Thames Water

Final Water Resources Management Plan 2015 - 2040

Main Report

Section 10: Scenario Testing

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Section 10 Scenario Testing

In this section we look at the robustness of our preferred programme and how it performs when tested with alternative future scenarios. We tested six different scenarios for London that impact supply, demand or the cost of potential options.

The results show that the plan is flexible to small changes in planning assumptions. However, the plan is sensitive to any moderate to large deterioration in the supply demand balance that could occur as a result of future sustainability reductions and to the occurrence of extended severe droughts, which independent research has demonstrated are a plausible scenario associated with climate change.

The solution to any deterioration would be to bring forward the planned demand management activity (if feasible), and develop remaining small groundwater and aquifer storage schemes. A large deterioration could be addressed by developing further re-use capability, although this may not provide the best value solution in the long-term. The work confirms the need to examine alternative long-term options such as storage and regional transfer options, in addition to wastewater re-use, as potential solutions over the next five years 2015-2020.

The plan is less sensitive to improvements in the supply-demand balance. Such changes alter the timing of implementation of schemes that make up the preferred programme plan but would not change our overall strategy, which focusses on demand management before resource development.

10.1 Overview

A water resources management plan should provide a robust basis for a water company to make decisions and plan for the future. However, the future is uncertain and will be affected by many variables. In our plan we include an allowance for some uncertainties within our target headroom element of the supply-demand balance, but there are a number of future uncertainties that are not included in this allowance and are therefore evaluated separately.

In this section we present the results of six different scenario tests on our London plan to determine how sensitive the plan is to future uncertainties. These are: (1) sustainability reductions, (2) changes in baseline deployable output, (3) gradual change in the supply demand balance linked to population growth and climate change, (4) using a 50 year planning horizon, (5) optimism bias in scheme costs, and (6) increases in power costs. We explain the rationale for the selection of these scenarios. The scenarios selected cover the biggest risks in the plan and cover a range from maximum to minimum impact. We have used the scenario tests to:

- Test whether the plan is robust to small changes in the supply-demand balance
- Understand the impact of the main areas of uncertainty (excluded from headroom) on our plan

- Ensure that we have not planned on a worst case scenario
- Identify which sources of uncertainty have a large impact on the plan and therefore require greater focus throughout the plan period

The Water Resources Planning Guideline (WRPG) requires that the company assesses the impact of increased abstraction on the Water Framework Directive (WFD) requirement for flow status. We have made an assessment of the impact in Section 10.5.

The recent 2010-2012 drought exposed potential weaknesses in the existing processes for assessing the impact of climate change on supplies, in that simply perturbing the historic record of rainfall and evaporation may not adequately reflect how the system might respond to multi-year droughts not present within the historic record. We have examined this further in Section 10.6.

10.2 Scenario Testing

10.2.1 Future Uncertainties

In developing our scenario tests we examined the key uncertainties in our plan. We examined the source of uncertainties based on:

- results of the headroom analysis
- factors that are outside the company control
- information on the uncertainty of key components in our plan
- scale and timing of any impact

Through this process we identified six key uncertainties in our plan. These are detailed below together with an estimate of the likely impact and our judgement on the likelihood of occurrence.

- Environmental Requirements/Sustainability Reductions in London

  Scale: -100 to -175Ml/d

  Likelihood: Medium -100Ml/d; low -175Ml/d[1]

[1] We use the term low meaning <25% chance, medium 25-75% and high >75%. These estimates are based on judgement taking into account the evidence available.

The baseline forecast of water available for use included a reduction resulting from both the confirmed and likely sustainability reductions provided by the Environment Agency (see Section 4). However, the NEP3 data received from the Environment Agency in August 2013 indicated that a potential reduction of existing abstractions in London WRZ beyond 2020 may be required. The data showed a potential level of future sustainability reduction that could be up to 175Ml/d for London. The scale of the impact in London is potentially large and a key uncertainty given the current forecast deficit and tight supply-demand balance over the planning period. Given the 'seriously water stressed' classification of our water supply area, the forecast increase in population and resultant stress on resources, and the potential impact of climate change on surface water sources, additional sustainability reductions are likely to be required if Water Framework Directive objectives are to be met. Work undertaken to date on the lower Thames abstractions suggest that the level of reduction may not be justified when the resulting costs are considered. Consequently we have also elected to model a lower reduction of 100Ml/d. We have taken a judgement on the likelihood of occurrence based on the results of studies undertaken to date and our knowledge of the local environment where possible reductions in abstraction have been identified.

This uncertainty arising due to 'unknown' sustainability reductions is not included in Target Headroom.

10.3 Baseline Deployable Output in London

Scale: +/-25Ml/d, +/-50Ml/d and +/-100Ml/d

Likelihood - unknown

Our baseline deployable output for London is derived from analysis of historic records of rainfall, evaporation and flow (see Section 4). This is a key component of the supply-demand balance. Given the forecast deficit in London at the start of the planning period it is important to understand how the plan could change if the baseline deployable output was higher or lower than current estimates. The Group Against Reservoir Development (GARD) has asserted that deployable output in London may be higher than our estimate by as much as 200Ml/d based on its analysis of river flow records[2]. This has not been confirmed and an independent review of London's DO by HR Wallingford found little evidence to support GARD's assertions and concluded that Thames Water's DO estimate was fit for purpose.[3] Nevertheless, given the importance of the baseline DO position on the plan, this is a key uncertainty against which to test the robustness of the plan. Whilst we expect to continuously update our deployable output estimates we cannot estimate the likelihood of a particular value occurring.

[2] GARD Response to Thames Water's Consultation on the Draft Water Resources Management Plan 2014.

[3] HR Wallingford (July 2013) Thames Water hydrological model review. Addressing comments from GARD (Final Report) MAM6468-RT013-R03-00

Uncertainty on supply-side data is already included in Target Headroom however the impact is small. GARD's challenge relates to a step change in deployable output from better information and is not included in Target Headroom. HR Wallingford's independent review of the low flows simulation in the WARMS model is reported separately[4] and only a brief summary is given here. Further details are included in Appendix I.

HR Wallingford has confirmed that Thames Water adopts industry standard practice in its DO calculation. The Kingston gauging station on the River Thames, which GARD has used in its analysis, meets British standards and is classified as 'good'. Errors are around +/- 8% which could be significant for DO assessment. The review notes that the WARMS model is operating as expected and DO runs from WARMS can produce lower natural flows than have been observed. However, comparison of these outputs with observations also shows that the difference from natural flow highlighted by GARD can be explained as the sum of differences between modelled and observed abstractions and gauged flows. HR Wallingford concluded that this highlights the difference between design conditions and actual conditions and the effects on flows and it is not a major cause for concern as long as the differences can be explained and the modelling assumptions are clear. HR Wallingford listed a number of uncertainties that may individually increase or reduce DO by -4% to +6% (c.-85 to 129 Ml/d). They suggested that the main uncertainties on natural flows related to choice of demand profiles and application of the LTCD which appear to be the main controls on the amount abstracted and the volume of water allowed to flow over Teddington Weir in the model. In this regard, the review highlighted the benefits of producing verification files for the Upper Thames Water Balance Model, in addition to the London Reservoir Model files which are currently produced. Thames Water's development of its new WARMS2 model in AQUATOR will make modelling assumptions more transparent and the overall DO assessment easier to audit by third parties. A detailed work programme to complete the enhancement and updating of the WARMS model is given in Appendix I.

It is valuable to assess the change in baseline deployable output as this is also equivalent to assessing the impact of a change in levels of service. An increase in deployable output of +50Ml/d is equivalent to bringing in all restrictions early because to bring in all restrictions early provides a benefit to deployable output of approximately 50 Ml/d; in the same way a decrease of 100Ml/d is equivalent to imposing no restrictions (Appendix I).

- Gradual change in the supply-demand balance (climate change/population growth/demand management savings)

  Scale: up to +/- 10% or 200Ml/d over 25 years

  Likelihood: low for 200Ml/d but medium for 100Ml/d

[4] HR Wallingford (July 2013) Thames Water hydrological model review. Addressing comments from GARD (Final Report) MAM6468-RT013-R03-00

The results of our Headroom analysis showed population growth and the impact of climate change on resource availability as key future uncertainties. The success of the demand management programme in London is not fully within the control of the company yet the plan is dependent on delivery of the forecast reductions in demand. These uncertainties would unfold over time rather than result in a step change in the plan.

Given the uncertainty of these factors and that they are key drivers in the plan, it is sensible to test the sensitivity of the plan to a gradual change in the supply-demand balance that could be due to one or both of these effects being worse than forecast. For symmetry, the plan should also be tested against improvement to the supply demand balance. There is some overlap between this uncertainty and the factors included in Target Headroom because Target Headroom has not been reassessed for each scenario[5]. This is recognised in the findings and therefore needs to be considered when interpreting the results.

With regard to population growth, in Section 3 we present the forecasts using plan based, trend based and most likely estimates. For London, there is a large range in the population forecast by the end of the period between three estimates (circa. 0.7million or approximately 95Ml/d). Our plan is built on the lowest population forecast and hence there is a key risk of demand being higher than forecast.

With regard to climate change, the results in Section 5 show these could have an impact in excess of 50Ml/d on the plan with regard to uncertainty (see Figure 5-10).

With regard to demand management, the plan includes savings of over 230Ml/d in London, including water use reduction associated with the introduction of sophisticated tariffs linked to metering.

We have chosen to model scenarios of +/- 10% or 200 Ml/d over the 25 year planning period.

- Taking a longer planning horizon

  Scale: 50 years

  Likelihood: N/A

Our programme appraisal examined the planning problem over the 25 year period from 2015 to 2040. A key uncertainty in the process is how the plan performs if a longer planning period is assessed. The impact of lower, or higher, demand or resource after the 25 year planning period could affect the decisions in our plan. For example, if demand beyond the 25 year planning period were to reduce, is the most appropriate plan to develop resource schemes in the 2025-2030 period?

This uncertainty is most significant in London WRZ as the plan includes a large resource scheme from 2027.

Consequently, we chose to model a 50 year planning horizon to examine the potential impact

[5] Effectively the same uncertainty profile exists around the supply/demand forecast used in the scenario test as existed around the supply/demand forecast used in the base assumption.

- Optimism Bias (cost estimates for schemes)

  Scale: varies

  Likelihood: low for large changes

The uncertainty around the capital construction costs of new options has been dealt with through the process of optimism bias as set out in Government guidance[6]. This process adjusts the initial estimate of cost of an option based on the confidence in the ability of the scheme as designed; it is discussed further in Section 7. In our programme appraisal we have used the most likely estimate of cost. However, costs could be higher or lower. London has the highest level of investment in our plan and is the most sensitive to changes in option costing. Testing how the plan changes to higher or lower costs of resource schemes is a key uncertainty. As many of the resource schemes are options we have experience of delivering, there is a low likelihood of capital scheme costs being materially different from that set out in the plan. The exceptions are large wastewater re-use, large water transfers and large storage options where the costs of these schemes can change significantly.

This cost uncertainty is not included in our estimate of Target Headroom.

- Power Costs

  Scale: up to 35p/KWh (estimate on assumption of at least a doubling of the DECC forecast)

  Likelihood: medium for small increase, low for very high increase

Power costs for water supply are becoming an increasing proportion of the overall annual operating costs each year. Our plan assumes power costs of 10.3p/KWh in the base year increasing to 13.38p/KWh by 2030 and uses the central estimate from DECC forecasts[7]. However, given the forecast shortfall in the capacity of the energy market in the 2015-2020 period, changes in wholesale energy prices could be significant[8].

The provision of water in our area uses approximately 490,000KWh/yr in power. Changes in the unit cost of power is a key future uncertainty and key cost impact on the business. This uncertainty bites most acutely in London as it is where c75% of our total water demand is concentrated and hence the majority of our annual power cost.

Long-term power costs cannot be reliably forecast but we consider the likelihood of power costs being greater than forecast to be a realistic scenario.

This uncertainty is not included in Target Headroom.

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[6] HM Treasury, Green Book, 2003

[7] DECC provide low, medium and high forecasts for three sectors: domestic, commercial and industrial. Our plan uses the central industrial forecast.

[8] http://www.telegraph.co.uk/finance/newsbysector/energy/9590905/Ofgems-blackout-warning-raises-fears-for-industry.html

Two further key risks to the plan were also identified. These were:

- The preferred plan of metering in Thames Valley from 2020 not being accepted by regulators.
- The rollout out of innovative tariffs in AMP7 not being accepted by customers/benefits not being realised

Neither of these risks were taken forward for scenario testing as the impact of both of these uncertainties is discussed in the programme appraisal process in Section 8.

10.3.1 Scenario Testing and Key Findings

From the data above we developed a range of scenarios. The structure and nature of these scenarios means that the plan is tested to sensitivities that have both gradual and one off impacts on the supply demand balance as well as testing the sensitivity of the plan to changes in cost.

The scenarios tested are summarised in Table 10-1 and a summary of each scenario is in Appendix X.

The scenario testing was only applied to London. As outlined above the key uncertainties in the plan applying to the Thames Valley have been discussed through the programme appraisal.

The key findings from the scenario testing on the preferred plan were:

1. **Environmental Requirements/Sustainability Reductions (-100 to -175Ml/d)**

The plan for London is sensitive to large sustainability reductions in the long-term.

Wastewater re-use, transfers and storage all feature depending on the scale of any additional sustainability reduction. At high levels of reduction, the scenario testing identified that multiple resource options are required to close the supply-demand gap.

The results show that additional demand management above that in the preferred plan is not selected. This is because it is less cost effective than resource options at higher levels of savings due to the diminishing returns. High sustainability reductions in the future reinforce the need for demand management early in the programme. This occurs in all the programmes tested. If decisions are made on sustainability reductions in the short-term, the plan has flexibility to accommodate these as there is sufficient lead time.

2. Change in base deployable output position (+/-25 Ml/d, +/- 50Ml/d, +/- 100Ml/d)

The plan is robust in the short and long-term to increases in Deployable Output due to its flexibility. Small increases in the short-term can be accommodated by flexing the timing of schemes.

Increases in baseline deployable output changes the timing of the demand management savings. The higher an increase in deployable output in the short-term, the fewer demand management measures are selected as there is less of a supply-demand driver. Even with large increases in base deployable output the plan remains a mix of demand management first followed by a resource scheme in the future, albeit with changed timing – indicating that the strategy in our preferred plan is appropriate.

The plan is however sensitive to any moderate or significant reduction in baseline deployable output. Even modest reductions lead to an unresolved supply-demand deficit for the start of the planning period.

3. Gradual change in the supply-demand balance (climate change/population growth/demand management) (+/- 200Ml/d or 10%)

The plan is robust to gradual improvements in the supply-demand balance due to its flexibility. A gradual increase in the supply demand balance avoids the need for a large water resource scheme in the longer term. The plan is sensitive to moderate reductions in the supply demand balance in the short term and medium term. If the supply demand balance deteriorates, higher levels of resource development are needed, with an additional 185Ml/d of wastewater re-use required in the period 2020-2030.

4. Taking a 50 year planning horizon

If long term demand increases beyond 2040, then the solution is more resource development rather than additional demand management.

A reduction in long term demand beyond 2040 would mean that no more resource schemes or demand management options would be chosen from 2040. Even with a large drop off in demand after 2040 the plan still needs schemes around the 2030 period to be resilient.

5. Optimism Bias

Removing resource scheme optimism bias or using alternative bias profiles did not have a material impact on the general size and shape of the plan. The programmes selected under these scenarios contained high levels of demand management in the short term and the profile and type of resource schemes in the long term remained stable. This suggests the preferred programme of implementing demand management first before resource development is a robust strategy.

6. Power Costs (35p/KWh)

The preferred plan is robust to increases in power costs due to the heavy demand management focus. That is to say, that whilst increases in power costs increase the overall cost of the programme, they do not change the ordering or type of scheme in the preferred plan. Due to the inclusion of a reverse osmosis wastewater re-use scheme in the preferred plan, higher power costs increase the cost of the preferred programme in the long term. It is unlikely that power costs - on their own - would change the long term solution away from re-use. Plans based on storage are the least sensitive to future increases in power costs.

10.3.2 Observations on Scenario Test Results

Drawing together the results from the scenario tests for London and the programme appraisal (Section 8), a number of observations are drawn on the preferred plan:

Minor changes and moderate changes in the supply-demand balance

- Due to the forecast supply-demand surplus in a number of WRZs, the plan in Thames Valley is robust to minor changes in the supply-demand balance and moderate changes in the medium term.
- The plan for London is robust and flexible to minor changes (<10Ml/d) in the supply demand balance in the short term.
- The plan for London is robust to moderate improvements (c50Ml/d) in the supply demand balance in the medium term as schemes can be accelerated or decelerated.
- The plan for London is sensitive to any moderate or significant reduction in the supply-demand balance in the short or long term. This reinforces the need for our plan to a) focus on demand management in the short term to ensure that long term supply resilience can be maintained, and b) suggests that considering a range of options for the long term is a justifiable and flexible response to the uncertainties evaluated.

Main risks in the plan

- Long-term sustainability reductions, moderate or large derogations in the supply-demand balance from climate change/population or lower than expected demand management savings are considered the key risks in the plan. These uncertainties result in significant additional resource requirement in the latter half of the planning period in London if they materialise.
- However, these risks are gradual or arise in the future and as such they can be planned for and monitored given that our plan is flexible.
- The focus of the plan on demand management in the short term positions the plan well to manage these uncertainties should they occur[9].

[9] With an early programme of demand management savings, if these outturn at lower than expected savings this option will have been exhausted before other resource solutions that cannot be so easily stopped and started are

Worst Case scenario

- Our plan has used the lower end of the potential population forecasts and has excluded uncertain sustainability reductions in London and the Thames Valley.
- No adjustment has been included in our plan for the non-delivery of demand management measures, yet in the short-term these account for approximately 80% of our deliverable plan in London.
- From the analysis we have undertaken we do not consider we have planned for a worst case scenario, rather that we have planned for a representative scenario within a range of plausible outcomes highlighted by our scenario analysis.

Factors that have a large impact on the plan and impact on timing of decisions

Three key factors have a large impact on the plan:

- The long-term sustainability reductions for London.
  For cost-effective planning, a decision on the long term sustainability reductions for London is needed in time for WRMP19 to ensure that we can provide for future resilience that is affordable and deliverable[10]. Our judgement is that the likelihood of large scale sustainability reductions (175Ml/d) is low.

- Any significant reduction in our supply-demand balance in the short-term for London.
  This would affect security of supply. Improvements in the supply-demand balance up to moderate levels do not affect the components of the plan, just the timing. The focus on demand management early in the programme helps deliver long-term flexibility.

- The proposed rollout of full household metering in Thames Valley from 2020 is not supported as the most appropriate long-term water resources plan solution.
  Whilst this decision does not affect the cost of our plan in the short-term, and our plan is flexible in the long-term to adopt other solutions, the support or otherwise of metering across the whole of our area in a staged way as set out in our plan is significant in terms of customer messaging and sustainable water use. If other plans are deemed more appropriate then early visibility is required as we would need to reflect this in our messaging on water efficiency and potentially the regional communication on water stress in the South East and the WRSE regional water strategy.

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commissioned. The demand management activities such as metering also provide additional indirect benefits in the plan through improved targeting of mains replacement.

[10] Based on minimising cost alone high additional sustainability reductions would introduce multiple wastewater re-use schemes. The queuing of such options may not be deliverable in practice.

Table 10-1: Scenario Tests – Description and Results

Risk	Scale	Estimated Likelihood	Description	Findings	Impact on Cost compared to least cost plan (Total NPV)	Is it significant to the plan? Short-term	Long-term
Sustainability reductions	-100 to -175Ml/d	Medium-low	Tested the plan against sustainability reductions of 100 and 175Ml/d in 2027. Range reflects the potential impacts of future WFD and low-flow study requirements	• At 100Ml/d the least cost plan would include 245Ml/d of wastewater re-use by 2040. • At 175Ml/d, the least cost plan would include 300Ml/d of wastewater re-use. • In both scenarios such high levels of re-use may not be achievable in practice. • Storage and transfers options are chosen if water re-use is not available.	+ £140m to £320m	No. Impact only affects long-term solutions.	Yes. Given the significance for the plan, a decision on the long-term level of sustainability reductions is needed prior to WRMP19.

Risk	Scale	Estimated	Description	Findings	Impact on Cost compared to least cost plan	Is it significant to the plan?	
		Likelihood			(Total NPV)	Short-term	Long-term
Baseline Deployable Output	+/-25Ml/d +/-50Ml/d +/-100Ml/d	Unknown	Tested the plan against changes in baseline deployable output of +100, +50, +25 and -25 -50, and -100Ml/d. Range reflects the possible uncertainty associated with the estimation of DO	• Plan is not robust to reductions in deployable output. • For 100Ml/d reduction the deficit would last until 2017/18. • An increase in DO changes the profile of demand management in the short term. • When the increase in DO is 100Ml/d, wastewater re-use is still chosen but at a reduced volume later in the planning period.	-£470m to +£560m[11]	Yes – for any reduction. Partially – for increase. The rate of implementation of demand management activity is reduced in the short term.	Yes - for all reductions No - for increases. Increases would change the timing of schemes and scale of water re-use but occurs in AMP7 and beyond.

[11] Cost is higher than Sustainability Reduction scenario as the deficit occurs earlier in the programme.

Risk	Scale	Estimated	Description	Findings	Impact on Cost compared to least cost plan	Is it significant to the plan?	
		Likelihood			(Total NPV)	Short-term	Long-term
Gradual change in the supply-demand balance (Climate change/population growth/demand management)	+/-10% or 200Ml/d	Medium-low	Tested the plan against gradual change of +/-1% in 2015/16 to +/-10% in 2040 in the supply-demand balance. Change equate to +/- c200Ml/d by 2040.	• Improvements in supply demand balance reduce the amount of demand management in the short term. • Long term reduction in the supply demand imbalance prevent the need for a long term resource scheme • Derogation in the supply-demand balance brings in 185Ml/d more water re-use in the 2020-2040 period.	-£610 to +£670m[12]	Yes – if position deteriorates Partial – if position improves. Overall level of demand management reduces in the short term.	Yes if position deteriorates Plan has flexibility to reduce long-term water re-use if not needed, but deterioration in the supply demand balance drives more resource needs.

[12] Upper cost is higher than WFD scenario as the deficit occurs earlier in the programme. And higher than the baseline DO assessment as the loss in supply-demand balance is larger.

Risk	Scale	Estimated	Description	Findings	Impact on Cost compared to least cost plan	Is it significant to the plan?	
		Likelihood			(Total NPV)	Short-term	Long-term
Taking a 50 year planning horizon	50 years	N/A	Testing the plan to increases or decrease of 200Ml/d in the supply-demand balance between 2040-2065	Plan not sensitive to reductions in demand post 2040. Schemes would scale down in size prior to 2040 Increases in demand bring in further resource schemes post 2040. Additional demand management is not selected in either case.	£110m to £390m	No	No But results reinforce that additional demand management is not chosen above the preferred plan.
Scheme costs	Range	Unknown	Removal of optimism bias and change in profile.	Demand management still retained early in the programme. No change away from wastewater re-use solution.	-£10m to +£150m	No	No

Risk	Scale	Estimated	Description	Findings	Impact on Cost compared to least cost plan	Is it significant to the plan?	
		Likelihood			(Total NPV)	Short-term	Long-term
Power costs	costs to 35p/KWh	Medium-low	Testing the plan to an increase in power costs from 10p/KWh (2012/13) to 35p/KWh (by 2030)	Level of demand management retained early in the programme. Wastewater re-use still chosen as long term solution.	+£40m	No.	Partly Wastewater re-use has a higher energy footprint and the cost to customer is higher as opex impact.

10.4 Impact of Preferred Plan on Water Framework Directive Requirements

The WRPG requires water companies to assess the impact of the WRMP on the compliance with the WFD requirements for flow status. This is required for new options and for any potential increased use of existing sources.

No specific guidance has been provided on how this should be achieved for potential increased use of existing sources within existing licence limits. This requirement has been discussed with the Environment Agency and it was agreed to adopt a high-level approach for the assessment. Thames Water has therefore not undertaken a detailed assessment of the likely impact of the increased use of existing sources on compliance with WFD flow status at this time and is awaiting guidance from the Environment Agency on how this should be conducted.

The high-level approach has been used to provide examples of how the assessment might be undertaken. The approach adopted has been to review existing abstraction licences to identify those that have not used their full licence limit in recent years and therefore have the potential for significant increase in use in the future. This assessment has been based on a review of licences where the use in the last five years has been less than 90%. This high-level analysis has identified two examples at sources at Fobney in Reading, which abstracts from the River Kennet, and at Shalford near Guildford, which abstracts from the River Wey. These are only examples and further analysis will identify all the other sources with less than 90% use over the last 5 years. These sources have the potential for significantly increased abstraction in the future. This has then been compared with the current WFD Environmental Flow Indicator (EFI) values at Q95 (Q95 is the term used to specify the flow in the river that would be exceeded 95% of the time on average). The Environment Agency has provided information on the surplus flow available above the EFI at Q95 under current abstraction conditions. This has enabled a comparison of the average unused licence volume over the last 5 years with the surplus available flow at these two sources. The comparison is shown in the following table.

Table 10-2: Comparison of unused licence and available flow above the EFI at Q95

Source	Average unused licence over last 5 years [Ml/d]	Surplus at recent actual abstraction scenario (Ml/d)
Fobney	35	58
Shalford	14	110

This data shows that in both cases if actual abstraction at Fobney and Shalford is increased to full licence it will not result in all the surplus flow being utilised for abstraction and that surplus flow would still remain in the river.

Clearly this approach would need to be extended to cover all sources with the potential for increased abstraction. However, the examples used in this high-level approach demonstrate that for two of Thames Water's licences where the largest potential exists for an increase in abstraction there is low risk to the WFD flow status. This suggests that throughout Thames Water's supply area there is a low risk that future increased use of existing licences will result in deterioration of WFD status.

Thames Water will undertake further analysis when guidance is received from the Environment Agency. This will also include consideration of downstream water bodies.

From the high-level assessment undertaken, future increased use of existing licences will not result in deterioration of WFD flow status and is therefore unlikely to drive significant sustainability reductions in existing licences. In any case the Restoring Sustainable Abstraction Programme (RSAP) has identified the abstraction sources where there is a concern relating to the impact of abstraction on low flows and these have been or are being addressed. Therefore no further scenario analysis has been undertaken to assess this impact beyond the assessment of the confirmed, likely and unknown sustainability reductions identified by the EA in the NEP.

Our preferred plan aims to reduce the demand for water over the planning period compared to that which would otherwise occur. The options in the plan are therefore not considered to cause an adverse impact on the WFD requirements on flow status.

10.5 Impact of Extreme Droughts

As discussed in Section 5, the methodology used to determine the impacts of climate change on DO follows the WRPG. However, there are some limitations to this approach, particularly with respect to understanding the resilience of the current or future system to different types of droughts that might occur under climate change, such as longer and more widespread droughts that are not represented in the historical record but are possible under future climate change scenarios.

The recent 2010-2012 drought exposed potential weaknesses in the existing processes for assessing the impact of climate change on supplies, in that simply perturbing the historic record of rainfall and evaporation may not adequately reflect how the system might respond to multi-year droughts not present within the historic record. This risk will not be robustly captured within Target Headroom. Thames Water is reliant on groundwater sources and groundwater dependent river flows for a substantial proportion of its supplies. These sources respond slowly to variability in rainfall meaning that rainfall deficits of up to two years can often be buffered by groundwater storage. However, prolonged droughts beyond this period can pose a serious problem as once groundwater stores become depleted, recharge also takes a considerable time to restore groundwater levels.

The WRPG encourages further sensitivity testing of proposed supply demand improvements and we have therefore examined resilience of the Thames Water system to such future extended droughts using the Future Flows and Groundwater Levels data (CEH, 2012)[13]. The data consists of a large volume of climate and river flow data for future climate scenarios which can be used in water resources planning. It was published by the NERC Centre for Ecology and Hydrology (CEH) and the NERC British Geological Survey in 2012 and in addition to NERC, the project was co-funded by the Environment Agency, Defra, UK Water Industry Research and Wallingford HydroSolutions.

The Future Flows and Groundwater Levels project has produced two unique datasets (Future Flows Climate and Future Flows Hydrology) using the latest climate projections from the UK Climate Impact Programme, including UKCP09 probabilistic climate projections, run under the medium emission scenario. The datasets represent a nationally consistent ensemble of 11 plausible realisations (all equally likely) in river flow and groundwater regime of nearly 150 years (1951-2098). Future Flows Hydrology projects daily river flow and monthly groundwater level time series for 282 river catchments and 24 boreholes in Great Britain using Future Flows Climate as the driving data. It is the first available river flow and groundwater time series characterising climate variability and change from 1951-2098 and can be used to assess water related impact studies.

[13] Centre for Ecology and Hydrology Natural Environment Research Council (2012) Future Flows and Groundwater Levels: British projections for the 21st century

Thames Water commissioned HR Wallingford to examine the Future Flows Hydrology dataset for the River Thames catchment to investigate the potential occurrence of more extended, severe droughts than those which have occurred in the historical record used for water resources planning, namely the period 1920-2010. This work was undertaken as part of the sensitivity testing used to examine the robustness of the preferred plan against future uncertainties that are not robustly captured in the prescribed WRPG methodology. The detailed results of this work are given in two reports[14] [15] and an overview of the findings and the application of the Future Flows scenarios to the London WRZ is presented here.

In the investigation, flow in the River Thames at Kingston was selected as an indicative hydrological indicator of dry conditions in Thames Water's resource system. The following steps were undertaken:

- Development of a drought indicator to represent extended drought conditions.
- Application of the drought indicator to both observed flows and Future Flows to test for the occurrence in the historical data set (baseline) and how the pattern of such events might subsequently change for the near term (2001-2050) and long-term future (2051-2100).
- Identification of plausible extended drought scenarios beyond the range of those experienced in the baseline and the subsequent use of these river flow scenarios to test the robustness of the preferred plan.

A simple flow indicator to characterise extended severe droughts was developed. This is the six month mean daily flow over the winter months (October to March inclusive), averaged over three consecutive winters. Although dry winters and a lack of aquifer recharge is the primary driver for extended droughts, it is also important to understand the intervening summer periods as dry winters punctuated with wetter than average summers may mitigate to some extent the effects of a dry winter. Therefore a similar indicator for three year average summer flow (April to September inclusive) was also developed. Figure 10-1 shows these indicators plotted against each other for the full period of the River Thames at Kingston naturalised flow record (1883 – 2010). Four years in particular cluster at the driest end of the indicator scale. These are years in which, over the three preceding summers and winters, flows have been substantially below average. The majority of these events occurred between 1890 and 1910 and this indicates that this type of severe extended dry period may not be well represented in the data record used for the WARMS analysis (1920–2010). This type of extended drought therefore merits further consideration as it presents patterns of drought which, with climate change, may result in a change in behaviour of the water resource system such that it becomes a critical drought for DO.

[14] HR Wallingford 2012 Thames Water Three Dry Winters Scenarios. Investigation of the potential for a three dry winter scenario for water resources planning. Technical Note MAM6468-11

[15] HR Wallingford 2013 Thames Water Three Dry Winters Scenarios. Using Future Flows to test climate resilience. MAM6468-RT012-R02-00

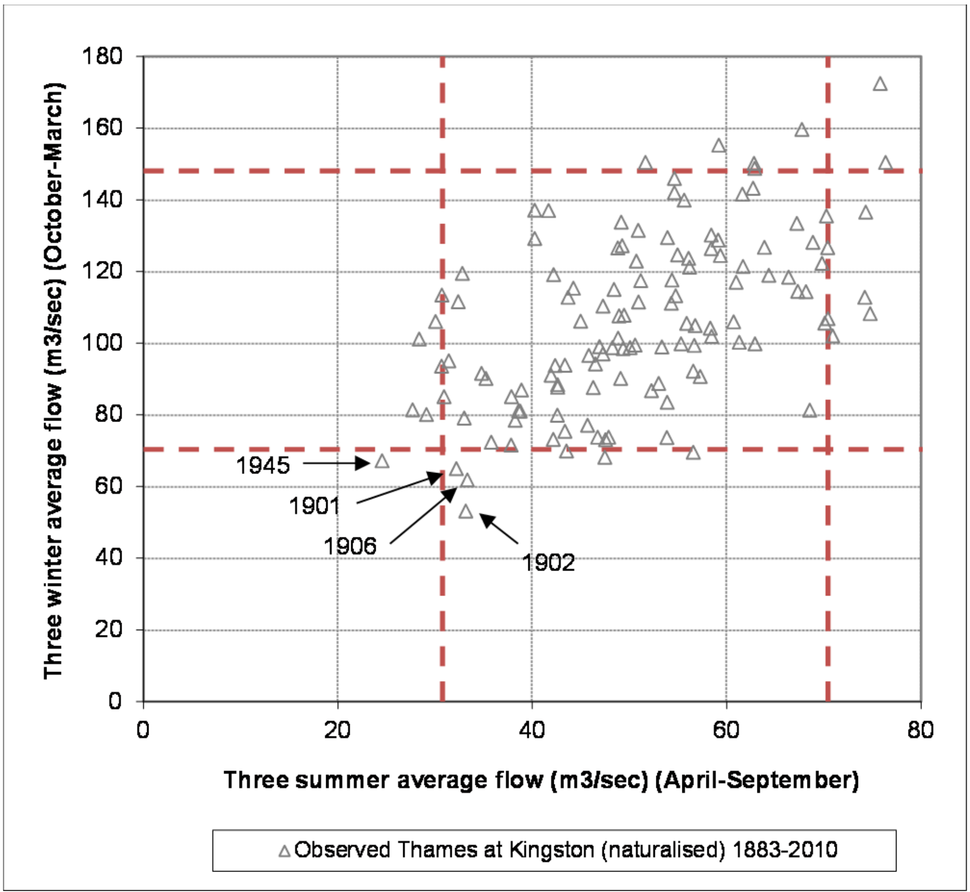

Figure 10-1: Plot of three dry winter and three dry summer indicators for the River Thames at Kingston naturalised observed flow, the 5th and 95th percentiles for three year average summer and winter flows are provided as dashed lines

It is important to understand how the three dry year sequences could change in the future as climate change progresses. This has been examined by comparing change in drought characteristics in the Future Flows flow series between the baseline period (1951-2000) and the near-term future (2001-2050) and long-term future (2051-2100). Table 10-3 gives a high level view of how the Future Flows projections of three winter and three summer flows are changing. The table gives minimum three year summer and winter flow in the baseline period for each of the Future Flows scenarios and then the number of years in which this minimum is exceeded in each of the two future periods. If no changes occurred in extreme droughts between time periods a value of 0 or 1 would be expected. If drier extreme conditions are projected these events would be projected to occur more often. The table indicates that for three year dry summer events, 6 of the 11 Future Flows scenarios show an increase above what would be expected in the number of extreme events in the 2001-2050 period. In the three year dry winter events, 3 of the 11 projections show an increase in 2001-2050. Although only 3 projections show an increase in extreme dry winters, this nevertheless indicates that drier winters are a plausible outcome of climate change as modelled in the Future Flows regional climate models. The study also examined percentage changes in three winter and summer flows relative to the baseline. When examining the near-term future, the changes in dry years (5th percentile) seem to be more severe than the average changes (50th percentile), indicating a greater increase in the number of extreme dry years than average changes in flow conditions.

Table 10-3: Number of Future Flows projections in which extreme droughts are more common than seen in baseline conditions

Note the column headers represent the 11 Future Flow scenarios

	afgcx	afixa	afixc	afixh	afixi	afixj	afixk	afixl	afixm	afixo	afixq
Three summer minimum average flow 1951-2000 (m^3/sec) baseline	38.5	31.8	39.2	38.7	39.1	31.1	26.5	35.3	38.4	37.7	36.5
Number of years below baseline minimum 2001-2050	0	1	2	1	2	3	0	0	3	2	2
Number of years below baseline minimum 2051-2100	2	0	0	0	0	1	0	3	4	5	1
Three winter minimum average flow 1951-2000 (m^3/sec) baseline	70.1	51.7	63.2	59.7	57.7	54.2	43.0	52.2	67.7	57.7	43.8
Number of years below baseline minimum 2001-2050	1	5	0	0	0	3	0	0	3	0	0
Number of years below baseline minimum 2051-2100	1	0	1	0	0	1	0	0	4	0	0

The analysis has confirmed that the Future Flows dataset contains periods of prolonged drought, more severe than those seen in the historical record. It should be noted that these sequences are at the extremes of the Future Flows dataset, on the basis of selecting a small number of scenarios within a modelled time period of 50 years across 11 ensemble members. Figure 10-2 shows that the top 10 three year dry winter drought sequences from the Future

Flows scenarios sit outside the range of historic flows seen in the River Thames[16]. This illustrates that simply perturbing the historic record of available data will not capture the full range of possible droughts and potential impacts on river flows.

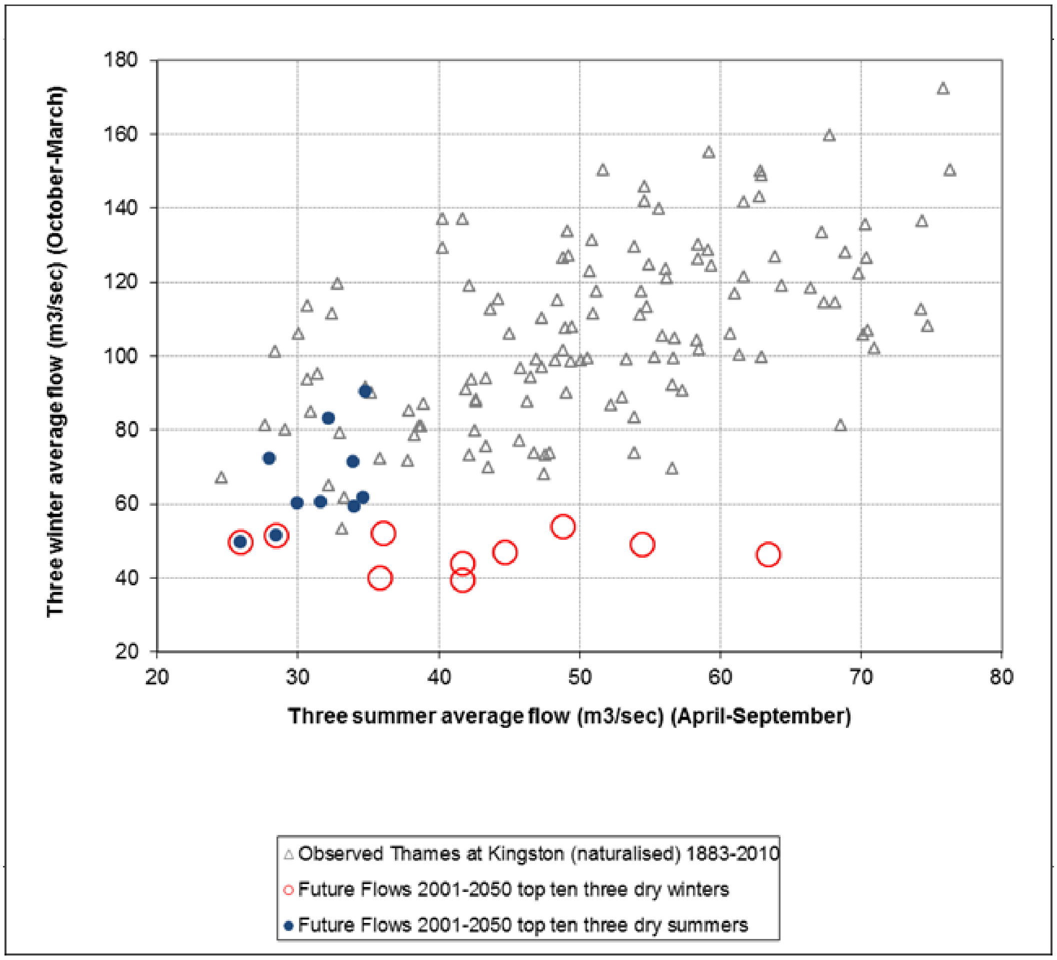

Figure 10-2: Scatter plot of Future Flows 2001-2050 top 10 three dry winters and summers for the River Thames at Kingston versus historical record

The flow records from the extended drought periods that were identified in the Future Flows scenarios have subsequently been applied to our own water resources simulation modelling to assess what this might mean in terms of the resilience of future water supply. The Future Flows flow series have been applied directly in the water resources model, rather than using the hydrological models built in to the water resources modelling system. Therefore any differences in the hydrological modelling approaches between Future Flows and Thames Water resources modelling approaches will be carried through to the projection of reservoir levels. Figure 10-3 uses Future Flows flow scenario afixa river flow data for the early 2040s and applies them to the current water resource system in London. The results demonstrate that severe water use restrictions would result in these circumstances, with level 4 water use restrictions being

[16]It should be noted that the hydrological models used to develop the Future Flows scenarios have been shown to produce drier winter flow conditions across the baseline period, hence the drier winters shown in Figure 2 may be a combination of model bias and the impact of climate change.

required for a period of a number of months. Figure 10-4 uses Future Flows flow scenario afixa river flow data for the early 2040s and applies them to the preferred plan water resource system. It is clear that even in these circumstances whilst the period of occurrence of severe water use restrictions is reduced, the measures in the preferred plan do not entirely mitigate the risk.

The analysis represents initial use of the Future Flows Hydrology and further research is required to examine the resilience of the Thames Water system. Whilst the Future Flows 2040s drought presents a plausible scenario[17] for 'stress testing' the Preferred Plan it has a low chance of occurring, even under future climate change scenarios.

The work has demonstrated that the 2040s drought has a low probability with a return period certainly in excess of 1 in 200 years, and approximately 1 in 700 years based on analysis of a single climate model run ('afixa')[18]. This compares to a company level of service that states that standpipes and rota cuts should never be required and a standard for flood defences in London of 1 in 1000 years. Even though the likelihood of this event is very low the fact that it is plausible presents a significant risk because the consequences of failing to supply water are very high for London and the national economy.

The work using Future Flows demonstrates the importance of continuing to examine all three long-term large water resource options to ensure the most robust, resilient solution is identified to deliver the best value plan. Thames Water is sponsoring EngD research at University College London which, in cooperation with the University of Manchester, is investigating alternative multi-criteria performance assessment modelling techniques to facilitate comparison of different water supply strategies against a wide variety of performance measures across multiple future scenarios. The IRAS-2010 model[19] is able to quickly test large numbers of alternative water supply strategies under different potential futures against a wide range of decision criteria. For the WRMP collaborative research between HR Wallingford, University College London and the University of Manchester assessed the performance of the wastewater re-use based preferred plan against alternative plans based on the River Severn unsupported transfer and the Upper Thames reservoir storage. These large water supply options were evaluated against a range of reliability, cost and environmental metrics, and future climate change and socio-economic scenarios. The findings are detailed in a separate report[20] and only a high level summary is repeated here.

[17] It is important to note that the Future Flows data sets provide plausible future scenarios not predictions or long term forecasts. Therefore the timing of this drought is not a prediction that a severe drought will occur in 2043/44; instead it provides evidence that such droughts are possible at the end of the planning period in the 2040s.

[18] HR Wallingford Thames Water recurrence intervals. Calculating future flows drought recurrence intervals MAM6468-RT014-R01-00 June 2013

[19] Evgenii S. Matrosov, Julien J. Harou Simulating the Thames Water resource system using IRAS-2010. International Environmental Modelling and Software Society 2010, Ottawa, Canada

[20] HR Wallingford Thames Water Water Resources Support. Testing the robustness of Thames Water's dWRMP to future climate change MAM6468_RT015_R01_00 November 2013

The report presents an improved assessment of the performance of all three plans, including the major sensitivities suggested in Ofwat's PR14 guidance[21]. The IRAS model "stress tests" the three plans against 11 Future Flows scenarios and 3 simple socio-economic futures that represent different rates of economic growth, sustainability reductions and energy costs. The headline findings show that opting for the higher capital cost Severn-Thames transfer or Upper Thames Reservoir schemes improves reliability, reduces risk and enhances environmental flows. In addition the reservoir reduces operating costs and carbon emissions compared to both the Preferred Plan and transfer programme. Overall the transfer programme exhibits marginally better performance against the resilience, reliability, supply deficit and eco-deficit objectives while it performs worse against environmental and social cost, carbon emissions and energy requirements. The storage programme shows the best performance in relation to operating costs and operational carbon emissions.

The main findings are as follows:

- Both the Severn-Thames transfer and Upper Thames Reservoir perform better than the preferred plan in terms of reducing risk and providing improved levels of service under all future climate change and socio-economic scenarios. In some cases performance is very similar across all three options but under others there are significant differences.

- Both the Severn-Thames transfer and Upper Thames Reservoir perform better than the preferred plan in terms of maintaining environmental flows on the River Thames. In general the transfer performs very well but there are some flow conditions where flows will not be available from the Severn when they are needed in the Thames due to widespread low flow conditions. This assessment does not consider any water quality or ecological implications for either the Thames or Severn. A significant volume of work is yet to be completed examining the water quality and ecological implications of mixing raw water from the lower Severn with that of the upper Thames linked to the potential transfer option, and as such there is an asymmetry in the supporting information relating to the two different options.

- The Upper Thames Reservoir performs better than the preferred plan and transfer plan in respect to operational costs and carbon emissions due to the high energy use of reverse osmosis and greater rates of pumping for the transfer. This does not consider issues around embedded carbon or the capital costs of these schemes. Both the preferred plan and transfer programmes are highly sensitive to energy costs.

As clearer climate change trends and energy price signals emerge over the next five years the baseline costs and benefits, reliability and risks associated with the different large water resource options will change. It is vital therefore that Thames Water maintains an adaptive approach and avoids locking itself into a plan, which although least cost today may be very expensive and less reliable under some potential future scenarios. Our final WRMP14 specifies detailed studies to be undertaken over the next five years to determine the 'best value' large resource option in time for our next WRMP in 2019 (Section 9). Furthermore, the EngD research that Thames Water is sponsoring at University College London in collaboration with the University of Manchester will continue to develop and enhance sophisticated modelling tools that will robustly facilitate assessment of the alternative water supply strategies against a wide variety of performance measures across multiple future scenarios.

[21] Ofwat Setting price controls for 2015-20 – final methodology and expectations for companies' business plans July 2013

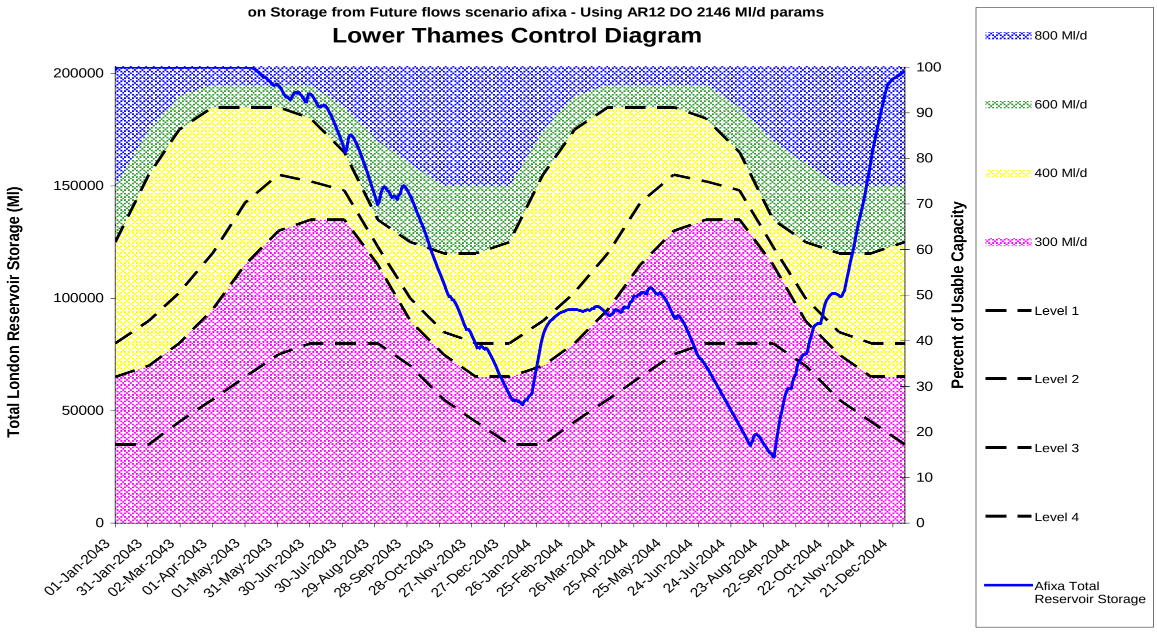

Figure 10-3: Application of Future Flows Scenario afixa to the existing water resource system in London

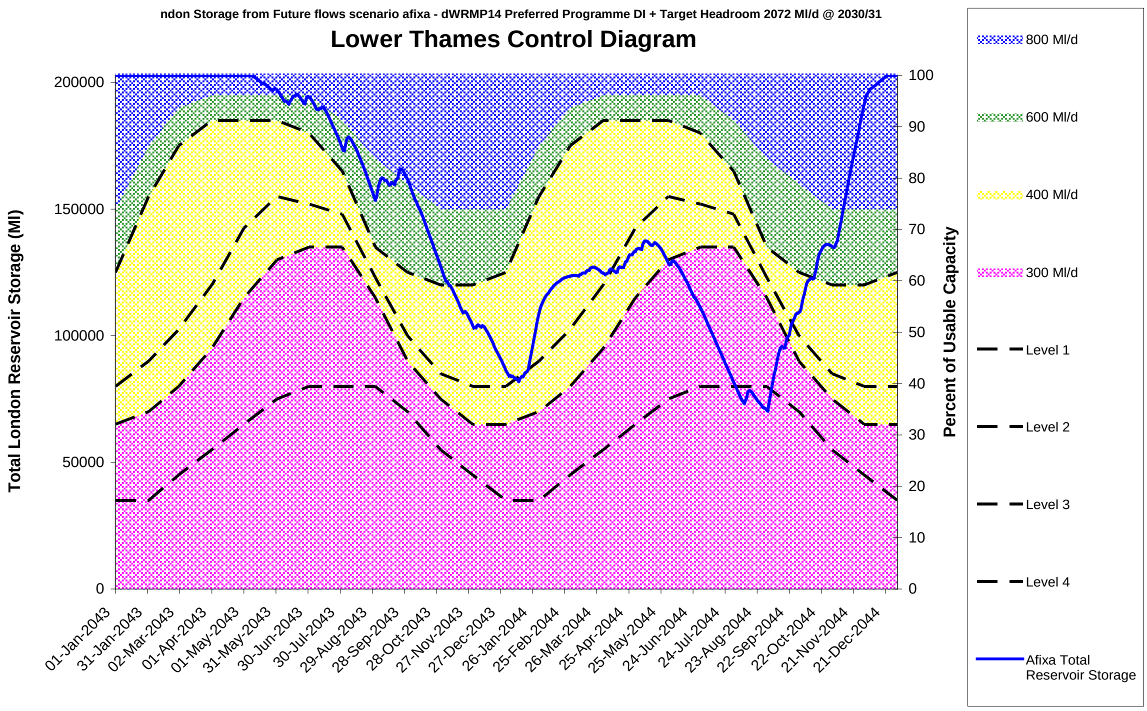

Figure 10-4: Application of Future Flows scenario afixa to the preferred plan water resource system in London

10.6 Summary

We have used this section of the plan to demonstrate the impact of a number of uncertainties on our preferred plan, and to evaluate the robustness of the plan should these uncertainties come to fruition.

We have evaluated six different foreseeable scenarios for the London WRZ and demonstrated that the preferred plan is flexible and can accommodate small changes in the planning assumptions without failing to meet security of supply objectives. Larger changes have more of an impact but are unlikely to materialise before the plan can be adapted to accommodate them. This emphasises the importance of retaining a subset of contingency options (Section 9) should the need to implement schemes at relatively short notice arise. For some of these uncertainties alternative long term options such as transfers or storage may be a more resilient solution than wastewater re-use.

Our high level assessment suggests that, throughout Thames Water's supply area there is a low risk that the increased use of existing abstraction licences would cause deterioration of status under the Water Framework Directive.

The work we have undertaken with HR Wallingford suggests that our plan may not be robust to the increased frequency of extreme events predicted using an alternative method to perturb the historical record to reflect climate change. Whilst an obvious solution would be to develop further re-use capability, our understanding of this process and technology is far from mature and its performance after repeated drought years has yet to be evaluated. Further development of storage options, in contrast, is a tried and tested response to such events, and the potential to develop this option should certainly be retained for the next five years whilst we develop our understanding of re-use and transfer options.