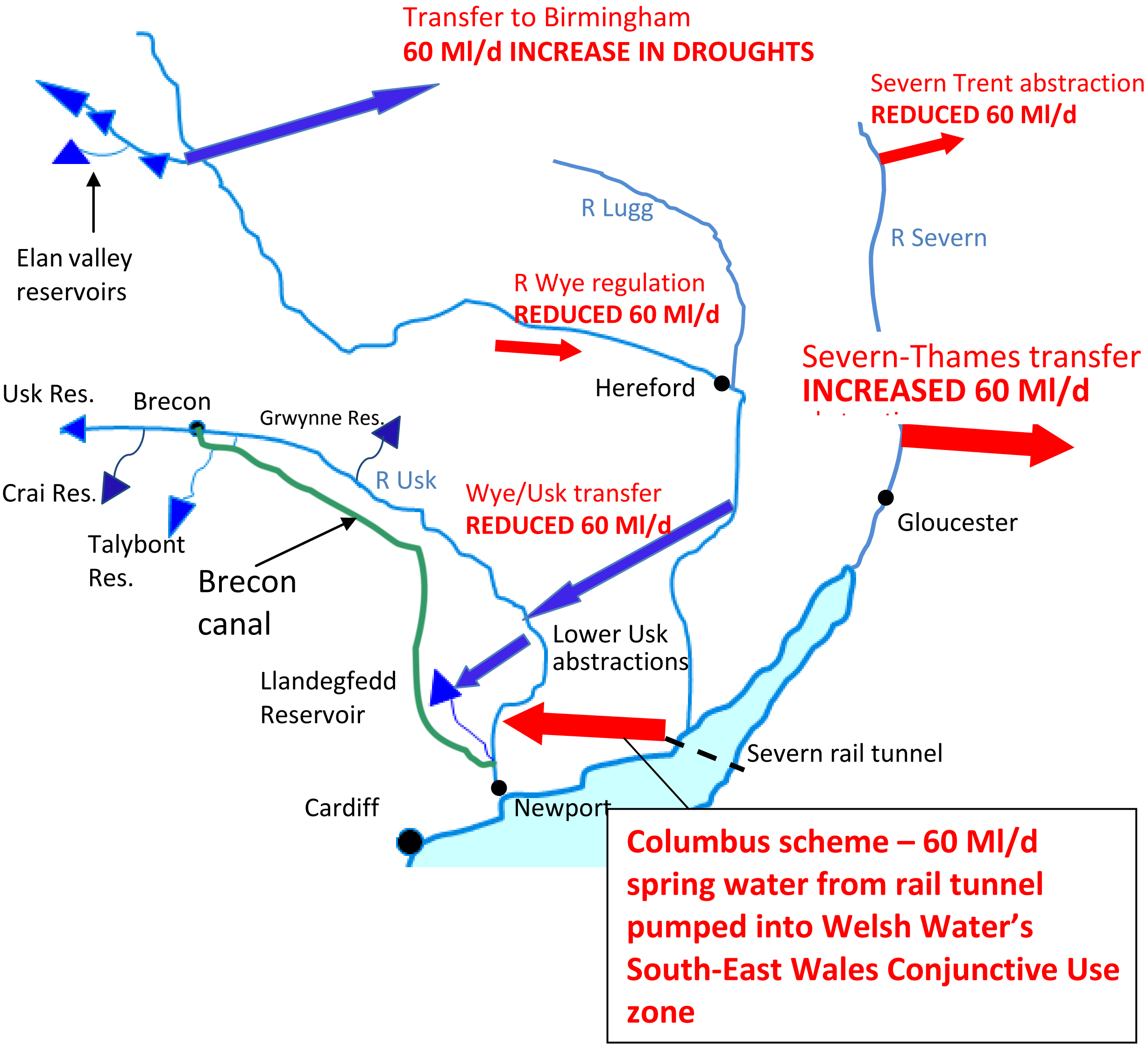
- Say, 60 Ml/d of spring water from the rail tunnel fed into Welsh Water's South-East Wales conjunctive use zone (SEWCUS).
- Supply from the Wye to SEWCUS via the Wye-Usk transfer reduced by 60 Ml/d
- Regulation from the Elan dams to support the Wye-Usk transfer reduced by 60 Ml/d
- Supply to Birmingham via the Elan aqueduct increased by 60 Ml/d in droughts (it is cut back in droughts under current licence conditions)
- Severn Trent abstractions from the Severn reduced by 60 Ml/d in droughts (not needed if Elan supply is increased), making available...
- Additional 60 Ml/d of water for Thames Water via the Severn to Thames transfer

This option may be more palatable to NRW and the Welsh Assembly than a direct supply of 60 Ml/d from the tunnel to Thames Water. The introduction of 60 Ml/d of Severn tunnel water into the South-East Wales supply system would introduce options for improved management of abstraction from the Rivers Wye and Usk, both of which are aiming for more natural flow regimes under the Habitats Directive.

Yours sincerely

Nick Thompson

Brigadier NH Thompson, CBE, FICE   Hon Chairman GARD



Schematic arrangement of "Columbus" scheme, supplying 50 Ml/d to Thames Water

Appendix A – Correspondence about Severn regulation losses

-----Original Message-----

From: Richard Bailey [mailto:RABailey@btinternet.com]

Sent: 01 December 2006 11:51

To: LawsonJ@halcrow.com

Subject: REGULATION OF THE RIVER SEVERN

Hello John,

I was so pleased to see you a couple of weeks ago at the CIWEM structured training scheme event. You asked about 'regulation losses' and I was intrigued to find out more, so have spent a day or more researching.

I looked in my files and contacted Richard Cross at the Environment Agency in Solihull. Dickie started work with me at Severn Trent Water Auth'y Resources Dept. after graduating in 1984 and is now the Officer in Charge of operating the regulation system on the River Severn for the Environment Agency.

I have established that less than 10% of water released during a significant regulation period is not used for the purpose of regulation. As you know, such water benefits the river environment on its way to the sea. The Severn is a system with minimal bankside storage to even out minor fluctuations (Chelmarsh reservoir at Hampton Loade is the only one). A system with storage in the lower reaches would be even more 'efficient'.

So the figure of 90% losses you said was quoted in connection with the new Thames Reservoir is inaccurate.

I would be pleased to continue this research if it is of interest to you.

All good wishes,

Richard

RICHARD BAILEY

Adviser in Water & Environmental Management Birds Farm, Twyning, Glos GL20 6DF Tel/Fax 01 684 298 268

-----Original Message-----

From: Richard Bailey [mailto:RABailey@btinternet.com]

Sent: 01 December 2006 11:30

To: Richard Cross

Subject: REGULATION OF THE RIVER SEVERN

Hello Dickie,

Many thanks for your attention to my queries on drought in the middle of recent flood events. T'was ever thus.

I have rearranged the data you kindly sent. May I attach two tables - an Overview and Details. These show that the actual releases made, which are subsequently not required for river regulation, are generally less than 10% of all releases during a regulation period - when more than half of Llyn Clywedog's storage (25,000 Ml) is required.

When there are more intermittent periods of regulation during insignificant dry summers, the amounts can increase to 20% but this is not really relevant in the design or operation of the system.

I do recall calculations of similar figures for significant droughts in 1975, 1976 and 1984 and would be interested in following this up later.

As I mentioned, John Lawson of Halcrows Swindon was interested this such analysis and I have passed my tables to him.

All good wishes,

Richard

RICHARD BAILEY

Adviser in Water & Environmental Management Birds Farm, Twyning, Glos GL20 6DF Tel/Fax 01 684 298 268

SUMMARY OF REGULATION OR RIVER SEVERN

NOTES

Year			Ml
1967	Llyn Clywedog starts filling	capacity	50,000
1973	First tests of groundwater discharged from Shropshire		
1975	Lake Vyrnwy used for river regulation		
1978	Bewdley residual flow changed to a 5-day average of 850 Ml/d		

COLUMN 1	2	3	4	5	6	7	6 + 7
Year	**Period of alert**	**First day of Regulation Last day of Regulation**	**Regulation Period**	**Amount released**	**Amounts released which abstractors did not take**	**For operational hydroelectric generation and maintenance**	**Not required for river regulation**
			Days	Ml	%	%	%
1975							
1976			121				
1984							
1989	June - October		125	48,600		3	3
1990	May - September			36,952			0
1994	31 May - 15 Sep	17 Jun - 8 Sep	68				
1995	5 May - 23 Nov	17 Jun - 11 Nov	124	41,290	4		4
1996	17 Jun - 28 Oct	25 Jun - 15 Oct	73	33,702	2	3	5
1997	4 Apr - 13 Oct	19 Apr - 6 Oct	29	3,695	7		7
1998	19 May - 8 Oct	14-Aug	1	450			0
1999	27 May - 27 Sep	11 Jul - 16 Sep	33	13,132	6		6
2000	21 Jun - 29 Sep	22 Aug - 7 Sep	11				
2001	11 Jun - 3 Oct	1 Aug - 30 Aug	6				
2002	12 Apr - 16 Oct	16 Jul - 13 Oct	70	16,381	10	10	20
2003	11 Apr - 17 Nov	16 Jun - 28 Oct	88	26,494	12		12
2004	19 May - 4 Oct	9 Jun - 3 Aug	23	6,107	5	1	6
2005	19 May - 25 Oct	9 Jun - 26 Sep	63	20,567	6	2	8
2006	8 Jun - 12 Oct	21 Jun - 30 Sep	82	27,022	9	0	9

SUMMARY OF REGULATION OR RIVER SEVERN

ALLOCATION OF RELEASES TO SPECIFIC PURPOSES - values given as a % of total volume released during regulation period

NOTES

1. The travel time from Clywedog or Vyrnwy Dams to the Control Point at Bewdley is 3 to 4 days. From Shrophire Groundwater is is 2 days.
2. Flows are Bewdley are affected by artificial changes (abstracted amounts) and natural changes (caused by rainfall).
3. Forecast flows at Bewdley 3 to 4 days ahead are based on forecast abstractions and Agency forecast runoffs from Met Office forecast rainfa
4. Sometimes abstractors take less than they forecast. There is no bankside storage of river water (only one site has storage) to even out ch
5. Sometimes actual runoff is more or less than forecast using Met Office rainfall and Agency hydrological models.

Year	**To support abstractions upstream of Bewdley**	**To support abstractions downstream of Bewdley**	**Amounts released which abstractors did not take**	**Amounts released but more runoff than forecast**	**Amounts released but more rainfall than forecast**	**To alleviate environmental pollution and tidal ingress**	**For operational hydroelectric generation and maintenance**		
	Bewdley Residual flow maintained at 850 Ml/d	**Bewdley Residual flow maintained at 850 Ml/d**		**caused Bewdley Residual flow to exceed 850 Ml/d**	**caused Bewdley Residual flow to exceed 850 Ml/d**		**Not required for river regulation**	**Total**	**Amount released**
	%	%	%	%	%	%	%	%	Ml
1975									
1976									
1984									
1989	48	30		7	12		3	100	48,600
1990	56	33		5	6			100	36,952
1994								0	
1995	46	4	4	9	11	26		100	41,290
1996	46		2	9	9	31	3	100	33,702
1997	56	7	7	11	19			100	3,695
1998								0	450
1999	44	28	6	4	2	16		100	13,132
2000								0	
2001								0	
2002	30	11	10	17	17	5	10	100	16,381
2003	44	14	12	13	7	10		100	26,494
2004	67	7	5	13	4	3	1	100	6,107
2005	50	20	6	10	4	8	2	100	20,567
2006	48	19	9	16	7	1	0	100	27,022