Section 7

Appraisal of resource options

Table of contents

Figures

Tables

Section 7.

Appraisal of resource options

Section 7 describes:

- How we have identified our Feasible List and Constrained List of water resource options
- The associated system elements that are required to deliver the Constrained List resource options into supply
- The further option development that has been conducted on the Constrained List options to inform programme appraisal

A. Introduction

Purpose of section

7.1 Section 7 summarises the approach that has been followed for identifying water resource options and how screening has been applied to determine the Constrained List of options that has been taken forward into programme appraisal. The section then summarises the information that has been gathered on the Constrained List of options.

7.2 In conducting option screening we have balanced the need to have the widest choice of water resource options for assessment at programme appraisal against the need to have a manageable number of options.

Structure of this section

7.3 Following this introduction, Section 7 of the Water Resources Management Plan 2019 summarises:

- the generic option type screening we have conducted (Section 7.B)
- the feasibility assessments we carried out to define the Feasible List of specific resource options (Section 7.C)
- the cross option studies we conducted to identify raw water system, treatment and network reinforcement requirements needed to deliver potable water to customers (Section 7.D)
- the fine screening exercise that combined consideration of the outputs of the feasibility reports and the cross option studies to produce a Constrained List of elements to be carried forward for further development (Section 7.E)
- the further development conducted with regard to elements on the Constrained List to inform programme appraisal (Section 7.F)
- Drought Permit options considered (Section 7.G)

- references to the sources of further information available in respect of the elements on the Constrained List (Section 7.H)

Phased approach to water resource option development

7.4 Following the principles of the Water Resource Planning Guideline[1] (WRPG) (04/2017) section 6, a phased approach to developing water resource options for WRMP19 has been undertaken so that effort on reducing uncertainties is focused on the issues that could reasonably be expected to influence option screening decisions. An overview of the four-phase approach to reviewing and assessing resource options in the preparation of WRMP19 is shown in Figure 7-1. The four phases comprise: option review and screening; detailed investigations; programme appraisal; and scheme selection design and planning. These are described in more detail below.

7.5 **Phase 1 – Option review and screening:** The objective of Phase 1 was to review the water resource options carried forward from WRMP14 and to enable better targeting of Phase 2 option assessments by focusing on uncertainties and risks that were fundamentally material to option selection. The outputs from Phase 1 were fine screening reports for large[2] and small[3] water resource options.

7.6 **Phase 2 – Detailed investigations:** In Phase 2, targeted detailed investigations were undertaken to enable a clear explanation of how specific options have been identified and to reduce uncertainties concerning the identification of the best value options. The required investigations undertaken in Phase 1 were reported in a series of feasibility reports and cross-option studies listed in section 7.H.

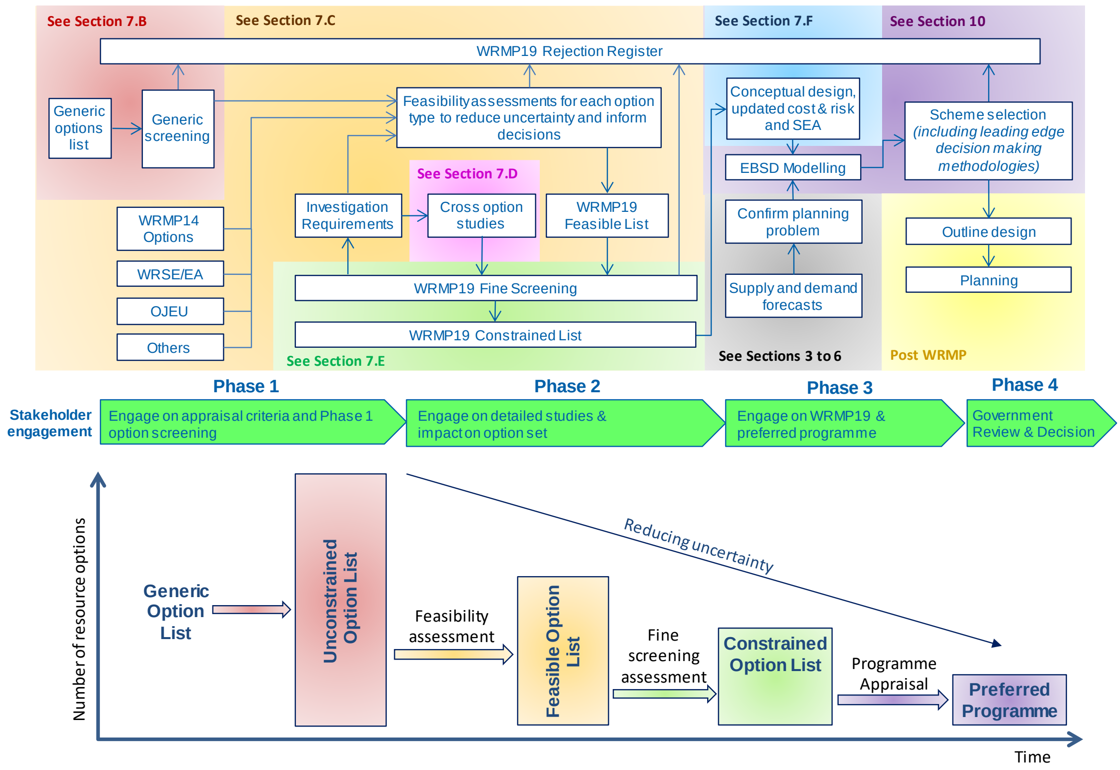
7.7 As these investigations have been completed, the fine screening process has been revisited to ensure that the new information thrown up has been accounted for in the assessment of options and in screening decisions. The resulting output of this updated fine screening exercise, reported in the Fine Screening Report[4], is the Constrained List of options that have then been carried forward for conceptual design and programme appraisal in Phase 3.

7.8 **Phase 3 – Programme appraisal:** In Phase 3, conceptual designs were prepared for options on the Constrained List, costs have been updated for all options, bottom-up risk assessments have been undertaken for options larger than 50 Ml/d and strategic environmental assessments of options have been carried out. Options on the Constrained List have then been subject to programme appraisal to determine the optimum best value programme of solutions to the water supply/demand deficit to ensure that supply balances demand, taking account of relevant future forecast water resource scenarios.

7.9 **Phase 4 – Scheme selection, outline design and planning:** Subject to confirmation of the preferred programme following consultation, Phase 4 will involve progressing the selected water resource options through to outline design for submission as applications for planning permission or a Development Consent Order.

[1] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018
[2] Phase 1 Large Option Screening Report, Mott MacDonald, (May 2015)
[3] Phase 1 Small Option Screening Report, Mott MacDonald, (November 2015)
[4] Fine Screening Report, Mott Macdonald, (September 2018)

Figure 7-1: A phased approach to reviewing and assessing water resource options



Stakeholder engagement

7.10 Throughout the water resource option development process, we have worked closely with stakeholders. We held Technical Stakeholder meetings with representatives of interested stakeholder groups[5] and have held regular meetings to give briefings on the work that we have been doing, and to seek feedback and input to the process so that we could take interested parties' responses into account in developing the Constrained List of options. Technical Stakeholder Group meetings were held on the following dates, to discuss resource option development:

- September 2014 – review of WRMP14 options, any other options that should be considered and approach to option screening
- January 2015 – review of draft Phase 1 option screening report for large options
- March 2015 – review of updated Phase 1 option screening report for large options
- May 2015 – review of Severn Thames Transfer Water Quality and Ecology Study
- July 2015 – review of draft Phase 1a option screening report for small options
- November 2015 – overview and update on Phase 2 investigations into resource options
- December 2015 – stochastic drought generation
- May 2016 – Update on Phase 2 investigation findings

[5] Refer to Appendix S: Stakeholder engagement

- October 2016 – review of draft feasibility report and cross option study findings, together with updated Fine Screening Report
- February 2017 – initial response to comments from stakeholders on feasibility and fine screening reports
- April 2017 – presentation of updated Fine Screening Report
- June 2017 – presentation on environmental assessment of Constrained List
- January 2018 – presentation of the assessment of drought resilience

Since January 2018 we have held other discussions with stakeholders on our Plan, these have included information on resource schemes.

7.11 Documents shared with stakeholders, meeting minutes and presentations are all available on our website[6]. A log of stakeholder comments has also been kept, together with a record of how the comments have been considered and what the response was (including what, if any, changes have been required).

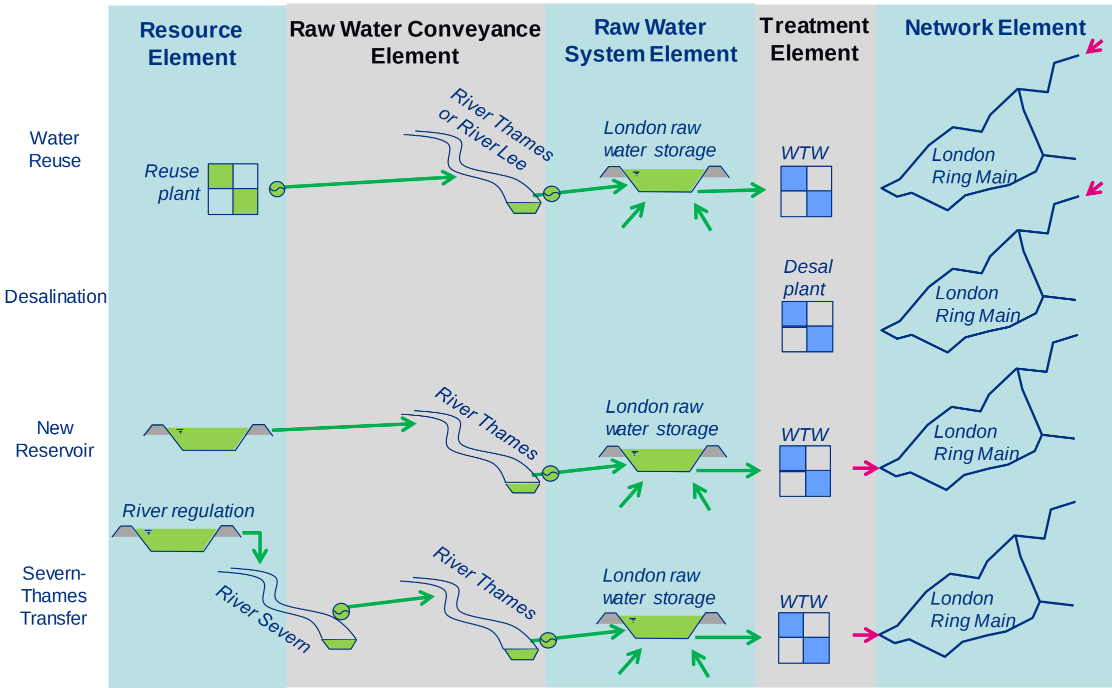
Taking a system approach

7.12 For new water resources to be put into supply, reinforcements are often required to other parts of the water supply system downstream of the resource, including to the raw water conveyance system, water treatment works and water distribution infrastructure. In many cases these water supply system reinforcements are common to a number of different water resource options. The supply system elements may also be implemented at a different time to water resource elements, for example if a zone is resource constrained and has sufficient treatment/network capacity in the short term but will require reinforcements in the medium-long term as demand increases. For these reasons separate supply system elements have been developed for new water resources, raw water conveyance, raw water system reinforcements, treatment reinforcements and treated water network reinforcements. The reinforcement elements have been combined with the resource and conveyance elements, where required, into options for the purpose of fine screening and programme appraisal.

7.13 Cross option studies have been carried out to identify the supply system reinforcement elements required and to establish the system operating philosophy. Figure 7-2 illustrates examples of how the different supply system elements combine to make up an overall water resources option.

[6] https://corporate.thameswater.co.uk/about-us/our-strategies-and-plans/water-resources/document-library

Figure 7-2: Separation of water resource options into supply system elements



B. Generic screening

7.14 The starting point for water resource option development is the generic list of resource option types (e.g. reservoirs, water transfers) referenced in the UKWIR Water Resources Planning Tools report[7]. The list has been reviewed to identify option types that have potential for providing feasible specific water resource options for the Thames Water supply area. A summary of the results of the generic screening exercise that we carried out is shown in Figure 7-3.

7.15 Water resource option types that have been rejected are marked with a cross in Figure 7-3. A summary of reasons for rejection can be found in Table 7-1, with further detail provided in the Rejection Register (see Appendix Q)

7.16 Resource option types that were assessed as having potential to provide specific options for WRMP19 are marked with a tick in Figure 7-3. For these option types the figure also references the report that goes on to identify feasible specific options for our supply area.

[7] UKWIR (2012), Water Resources Planning Tools 2012, Economics of Balancing Supply and Demand Report (Ref 12/WR/27/6), pp 10-12.

Figure 7-3: Summary of generic water resource option type review

	Generic resource management options[†]	Generic screening	Specific option identification	Feasibility report	Feasible list	Fine screening	Constrained list
1	Direct river abstraction	✓	Direct River Abstraction Feasibility Report	✗			
2	New reservoir	✓	New Reservoirs Feasibility Report	✓	[redacted]	✓	[redacted]
3	Groundwater sources	✓	Groundwater Feasibility Report	✓	[redacted]	✓	[redacted]
4	Infiltration galleries	✓	Included in DRA/Desal as possible intake	n/a			
5	Aquifer storage and recovery	✓	Groundwater Feasibility Report	✓	[redacted]	✓	[redacted]
6	Aquifer recharge	✓	Groundwater Feasibility Report	✓	[redacted]	✓	[redacted]
7	Desalination	✓	Desalination Feasibility Report	✓	[redacted]	✓	[redacted]
8a	Bulk transfers of raw water	✓	Raw Water Transfer Feasibility Report	✓	[redacted]	✓	[redacted]
8b	Bulk inter/intra company transfers of treated water	✓	Inter-zonal Water Transfers Feasibility Report	✓	[redacted]	✓	[redacted]
9	Tankering of water	✗					
10	Redevelopment of existing resources	✗					
11	Reuse of existing private supplies	✓	Third party options report	✗			
12	Water re-use	✓	Water Reuse Feasibility Report	✓	[redacted]	✓	[redacted]
13	Imports (icebergs)	✗					
14	Rain cloud seeding	✗					
15	Tidal barrage	✗					
16	Rainwater harvesting	✗					
17	Abstraction licence trading	✓	Third party options report	✓	[redacted]	✓	[redacted]
18	Water quality schemes that increase DO	✓	Catchment Management Feasibility Report	✗			
19	Catchment management schemes	✓	Catchment Management Feasibility Report	✗			
20	Conjunctive use operation of sources	✓	Built into DOs through WARMS	n/a			
21	Joint ("shared asset") resource	✓	Included in feasibility reports where applicable	n/a			
22	Asset transfers	✓	Third party options report	✗			
23	Options to trade other (infrastructure) assets	✓	Third party options report	✗			

[†] Taken from UKWIR 2012, Water Resources Planning Tools, EBSD Report, Ref 12/WR/27/6

Source: Taken from UKWIR 2012, Water Resources Planning Tools, EBSD Report, Ref 12/WR/27/6

7.17 We also have a number of drought permit options. These options require a drought permit or drought order to be issued by the Environment Agency or the Secretary of State and are subject to a significant level of uncertainty. Therefore, they are not considered to provide any deployable output (DO) and are only available in the event of a drought arising from an exceptional shortage of rainfall. These options are covered in more detail in section 7.G.

Table 7-1: Summary of generic option rejection reasons

Scheme	Key elements	Screening decision	Comments
9 Tankering of water			
Tankering by sea	Tankering requires the development of new infrastructure, including pipelines and deep water facilities for loading / unloading. The logistical, environmental and planning constraints at the Thames Estuary are considerable as the estuary is relatively shallow and access would be restricted.	✗	A proposal by Albion Water for tankering from sources in Norway and the Netherlands has been considered. We concluded that while technically feasible at full utilisation (one tanker per day) it would be excessively costly; and at low utilisation (one tanker per week) the option remains uncompetitive with other options of a similar size. Tankering has therefore not been developed as a water resources option, but we are considering it as a potential emergency drought plan option to avoid level 4 restrictions.
13 Imports (icebergs)			
Icebergs	This option would require the development of a system for towing of icebergs over long distances e.g. from the Norwegian Sea to the	✗	Rejected on the basis that the techniques involved are not sufficiently advanced for commercial use and because of the high level of uncertainty around scheme yield. Also, as the Thames Estuary is designated under the Environment Agency Habitats Directive, an Appropriate Assessment is likely to be

	Thames Estuary.		required. As part of this, the company would be required to demonstrate that there are no feasible alternative options; which is not the case.
14 Rain cloud seeding			
Rain cloud seeding	This option would require the development of a system for wide commercial implementation.	✗	Rejected on the basis that the techniques involved are not sufficiently advanced for commercial use and because of the high level of uncertainty that the scheme would provide significant yield.
15 Tidal barrage			
The Thames Barrier	The option for the use of the Thames Barrier to impound fresh water.	✗	Rejected as this option would limit the navigation of the river Thames to both private and commercial traffic resulting in disproportionate social and economic costs. It would also limit the passage of aquatic life which would cause significant ecological damage. The option could also result in raising the groundwater levels in the surrounding areas which could increase the incidence of flooding and cause damage to services and historic buildings in London.
16 Rainwater harvesting			
Rainwater harvesting	Direct collection and storage of rainwater.	✗	Rejected on the basis of limited drought resilience.
10 Redevelopment of existing resources			
Redevelopment of existing resources (e.g. Staines Reservoir)	Changes to current system that could yield benefits to the supply /demand balance.	✗	Redevelopment of reservoir storage is not possible unless sufficient surplus resources are available to compensate for the temporary loss of storage and the consequent risks to security of supply that would therefore result whilst the reservoir is being redeveloped. The provision of the surplus resources would be likely to be required for several years to allow the redevelopment of existing sources.

C. Water resource feasibility assessment

Approach to feasibility assessment

7.18 For the water resource option types that have passed the generic screening, feasibility assessments have been conducted. A staged approach has been adopted for the feasibility assessment:

- **Stage 1:** a systematic search was conducted to identify potential new resources of each type, these collectively form the Unconstrained List of resource elements (see Appendix P) that were then screened against absolute constraints (pass/fail)
- **Stage 2:** the performance of each potential new resource was evaluated qualitatively against a number of criteria that enabled differentiation between options of that type
- **Stage 3:** the performance of the potential new resources was assessed in further detail (e.g. including costing)
- **Validation:** verification and review of the final list of specific resource elements was undertaken to determine the Feasible List

7.19 Further detail relating to the criteria used at each stage of the feasibility assessment can be found within each of the feasibility reports referred to in section 7.H.

7.20 New resource elements have been carried forward from the feasibility assessment into the Feasible List for further fine screening where they meet the following criteria:

- the resource is not compromised by any absolute or key constraints
- if there is mutual exclusivity between elements, only the best performing has been carried forward, provided that this assessment can reasonably be made based upon the information available at the feasibility assessment stage
- if the total estimated DO of resources for a given option type in a water resource zone (WRZ) exceeds the indicative deficit for the WRZ over the period of the planning horizon then only the best performing new resources have been carried forward to the Feasible List, provided that this assessment could reasonably be made based upon the information available at the feasibility assessment stage

Identifying third party options

7.21 We have sought to identify potential third party water resource options through three main approaches:

1) Request for proposals for water resources in the Official Journal of the European Union (OJEU)
2) Bilateral discussions with other water companies
3) Active engagement with regional water resource planning groups including the Water Resources in the South East Group (WRSE) and the Water Resources East Group (WRE)

Request for proposals for water resources

7.22 In preparation for WRMP14, on 1 June 2012 we published an OJEU notice to invite third party organisations to register interest in providing a bulk supply of raw or treated water. We regularly update the OJEU notice (17 February 2015, 25 January 2016 and 18 February 2017). A summary of the responses received related to new water resource options is set out in Table 7-2 together with an update on their WRMP19 status.

Table 7-2: Status of OJEU water resource options

Company	Nature of supply option	Volume (Ml/d)	WRMP19 status
Tankering by sea			
Albion Water	Raw water tankering by sea from Norway	30 - 440	Assessment at WRMP14 found tankering by sea to be excessively costly to supply our geographic area. Albion engaged further with us during preparation of WRMP19 through the stakeholder engagement process. However the assessment of the option remains that it is excessively costly as a water resource option. Tankering has therefore not been developed as a water resources option, but we are considering it as a potential emergency drought plan option to avoid level 4 restrictions
Iceland Ventures Limited	Raw water from Iceland via shipping tankers, bladders or pipeline	>400	
Scottish Water Horizons	Raw water tankering by sea from Loch Glass catchment, Scotland	5	
Raw water inter-company transfers			
United Utilities	Redeployment of Lake Vyrnwy for Severn-Thames Transfer	=<180	Proposals further developed during preparation of WRMP19 and included in the Raw Water Transfers Feasibility Report[8].
Severn Trent	Combination of redeployment of resources, resource development and water reuse to support Severn-Thames Transfer	=<165	
Joint United Utilities/Severn Trent Option	Alternative method for making water from Lake Vyrnwy release available to Thames Water through joint approach from United Utilities and Severn Trent	12-30	Included in Programme Appraisal
Desalination			
Subsea Desalination	Redeployment of an existing mobile desalination plant to Beckton	20.5	Technical and commercial risks too high compared with a permanent solution tailored to our specific needs.
Raw Water Purchase			
RWE Npower	Temporary agreement in relation to Didcot power station abstraction licence.	18 Ml/d	Agreement reached over temporary transfer (10 years) of 18 Ml/d. Included in Programme Appraisal.

Source: Adapted from WRMP14, Table 7-10

[8] Raw Water Transfer Feasibility Report, Mott MacDonald, September 2018

Bilateral discussions with other water companies

7.23 We have engaged on a bilateral basis with other water companies to identify and develop potential new resource options in the form of:

- inter-company raw water transfers – these are assessed in the Raw Water Transfers Feasibility Report
- inter-company treated water transfers[9] – these are assessed in the Inter-Zonal Transfer Feasibility Report

7.24 Companies that are willing to offer water to supply us include: Wessex Water, South East Water, Severn Trent Water, Welsh Water, Essex and Suffolk Water, Canal and River Trust, RWE NPower and United Utilities.

7.25 We have also engaged with other companies concerning their future deficits and how we may be able to provide water to address these.

7.26 In addition, a further Phase 4 modelling exercise has been undertaken to examine changes in WRSE outputs in response to changes in company water resource options which have occurred between draft and final plans.

Regional groups (WRSE)

Overview of WRSE

7.27 The purpose, background and modelling methods of the WRSE group are explained in Section 4. The options utilised in the regional model represent the constrained options from all six companies at the time each phase was formulated. This section describes the cost annuitisation used for options input to WRSE, and the transfers available.

Cost Annuitisation

7.28 The construction capex and carbon, renewal capex and carbon and fixed operational expenditure and carbon for available options and transfers are annuitised for WRSE modelling using a fixed asset life per option type. The variable opex of utilisation is input separately in the WRSE model.

Strategic transfer options to other companies

7.29 The strategic water resource options for Thames Water that have been explored across the different phases of analysis within the WRSE include:

- Bulk transfer of raw water by pipeline from Oxfordshire to Southern Water's network in Hampshire. A number of different volumes have been available for transfer of up to 100 Ml/d
- Bulk transfer of 100 Ml/d of raw water from Oxfordshire using the River Thames as the conveyance mechanism to Affinity Water's existing abstraction points on the Lower Thames
- Bulk transfer of up to 60 Ml/d of raw water from Oxfordshire using the River Thames as a conveyance mechanism to South East Water using a new abstraction location on the River Thames at Reading

[9] Inter-zonal Water Transfers Feasibility Report, Mott MacDonald, February 2018

- Bulk transfer by pipeline from our treated water network in south east London to Southern Water's network in Kent. A number of different volumes were available for transfer, of up to 50 Ml/d
- Bulk transfer by pipeline from our treated water network in south London to Sutton and East Surrey Water. A number of different volumes were available for transfer, of up to 30 Ml/d
- Bulk transfer of treated water by pipeline from London and Guildford to Affinity Water. These options capture the existing treated water bulk supply agreements between Thames Water and Affinity Water where the total amount of available water is not yet taken

Existing transfers within WRSE modelling

7.30 All companies provide capacity and variable opex for all existing transfers within the WRSE region. These transfers are not fixed within the deterministic supply forecast input in the model. Instead, the WRSE model determines their use in conjunction with the surplus available in donor zones and utilisation cost of new transfers and options selected. For Thames Water, the existing transfers which are available for use in WRSE EBSD modelling are:

- Fortis Green (LON) transfer to Affinity Water zone 4 (capacity 27 Ml/d)
- Sunnymeads (LON) transfer to Affinity Water zone 4 (capacity 2 Ml/d)
- Ladymead (GUI) transfer to Affinity Water zone 6 (capacity 2.2 Ml/d)
- Hampstead Lane (LON) transfer to Affinity Water zone 4 (capacity 0.2 Ml/d)
- Three minor transfers from SWA to SWOX (combined capacity DYAA 2.06 Ml/d; DYCP 5 Ml/d)

7.31 The revised draft options were updated for Phase 4 and 5 of the WRSE modelling. Results of the Phase 5 modelling are presented in Section 11 Preferred programme, Part L.

Strategic transfer options to other companies

7.32 The strategic water resource options for Thames Water that have been explored across the different phases of analysis which include:

- Bulk transfer of raw water by pipeline from Oxfordshire to Southern Water's network in Hampshire. A number of different volumes were available for transfer of up to 100 Ml/d
- Bulk transfer of 100 Ml/d of raw water from Oxfordshire using the River Thames as the conveyance mechanism to Affinity Water's existing abstraction points on the Lower Thames
- Bulk transfer of up to 60 Ml/d of raw water from Oxfordshire using the River Thames as a conveyance mechanism to South East Water using a new abstraction location on the River Thames at Reading
- Bulk transfer by pipeline from our treated water network in south east London to Southern Water's network in Kent. A number of different volumes were available for transfer, of up to 50 Ml/d
- Bulk transfer by pipeline from our treated water network in south London to Sutton and East Surrey Water. A number of different volumes were available for transfer, of up to 30 Ml/d
- Bulk transfer of treated water by pipeline from London and Guildford to Affinity Water. These options capture the existing treated water bulk supply agreements between Thames Water and Affinity Water where the total amount of available water is not yet taken

WRSE modelling

7.33 All companies provided their baseline supply and demand data and draft option costs for all water supply/demand options for modelling purposes in September 2017.

7.34 The WRSE project was divided into three phases:

- **Phase 1:** April 2014 to March 2015 – scoping, preparation, formalisation of modelling work
- **Phase 2:** April 2015 to August 2017 – main period of technical assessment and development using WRMP14 data. Application of Info-Gap stress testing of selected investment portfolios
- **Phase 3:** September 2017 to January 2018 – final strategic modelling runs using data that companies used for their revised draft WRMP19 plans

7.35 The intention of the Phase 3 modelling was to allow water companies to assess the consistency of the WRSE results with their own draft WRMPs, to understand the causes of any significant differences and to support companies in the submission of their draft plans. The Thames Water WRMP19 was shown to be consistent with the plans of our neighbouring WRSE companies and where transfers have been agreed between us, these are included in WRMP19 Section 10: Programme appraisal.

Feasible List

7.36 The output from the Phase 2 feasibility reports was the Feasible List of water resource options. The specific options in the Feasible List are summarised in Table 7-3 below.

Table 7-3: Feasible List of resource options

Option type	Name	Baseline DO (Ml/d)	Climate Change 2080s DO (Ml/d)	Commentary
London WRZ		**DYAA**	**DYAA**	
Water Reuse	Beckton Reuse - 380 Ml/d	336	336	Fine screening reports suggest that, for effluent reuse options where the proposed effluent volume required approaches the dry weather flow (excluding sewer infiltration) anticipated from a given sewage treatment works, there is a risk that, under emergency use (Level 4) restrictions, sufficient effluent will not be available to produce the full volume of water associated with the option, due to the reduced volumes of sewage being produced under heavily restricted water use. There is the potential that climate change may make this risk more likely. However, the deployable output (DO) benefit of effluent reuse schemes is determined during the period before Level 4 restrictions are reached (as DO is defined with reference to very nearly, but not quite, crossing L4), so no DO impact due to climate change is assumed. Alongside this, the highly conservative nature of the calculations used in determining dry weather flow (excluding all sewer infiltration, for example) means that the unavailability of sufficient effluent is not certain, even in the case of emergency restrictions. If there is a limitation on the yield of the scheme due to limited effluent availability, this would result in a reduction of scheme yield temporarily, but would not result in elimination of yield during severe drought.
	Beckton Reuse - 300 Ml/d	268	268	
	Beckton Reuse - 200 Ml/d	183	183	
	Beckton Reuse - 150 Ml/d	138	138	
	Beckton Reuse - 100 Ml/d	95	95	
	Beckton Reuse - 50 Ml/d	49	49	
	Mogden Reuse (discharging Thames Lee Tunnel) – 212 Ml/d	191	191	
	Mogden Reuse - 200 Ml/d	180	180	
	Mogden Reuse - 150 Ml/d	137	137	
	Mogden Reuse - 100 Ml/d	94	94	
	Mogden Reuse - 50 Ml/d	49	46	
	Crossness Reuse - 190 Ml/d	174	174	
	Crossness Reuse - 150 Ml/d	138	138	
	Crossness Reuse - 100 Ml/d	95	95	
	Crossness Reuse - 50 Ml/d	49	49	
	Mogden South Sewer Reuse - 50 Ml/d	49	49	
	Crossness Desalination (Unblended) - 65 Ml/d	60		
	Deephams Reuse – 46.5	45	45	All of the assumptions contained within the calculation of the 46.5Ml/d are based on conservative dry weather flows with the analysis completed on a precautionary basis so no DO impact due to climate change is assumed. It is noted that environmental constraints at Hackney Marshes are subject to confirmation in conjunction with the EA at the moment. In addition, the EA have also raised questions around the pass

					forward flow requirement at Three Mills Lock – which is also subject to further engagement with the EA.
Desalination	Crossness Desalination (Unblended) – 65 Ml/d		60	60	From WRMP fine screening reports, a risk item regarding desalination plants exists in the potential need for seawater membranes to be required (these options are designed based on brackish water membranes being installed). This is due to the potential for reduced freshwater input into the tidal Thames due to some WRMP options and/or climate change, resulting in an increased salinity in the tideway during drought. Were seawater membranes not used then desalination plants may not be able to treat water during severe drought, due to the increased salinity. The consequence of the use of seawater, as opposed to brackish water, membranes is a reduced recovery rate (65% for seawater compared to 80% for brackish water). However, this reduced recovery rate would not result in a reduced output as increased abstraction would be used to offset this lower recovery rate. As such, there is no climate change DO impact assumed, although there is a risk that the impact of climate change could increase OPEX requirements of the scheme due to increased abstraction and membrane costs.
	Crossness Desalination (Blended) - 300 Ml/d		284	284	
	Crossness Desalination (Blended) - 200 Ml/d		189	189	
	Crossness Desalination (Blended) - 100 Ml/d		95	95	
	Beckton Desalination - 150 Ml/d		142	142	
Raw water transfer	Severn Thames Transfer*, Deerhurst – Culham 300 Ml/d	Unsupported	120	80	Approach to analysis of climate change impact on unsupported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Unsupported Severn Thames Transfer'. Approach to analysis of climate change impact on supported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Severn Thames Transfer Support Schemes'. Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached. Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material):
		RWP_Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	24	30	
		RWP_Raw Water Transfer Mythe 15 Ml/d	12	12	
		RWP_Netheridge STW effluent 35 Ml/d	18	23	
		RWP_Redeployment of Shelton 12 Ml/d	5	6	
		RWP_Raw Water Transfer Minworth 115 Ml/d	46	58	
		RWP_Redeployment of Shelton 30 Ml/d	12	15	
		RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	58	73	
		RWP_River Wye to Deerhurst 60 Ml/d	30	37	

	RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	71	89	• **Netheridge and Wye 60 at 300 Ml/d Pipe Capacity: + 5 Ml/d and +4 Ml/d** respectively due to, for the revised draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • **Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 300 Ml/d Pipe Capacity: -1 Ml/d** due to, for the revised draft RMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by (0.8/0.9 = 0.888).
Severn Thames Transfer*, Deerhurst - Culham 400 Ml/d	Unsupported	135	95	Approach to analysis of climate change impact on unsupported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Unsupported Severn Thames Transfer'. Approach to analysis of climate change impact on supported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Severn Thames Transfer Support Schemes'. Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached. Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Netheridge and Wye 60 at 400 Ml/d Pipe Capacity: + 4 Ml/d and +4 Ml/d** respectively due to, for the revised
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	29	34	
	RWP_ Raw Water Transfer Mythe 15 Ml/d	12	12	
	RWP_Netheridge STW effluent 35 Ml/d	21	24	
	RWP_Redeployment of Shelton 12 Ml/d	6	7	
	RWP_Raw Water Transfer Minworth 115Ml/d	55	64	
	RWP_Redeployment of Shelton 30 Ml/d	14	17	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	71	83	
	RWP_River Wye to Deerhurst 60 Ml/d	36	42	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	86	101	

				draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • **Minworth (115 Ml/d), Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 400 Ml/d Pipe Capacity: -1 Ml/d** due to, or the revised draft WRMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by (0.8/0.9 = 0.888).
Severn Thames Transfer*, Deerhurst - Culham 500 Ml/d	Unsupported	150	110	Approach to analysis of climate change impact on unsupported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Unsupported Severn Thames Transfer'. Approach to analysis of climate change impact on supported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Severn Thames Transfer Support Schemes'. Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached. Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Netheridge and Wye 60 Ml/d at 500Ml/d Pipe Capacity: + 4 Ml/d and +4 Ml/d** respectively due to, for the revised draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	29	34	
	RWP_ Raw Water Transfer Mythe 15 Ml/d	12	12	
	RWP_Netheridge STW effluent 35 Ml/d	21	24	
	RWP_Redeployment of Shelton 12 Ml/d	6	7	
	RWP_Raw Water Transfer Minworth 115 Ml/d	55	64	
	RWP_Redeployment of Shelton 30 Ml/d	14	17	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	71	83	
	RWP_River Wye to Deerhurst 60 Ml/d	36	42	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	86	101	

				the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • **Minworth (115 Ml/d), Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 500 Ml/d Pipe Capacity: -1 Ml/d** due to, for the revised draft WRMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by (0.8/0.9 = 0.888).
	Oxford Canal	11	11	Resilient to 1 in 200 drought and climate change as modelled by the Canals and Rivers Trust with support from Mott MacDonald and Thames Water. An assessment of a 1 in 200-year event has been made, based on the CRT reservoir inflow series. Taking a typical 18-month critical period for reservoir drawdown (to end October), the 1-in-200 year inflow is estimated to be about 91% of the minimum 18-month inflow in the historic record. There was no failure to meet the transfer or other water demands, and the minimum remaining resource in the full model period was about 600Ml. It is therefore considered that during periods when the supply of 15Ml/d is required by Thames Water that this option is likely to be resilient to a 1-in-200 year drought. Three 2080s medium emissions climate change scenarios have also been tested (from the full 10,000 scenarios that were included in UKCP09). These were identified to approximately represent 10%, 50% and 90% exceedance. Two of the scenarios show reductions in average flow (by 20-25% and 10-15% respectively), while the third shows increases of 5-10%. For two of the scenarios the required transfer was met throughout without failure, while in the most severe scenario there was a minor failure (less than 100Ml on the remaining resource calculation) in one year. In the failure year the critical constraint was the 5-year Bradley licence limit of 40,000Ml. Since the model results for 3-4 years earlier indicated substantial periods when Chasewater was full (and presumably losing water through spill) it is probable that greater use of the reservoir resource in earlier years would

				have allowed greater use of the groundwater in the critical year, thereby avoiding failure. An assessment of the groundwater sources based on other work in the area suggests that the impacts of drought and climate change on DO are likely to be modest, and hence that future DO may remain licence-constrained. Consequently, the assumption in the model runs that groundwater licences can be fully used is believed to be reasonable in terms of yield assessment.
New reservoir#	Abingdon Reservoir 150 Mm3	275	270	Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Abingdon reservoir (all sizes):** No climate change impact for Abingdon dual purpose (supplying London and SWOX) Reservoir 150 Mm3 as modelled by WARMS2 under UKCP09 2030s 90% and 2080s 50% was included in revised draft WRMP19. Between the revised draft and final WRMP climate change impacts under all 20 UKCP09 2080s scenarios have been modelled for the Abingdon dual purpose Reservoir 150 Mm3 with a -1.89% weighted impact on the DO benefit. **For the dual purpose reservoir, DOs across all reservoir sizes have been reduced by 1.89% for the final plan.**
	Abingdon Reservoir 125 Mm3	234	230	
	Abingdon Reservoir 100 Mm3	190	186	
	Abingdon Reservoir 75 Mm3	142	139	
	Abingdon Reservoir 50 Mm3	91	89	
	Abingdon Reservoir 30 Mm3	49	48	
	Abingdon Reservoir Phased 80+42 Mm3 Phase 1	151	148	Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Abingdon reservoir (all phased sizes):** Phase 1 is dual purpose (supplying London and SWOX) and Phase 2 is for river regulation only (supplying London only). The climate change impact on London DO for the dual purpose reservoir is -1.89% (under all 20 UKCP09 2080s scenarios as described for the dual purpose single phased reservoirs) however for the regulating
	Abingdon Reservoir Phased 80+42 Mm3 Phase 2	83	81	
	Abingdon Reservoir Phased 30+100 Mm3 Phase 1	49	48	
	Abingdon Reservoir Phased 30+100 Mm3 Phase 2	199	193	

				reservoir the climate change impact on London DO is -2.9% also modelled under all 20 UKCP09 2080s scenarios. The dual purpose Phase 1 reservoir has a smaller climate change impact on London DO compared to the Phase 2 reservoir for river regulation only as there is an effluent return benefit to the Thames derived from supplying SWOX as well as London. **For the phased reservoir, DOs across all reservoir sizes have been reduced by 1.89% for Phase 1 (dual purpose) and by 2.9% for Phase 2 (regulating) in the final plan.**
	Chinnor Reservoir 50 Mm3	91	89	The same comment for Abingdon Reservoir applies to Chinnor Reservoir.
	Chinnor Reservoir 30 Mm3	49	48	
	Marsh Gibbon Reservoir 75 Mm3	142	139	The same comment for Abingdon Reservoir applies to Marsh Gibbon Reservoir.
	Marsh Gibbon Reservoir 50 Mm^3	91	89	
	Marsh Gibbon Reservoir 30 Mm^3	49	48	
Direct river abstraction	River Lee Direct River Abstraction - 150 Ml/d	35	35	All of the assumptions contained within the calculation of the 35Ml/d are based on conservative extreme dry weather flows with the analysis completed on a very precautionary basis so no DO impact due to climate change is assumed.
Raw water purchase	Didcot Raw Water Purchase	18	18	This is an AMP7 option with minimal climate change impact to account for when scaled from the 2080s. The option involves Thames Water purchasing RWE’s excess licence with water remaining in the River Thames providing the DO benefit. Climate change could increase the time in lower flow bands however under this scenario RWE would stop abstracting at Didcot power station and the volume remaining in the river available to Thames Water would not be derogated.
	Chingford Raw Water Purchase	20	20	No climate change impact due to Essex and Suffolk Water having a surplus
Aquifer recharge	Kidbrooke Aquifer Recharge (SLARS1)[10]	7	7	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.

[10] SLARS – south London Artificial Recharge Scheme

	Merton Aquifer Recharge (SLARS3)	5	5	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.
	Streatham Aquifer Recharge (SLARS2)	4	4	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.
Aquifer storage and recovery	South East London (Addington) Aquifer Storage and Recovery	3	3	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.
	Thames Valley Central Aquifer Storage and Recovery	3	3	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.
	Horton Kirby Aquifer Storage and Recovery	5	5	Managed aquifer recharge options will not have a climate change impact as they use confined aquifers and we will manage recharge to mitigate climate change risk.
Removal of constraints	Epsom	2	2	Existing groundwater source that abstracts from semi-confined Chalk aquifer. The East Street source currently has moderate vulnerability to climate change, with an assessed impact of the order of +2.5 Ml/d equivalent to ~20% impact on its baseline source DO. The baseline source DO of the East St source is predominantly influenced by the hydrogeological constraint imposed by the crown of the adit in the Main Well, plus water quality constraints in the Railway Borehole. Proposed solution is to construct a new abstraction borehole that would remove the water quality constraint and not be affected by the Main Well adit constraint. The source DO contribution from this new borehole would be constrained by licence and not pumping water levels, so it is expected not to be significantly vulnerable to climate change.
	New River Head	3	3	Confined source so resilient.
Groundwater	Addington	1	1	Existing groundwater source that abstracts from unconfined Chalk aquifer. Source currently has low vulnerability to climate change, with an assessed impact of the order of +0.5 Ml/d equivalent to <10% impact on its baseline source DO. The baseline source DO is constrained hydrogeologically by the crown of the adit to which the pumping well is connected. Proposed solution is to construct a new abstraction borehole that would remove the crown of the adit as the hydrogeological constraint. This would remove most, if not all, of the source's

					vulnerability to climate change.
	London Confined Chalk (north)		2	2	Confined source so resilient.
	Southfleet/Greenhithe (new water treatment works (WTW))		8	8	Existing disused source in unconfined Chalk aquifer, currently licensed in aggregate with the Bean Wellfield. Previous test pumping indicated the source DO would be constrained by the individual licence. Proposed option to disaggregate from the Bean Wellfield is not expected to produce a source DO benefit that is significantly vulnerable to climate change.
	Honor Oak groundwater development		1	1	Confined source so resilient. Existing confined Chalk aquifer where groundwater levels are influenced by abstraction and not natural recharge, so considered that climate change impact will be insignificant.
	Merton recommissioning		2	2	Confined source so resilient. Conceptualised as Honor Oak.
Swindon & Oxfordshire (SWOX) WRZ			**ADPW**	**ADPW**	
Raw water transfer	Severn Thames Transfer*, Deerhurst - Culham 300 Ml/d	RWP_ Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	24	30	Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached. Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • Netheridge and Wye 60 at 300 Ml/d Pipe Capacity: + 5 Ml/d and +4 Ml/d respectively due to, for the revised draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 300 Ml/d Pipe Capacity: -1 Ml/d due to, for the revised draft WRMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by
		RWP_ Raw Water Transfer Mythe 15 Ml/d	12	12	
		RWP_Netheridge STW effluent 35 Ml/d	18	23	
		RWP_Redeployment of Shelton 12 Ml/d	5	6	
		RWP_Raw Water Transfer Minworth 115Mld	46	58	
		RWP_Redeployment of Shelton 30 Ml/d	12	15	
		RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	58	73	
		RWP_River Wye to Deerhurst 60 Ml/d	30	37	
		RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	71	89	

				(0.8/0.9 = 0.888).
Severn Thames Transfer*, Deerhurst - Culham 400 Ml/d	RWP_ Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	29	34	Approach to analysis of climate change impact on supported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Severn Thames Transfer Support Schemes'. Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached. Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Netheridge and Wye 60 at 400 Ml/d Pipe Capacity: 4 Ml/d and +4 Ml/d** respectively due to, for the revised draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • **Minworth (115 Ml/d), Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 400 Ml/d Pipe Capacity: -1 Ml/d** due to, for the revised draft WRMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by (0.8/0.9 = 0.888).
	RWP_ Raw Water Transfer Mythe 15 Ml/d	12	12	
	RWP_Netheridge STW effluent 35 Ml/d	21	24	
	RWP_Redeployment of Shelton 12 Ml/d	6	7	
	RWP_Raw Water Transfer Minworth 115 Ml/d	55	64	
	RWP_Redeployment of Shelton 30 Ml/d	14	17	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	71	83	
	RWP_River Wye to Deerhurst 60 Ml/d	36	42	
	RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	86	101	
Severn Thames Transfer*, Deerhurst - Culham 500	RWP_ Raw Water Transfer Upper Severn Vyrnwy 60 Ml/d	29	34	Approach to analysis of climate change impact on supported Severn Thames Transfer Deployable Outputs outlined in Section 4 of Atkins' 16th July 2018 report 'Thames Water WRMP19 Stochastic Methods: WRMP19 Options Appraisal Appendix Document for the Severn Thames Transfer Support
	RWP_ Raw Water Transfer Mythe 15 Ml/d	12	12	
	RWP_Netheridge STW effluent	21	24	

	Ml/d	35 Ml/d			Schemes'.
		RWP_Redeployment of Shelton 12 Ml/d	6	7	Note: The incremental benefits from storage are smaller for the baseline than under climate change as there is a greater amount of unsupported flow, so there is less of a gap to fill before the pipeline capacity is reached.
		RWP_Raw Water Transfer Minworth 115 Ml/d	55	64	
		RWP_Redeployment of Shelton 30 Ml/d	14	17	Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Netheridge and Wye 60 at 500 Ml/d Pipe Capacity: + 4 Ml/d and +4 Ml/d** respectively due to, for the revised draft WRMP19, the support elements not affected by losses having the benefit inflated by 1/0.9 as the baseline IRAS modelling incorporated losses for everything apart from the 15Ml/d sweetening flow support. • **Minworth (115 Ml/d), Vyrnwy (148 Ml/d) and Vyrnwy (180 Ml/d) at 500 Ml/d Pipe Capacity: -1 Ml/d** due to, for the revised draft WRMP19, a conceptual flaw in the analysis. Our IRAS based modelling assumed 10% losses already, so the analysis multiplied the benefits by 0.9 (i.e. effective 10% additional loss) to get the 20% figures. However, technically the analysis should have multiplied by (0.8/0.9 = 0.888).
		RWP_ Raw Water Transfer Upper Severn Vyrnwy 148 Ml/d	71	83	
		RWP_River Wye to Deerhurst 60 Ml/d	36	42	
		RWP_ Raw Water Transfer Upper Severn Vyrnwy 180 Ml/d	86	101	
	Oxford Canal		12	12	Resilient to 1 in 200 drought and climate change as modelled by the Canals and Rivers Trust with support from Mott MacDonald and Thames Water.
New reservoir#	Abingdon Reservoir 150 Mm^3		294	288	Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Abingdon reservoir (all sizes):** No climate change impact for Abingdon dual purpose (supplying London and SWOX) Reservoir 150 Mm3 as modelled by WARMS2 under UKCP09 2030s 90% and 2080s 50% included in revised draft WRMP19. Between the revised draft and final WRMP climate change impacts under all
	Abingdon Reservoir 125 Mm^3		253	248	
	Abingdon Reservoir 100 Mm^3		210	206	
	Abingdon Reservoir 75 Mm^3		161	158	
	Abingdon Reservoir 50 Mm^3		111	109	
	Abingdon Reservoir 30 Mm^3		69	68	

				20 UKCP09 2080s scenarios have been modelled for Abingdon dual purpose Reservoir 150 Mm3 with a -1.89% weighted impact on the DO benefit. **For the dual purpose reservoir, DOs across all reservoir sizes have been reduced by 1.89% for the final plan.**
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 1	170	167	Change to baseline DOs including climate change between revised draft WRMP19 and final WRMP19 (note these changes are minor and not considered material): • **Abingdon reservoir (all phased sizes):** Phase 1 is dual purpose (supplying London and SWOX) and Phase 2 is for river regulation only (supplying London only). The climate change impact on London DO for the dual purpose reservoir is -1.89% (under all 20 UKCP09 2080s scenarios as described for the dual purpose single phased reservoirs) however for the regulating reservoir the climate change impact on London DO is -2.9% also modelled under all 20 UKCP09 2080s scenarios. The dual purpose Phase 1 reservoir has a smaller climate change impact on London DO compared to the Phase 2 reservoir for river regulation only as there is an effluent return benefit to the Thames derived from supplying SWOX as well as London. **For the phased reservoir, DOs across all reservoir sizes have been reduced by 1.89% for Phase 1 (dual purpose) and by 2.9% for Phase 2 (regulating) in the final plan.**
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 2	83	81	
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 1	69	68	
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 2	199	193	
	Chinnor Reservoir 50 Mm^3	111	109	The same comment for Abingdon Reservoir applies to Chinnor Reservoir.
	Chinnor Reservoir 30 Mm^3	69	68	
	Marsh Gibbon Reservoir 75 Mm^3	161	158	The same comment for Abingdon Reservoir applies to Marsh Gibbon Reservoir.
	Marsh Gibbon Reservoir 50 Mm^3	111	109	
	Marsh Gibbon Reservoir 30 Mm^3	69	68	
Groundwater	Moulsford 1	3.5	3.5	Adjacent to River Thames so resilient. This is a new groundwater source from the unconfined Chalk alongside the River Thames where groundwater level fluctuations are

				expected to be small. Existing sources in the area, e.g. Gatehampton, Cleeve, have very limited climate change impact on their source DO, i.e. <1%. The source DO of the Moulsford option is not expected to be significantly vulnerable to climate change.
Removal of constraints to DO	Ashton Keynes borehole pumps - Removal of Constraints to DO	1.5	1.5	Existing operational source. Proposed solution, of either lowering borehole pumps and/or modifying abstraction philosophy, makes the source resilient to climate change impact, especially as it is a confined groundwater source distant from the recharge area.
	Britwell Removal of Constraints	1.3	1.3	Existing disused source in semi-confined Upper Greensand aquifer. When previously operational the source DO was assessed as being constrained by its abstraction licence and not impacted by climate change effects on groundwater levels. When returned to supply it is not expected that the source DO will be significantly vulnerable to climate change.
Internal inter-zonal transfer	Henley to SWOX - 2.4 Ml/d	2.4	2.4	Henley is resilient to climate change so there is no climate change impact on this transfer.
	Henley to SWOX - 5 Ml/d	5	5	Henley is resilient to climate change so there is no climate change impact on this transfer.
	Kennet Valley to SWOX - 6.7 Ml/d	4.5	4.5	DO based on recommissioning Mortimer WTW, which is a climate resilient confined Chalk aquifer source, to support Reading with water from Fobney & Pangbourne WTWs then being used to support the transfer to SWOX. The transfer draws on base DO and therefore any climate impacts have already been assessed as part of the baseline.
	Kennet Valley to SWOX - 2.3 Ml/d	2.3	2.3	DO based on transfer to SWOX from Pangbourne WTW with Reading being supported by Fobney WTW. The transfer draws on base DO and therefore any climate impacts have already been assessed as part of the baseline.
Inter-company transfers	Wessex Water to SWOX	2.9	2.9	No climate change impact due to Wessex Water having a surplus.
Slough, Wycombe & Aylesbury (SWA) WRZ		**ADPW**	**ADPW**	
	Severn Thames Transfer*, Deerhurst – Culham: see SWOX WRZs for sizes and DO			
Raw water transfer	Oxford Canal	12	12	Resilient to 1 in 200 drought and climate change as modelled by the Canals and Rivers Trust with support from Mott MacDonald and Thames Water.

New reservoir#	Abingdon Reservoir: see SWOX WRZs for sizes and DO			
	Chinnor Reservoir: see SWOX WRZs for sizes and DO			
	Marsh Gibbon Reservoir: see SWOX WRZs for sizes and DO			
Raw water purchase	Didcot Raw Water Purchase	18	18	This is an AMP7 option with minimal climate change impact to account for when scaled from the 2080s. The option involves Thames Water purchasing RWE's excess licence with water remaining in the River Thames providing the DO benefit. Climate change could increase the time in lower flow bands however under this scenario RWE would stop abstracting at Didcot power station and the volume remaining in the river available to Thames Water would not be derogated.
Groundwater	Datchet	5.4	5.4	Adjacent to River Thames so resilient. Existing operational source whose source DO is not impacted by climate change effects on groundwater levels. This reflects the confined hydrogeological setting of the source, plus the potential recharge influence of the River Thames as a fixed head boundary. Proposed solution is to remove abstraction pumping constraints on the existing source DO within the current abstraction licence, and so the source DO increase is not expected to be significantly vulnerable to climate change.
Internal inter-zonal transfer	Henley to SWA - 2.4 Ml/d	2.4	2.4	Henley is resilient to climate change so there is no climate change impact on this transfer.
	Henley to SWA - 5 Ml/d	5	5	Henley is resilient to climate change so there is no climate change impact on this transfer.
Guildford WRZ		**ADPW**	**ADPW**	
Groundwater	Dapdune Licence Disaggregation	2.2	2.2	This is the licence disaggregation option, where each of the sources, Millmead, Ladymead and Dapdune, become constrained by their individual abstraction licences and are not hydrogeologically constrained, meaning the option is resilient to climate change impact.
Removal of constraints to DO	Dapdune Removal of constraints to DO	1	1	Existing operational source. Proposed solution removes asset constraint, while potential yield is not constrained by hydrogeological factors, meaning the source is resilient to climate change impact.

	Ladymead WTW Removal of Constraints to DO	4.6	4.6	Existing operational source. Proposed solution removes asset constraint, while potential yield is not constrained by hydrogeological factors, meaning the source is resilient to climate change impact.
Inter-company transfers	Southeast Water to Guildford	10	10	South East Water have a surplus through the 60 year planning horizon in their water resource zone from which the transfer would be exported to Thames Water from. This zone is also very resilient to 2080s climate change with either no impact or a positive impact on existing source DO. This option could therefore be developed by South East Water under future climate change whilst still maintaining a supply demand surplus.
Henley WRZ		**ADPW**	**ADPW**	
No feasible options identified				
Kennet Valley WRZ				
Groundwater	Mortimore Disused Source (Recommission)	4.5	4.5	Confined source so resilient. Existing disused source. Conceptualised as Honor Oak.
Removal of constraints to DO	East Woodhay borehole pumps Removal of Constraints to DO	2.1	2.1	Confined source so resilient. Existing operational source. Proposed solution removes asset constraint, while potential yield is not constrained by hydrogeological factors, meaning the source is resilient to climate change impact, especially as it is a confined groundwater source distant from the recharge area.

Table Notes:

** Stochastic yields for the Severn Thames Transfer are based upon stochastic analysis and take account of estimated impacts of climate change and other abstractors. The DO benefit of unsupported volumes in the River Severn are included under the Dry Year Annual Average condition (for the London WRZ), but not under Average Day Peak Week conditions (for the SWOX and SWA WRZs). Further information can be found in the Raw Water Transfers Feasibility Report and Fine Screening Report. All support sources, except Mythe, River Wye and Netheridge have been assessed assuming 20% loss between discharge into River Severn and abstraction at Deerhurst.*

Reporting of Severn Thames Transfer Deployable Output has changed between the Revised Draft and Final WRMP19 and some of the values have changed as reported in Table 7-3 above. The changes are not material to the overall WRMP and the values have not been changed in other sections and appendices of the plan. The values used in the revised draft WRMP are given below for information:

Table 7-4: Deployable Output figures quoted in the Revised Draft WRMP19 where different from above (now superseded)

Name		***Deployable Output DYAA (Ml/d)***		
London WRZ		***300***	***400***	***500***
Severn Thames Transfer, Deerhurst - Culham 300 Ml/d*	*+ Vyrnwy (60Ml/d) - 60 Ml/d*	*110*	*129*	*144*
	+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	*122*	*141*	*156*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	*128*	*148*	*163*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	*146*	*168*	*183*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	*204*	*233*	*248*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	*213*	*243*	*258*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	*250*	*285*	*300*
	+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	*294*	*335*	*350*
	+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth + River Wye – 405.3 Ml/d	*295*	*336*	*351*
Swindon & Oxfordshire (SWOX) WRZ				
Severn Thames Transfer, Deerhurst - Culham 300 Ml/d*	*+ Vyrnwy (60Ml/d) - 60 Ml/d*	*30*	*34*	*34*
	+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	*42*	*46*	*46*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	*48*	*53*	*53*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	*66*	*73*	*73*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	*124*	*138*	*138*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	*133*	*148*	*148*
	+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	*170*	*190*	*190*
	+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	*214*	*240*	*240*
	+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth + River Wye – 405.3 Ml/d	*215*	*241*	*241*
Slough, Wycombe & Aylesbury (SWA) WRZ				
Severn Thames Transfer, Deerhurst – Culham: see SWOX WRZs for sizes and DO*				
Guildford WRZ, Henley WRZ, Kennet Valley WRZ				
No changes				

 # Abingdon Reservoir DOs used at programme appraisal are based upon the two zone DOs from WARMS2 analysis, reduced by 3% to account for stochastic analysis and reduced by 1.89% to account for climate change. For the London WRZ the DOs are capped at the two zone London DO, being the lower of the two zone London DO and the single zone London DO. For the SWOX WRZ the two zone London and SWOX DOs are summed as for the purpose of EBSD modelling the resource for London is treated as an export from SWOX.

*Yields for London are for Dry Year Annual Average (DYAA) condition, whereas for the Th*ames Valley they are for Average Day Peak Week (ADPW) condition.

7.37 For those options that have not been carried forward to the Feasible List an explanation of the reasons for rejection is included in Appendix Q: Scheme rejection register.

D. System reinforcements

7.38 Cross-option studies have been conducted to identify the water treatment, raw water system and treated water transmission reinforcements required to deliver the new resources into distribution. In many cases the same system reinforcements are required for a number of different water resources and the timing of the need for the system reinforcements may also not coincide with the need for water resources. The system reinforcements have therefore been developed as separate system elements that can be combined with water resource elements when developing an overall programme. It should be noted that the exact configuration of system reinforcements required at a programme level will be refined and explained at the programme appraisal stage in WRMP19 Section 10. Demand management options that are selected will also have a significant impact on the requirement for additional system reinforcements.

Water treatment cross option study

7.39 We are continuing our review of the resilience of water treatment capability in the London WRZ. Demand management options that are selected will also have a significant impact on the requirement for additional water treatment. However, following preliminary findings, it has been concluded that when peak demands (after accounting for demand management measures) exceed existing treatment capacity then additional treatment capacity will be required, except where the new resource is provided through desalination which produces potable water. A cross-option study has been undertaken to investigate feasible options for additional treatment capacity. Two options have been identified in London, with sites at:

- **Kempton WTW** for additional resources from the west (e.g. Upper Thames Reservoir, Severn-Thames Transfer, Oxford Canal Transfer), including a new connection into the Thames Water Ring Main (TWRM)
- **Coppermills WTW** for additional resources from the east (e.g. Beckton and Deephams reuse) – this would entail redevelopment of the existing works as there is no further space on the existing site. Alternative sites to Coppermills in east London are also being investigated.

7.40 For the SWOX WRZ two sites have been identified for additional treatment:

- **Abingdon WTW** for resources from the Abingdon Reservoir
- **Radcot WTW** for resources from the Severn-Thames Transfer

7.41 For the SWA WRZ two options have also been identified for additional treatment of resources from either the Abingdon reservoir or the Severn-Thames Transfer

- **Abingdon WTW** for treated water transfer into the north of the SWA area
- **A new river abstraction from the River Thames** and treatment works in the vicinity of Medmenham supplying the south of SWA.

Network reinforcement cross option study

7.42 A cross-option study has been undertaken to identify supply network reinforcement requirements for London. The report identified six interventions that could be required, including two extensions to the TWRM, with the necessary reinforcements dependent on whether the additional water resource is treated in east or west London. The network reinforcement requirements identified are:

1) Replace pump infrastructure at New River Head
2) Replace pump infrastructure at Barrow Hill
3) TWRM extension - Hampton to Battersea
4) TWRM level controlled by new header tank and pumping station at Coppermills WTW
5) TWRM extension - Coppermills to Honor Oak
6) Resolve issues with supply to Surbiton during TWRM outage

7.43 The matrix in Table 7-4 shows which of these reinforcements would be required for different combinations of new treatment capacity, depending upon whether the additional water resource is available for treatment to the east or the west of the existing TWRM. It can be seen that initially no reinforcement may be required. The precise timing of the requirement for individual network reinforcements is optimised as part of programme appraisal but will also depend on the demand management options selected as part of the programme appraisal process.

Table 7-4: Network reinforcement requirements for additional water resources treated in east or west London

		East Ml/d								
		0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**
West (Ml/d)	**0**	-	-	5	4,5	4,5	4,5	4,5	1,4,5	1,4,5
	100	1	1	3,4,5	3,4,5	3,4,5	3,4,5	4,5	1,4,5	
	200	1,3	1,3	3,4	3,4,5	3,4,5	3,4,5	3,4,5		
	300	1,3	1,3	1,3,4	3,4,5	3,4,5	3,4,5			
	400	1,3	1,3	1,3,5	3,4,5	3,4,5				
	500	1,3,5,6	1,3,5,6	1,3,5	1,3,5					
	600	1,2,3,5,6	1,3,5,6	1,3,5,6						
	700	1,2,3,5,6	1,2,3,5,6							
	800	1,2,3,5,6								

7.44 Additional network reinforcement elements have been identified that are specific for individual options. These include:

- Tunnel from Beckton to Coppermills WTW for blending of water from Beckton and Crossness desalination options
- Tunnel from Crossness desalination plant site to Beckton to extend the Beckton-Coppermills tunnel to Crossness so that it can transfer resource from the proposed desalination plant at Crossness
- Pipeline from proposed Abingdon WTW to Long Crendon to supply SWA

7.45 Further work is being undertaken to identify local supply network reinforcements required to accommodate growth however these interventions are outside the scope of the WRMP and so are not included as specific reinforcement elements.

Raw water system cross option study

7.46 A cross-option study has been undertaken to identify supply reinforcements required to the raw water system (between the point of abstraction and the WTW inlet) for the different water resource options. This is of particular relevance for options that augment resources in the River Thames or the River Lee (including new reservoir options, raw water transfers, effluent reuse and some direct river abstraction options). The study used currently available models of the raw water system for the River Thames and River Lee abstractions.

7.47 The study identified ten interventions that may be required, the most significant including an extension to the Thames Lee Tunnel, a second Spine Tunnel and additional conveyance from Queen Mary Reservoir to Kempton WTW. The necessity for the reinforcements will be dependent on the water resource options selected and whether they enter the raw water system in east or west London. The identified raw water system reinforcements, divided between east and west London, are:

East London

1) King George V Reservoir intake capacity increase
2) Chingford South intake capacity increase
3) Thames Lee Tunnel extension from Lockwood pumping station to King George V Reservoir intake
4) Thames Lee Tunnel upgrade to remove existing constraints to maximise transfer capacity (not shown in Table 7-5)
5) Additional conveyance from King George V Reservoir to break tank
6) Second Spine Tunnel from break tank to Reservoir 5 upstream of Coppermills WTW

West London

7) Datchet intake capacity increase with transfer to Queen Mother and Wraysbury Reservoirs
8) Littleton intake capacity increase with transfer to Queen Mary Reservoir
9) Surbiton intake capacity increase with transfer to Walton inlet channel
10) Additional conveyance from Queen Mary Reservoir to Kempton WTW

7.48 The matrix in Table 7-5 shows which of these reinforcements are required depending upon the additional water resource added to the east and west London raw water systems. It can be seen that initially no reinforcement may be required. The precise timing of the requirement for individual reinforcements is optimised as part of programme appraisal.

Table 7-5: Raw water system reinforcement requirements for additional water resources in east or west London

	Additional raw water resource in the east (Ml/d)								
	0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**

Additional raw water resource in the west (Ml/d)									
0	-	3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6
100	-	3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	
200		3	1,3,5	1-3,5,6	1-3, 5,6	1-3, 5, 6	1-3, 5, 6		
300		3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6			
400	7	3,7		1,3,5,7		1-3,5-7		1-3, 5-7	
500	7/8,10	3,7/8,10		1,3,5,7/8,10		1-3,5-7/8,10			
600	7/8,10	3, 7/8,10		1,3,5,7/8,10					
700	7/8,10	3, 7/8,10							
800	7/8,10								

7.49 For the Deephams Reuse option two alternative conveyances have been considered, depending upon whether the Thames Lee Tunnel extension is developed. If the extension is developed then Deephams reuse would discharge into it, otherwise a separate pipeline conveyance element has been included from Deephams to King George V Reservoir intake.

E. Fine screening of water resource options

Approach to fine screening

7.50 The water resource elements that passed the validation stage of the feasibility assessments form the Feasible List. These elements have then been subjected to a further fine screening stage to produce the Constrained List of options for further development before Phase 3 programme appraisal. The fine screening process brought together all water resource types and compared them using a consistent set of criteria. Where options have been rejected an explanation is provided in the Fine Screening Report[11] and in the Rejection Register (Appendix Q: Scheme rejection register).

7.51 The fine screening process compared water resource options within each WRZ. It combined quantitative analysis of costs with qualitative analysis using six relevant factors or 'dimensions'. These qualitative factors relate to the different stages in the project lifecycle as shown in Figure 7-4. These dimensions are defined in the Fine Screening Report.

[11] Fine Screening Report, Mot MacDonald, September 2018

Figure 7-4: Mapping of six fine screening dimensions to project lifecycle

Dimension	Stage in project lifecycle (Time →): Option Development	Planning permission granted	Construction	Commissioning	Operation
Environment & Social			✓		✓
Cost			✓		✓
Promotability	✓				
Deliverability			✓		
Flexibility			✓		✓
Resilience					✓

7.52 All resource options on the Feasible List have been assessed against these dimensions to identify the potential benefits/opportunities and the dis-benefits/risks of each option. The assessment against each dimension is categorised and visualised in summary matrices (included in the appendices to the Fine Screening Report) using the categories shown in Table 7-6. For any one dimension more than one symbol was in some cases needed to capture the nature of the risks and benefits. For example, under the environmental and social dimension some options included material dis-benefits during the construction stage, but material benefits during the operational phase.

Table 7-6: Dimension category definitions

Symbol	Meaning	Definition
◉	Substantial benefit/opportunity	The option has substantial benefits/opportunities either individually or cumulatively.
◎	Material benefit/opportunity	The option has some material benefits/opportunities.
○	Neutral	The option does not have significant residual effects.
◑ (r)	Material dis-benefit/risk	The option has some material residual dis-benefits/risks, either individually or cumulatively
● (r)	Substantial dis-benefit/risk	The option has substantial residual dis-benefits/risks, either individually or cumulatively

Note: A superscript '(r)' next to the symbol would highlight that a dis-benefit/risk could potentially be reduced to 'neutral' by additional development of mitigation measures during detailed design.

Results of fine screening

7.53 To arrive at the Constrained List of options from the Feasible List, fine screening decisions have been made by evaluating water resource options across all six qualitative dimensions. Rather than imposing rigid rules to make screening decisions, the focus has been on ensuring that there is a clear and robust reasoning for each screening decision which has then been recorded in Appendix Q: Scheme rejection register. The adoption of this approach has, nevertheless, shown that the reasons for rejecting options have tended to fall into three categories:

- Options were rejected if they presented substantial irreducible dis-benefits/risks unless these could be offset by a substantial benefit/opportunity
- Options would be rejected if they were clearly less favourable than other mutually exclusive options
- Options would be rejected if they were the least favourable of all options where there were more options than could reasonably be required over the planning horizon under future scenarios.

7.54 A summary of the fine screening results is presented in Table 7-7 showing those options that have passed from the Feasible List to the Constrained List and those that have been rejected. The reasons for screening decisions are recorded in Appendix Q: Scheme rejection register.

Table 7-7: Fine screening summary for specific options

Resource Option	Size Band (Ml/d)						
	0 to 25	25 to 75	75 to 125	125 to 175	175 to 225	225 to 275	275 to 325
London WRZ							
Reuse - Beckton		red	green	green	green	green	green
Reuse - Mogden		red	red	red	red		
Reuse - Deephams		green					
Reuse - Crossness		red	red	red			
Reuse - Mogden South Sewer		green *					
RWT - STT Deerhurst			green	green	green	green	green
RWT - Oxford Canal	green						
New Reservoir - Abingdon		green	green	green	green	green	green
New Reservoir - Chinnor		red	red				
New Reservoir - Marsh Gibbon		red	red	red			
DRA - Lower Lee		red					
Desalination - Beckton				green			
Desalination - Crossness (unblended)		red					
Desalination - Crossness (blended)			green	green	green	green	green
AR/ASR - Kidbrooke (SLARS1)	green						
AR Merton (SLARS3)	green						
AR Streatham (SLARS2)	green						
ASR South East London (Addington)	green						
ASR Thames Valley/Thames Central	green						
ASR Horton Kirby	green						
GW - Addington	green						
GW - London confined Chalk (north)	green						
GW - Southfleet/Greenhithe (new WTW)	green						
GW - Merton recomissioning	green						
GW - Honor Oak	green						
New River Head removal of constraints	green						
Epsom removal of constraints	green						
Swindon and Oxfordshire (SWOX) WRZ							
RWT - STT Deerhurst			green	green	green	green	green
RWT - Oxford Canal	green						
New Reservoir - Abingdon		green	green	green	green	green	green
New Reservoir - Chinnor		red	red				
New Reservoir - Marsh Gibbon		red	red	red			
GW - Moulsford	green						
Ashton Keynes borehole pumps	green						

Resource Option	Size Band (Ml/d)						
	0 to 25	25 to 75	75 to 125	125 to 175	175 to 225	225 to 275	275 to 325
Britwell removal of constraints							
IZT - Kennet Valley to SWOX							
IZT - Henley to SWOX							
ICT - Wessex Water to SWOX							
Slough, Wycombe & Aylesbury (SWA) WRZ							
RWT - STT Deerhurst							
RWT - Oxford Canal							
New Reservoir - Abingdon							
New Reservoir - Chinnor							
New Reservoir - Marsh Gibbon							
GW - Datchet							
IZT - Henley to SWA							
Henley WRZ							
No feasble options identified							
Guildford WRZ							
Dapdune licence disaggregation							
Dapdune removal of constraints							
Ladymead WTW							
ICT - South East Water to Guildford							
Kennet Valley (KV) WRZ							
GW - Mortimer recommissioning							
East Woodhay borehole pumps							

Key

Screened out at fine screening

Passes fine screening

* Mogden South Sewer option has passed fine screening but is not included on the Constrained List

Constrained List

7.55 For the purposes of programme appraisal, resource elements from the Constrained List and system elements have been combined to provide the best value 80 year programme to address future water supply requirements. A summary of the elements included on the Constrained List is provided in Table 7-8 for the London WRZ and in Table 7-9 for the Thames Valley WRZs. The tables indicate how the system elements combine with each resource element to provide an overall supply option. The location of the resource elements is mapped on Figure 7-5.

Table 7-8: Constrained List for London WRZs

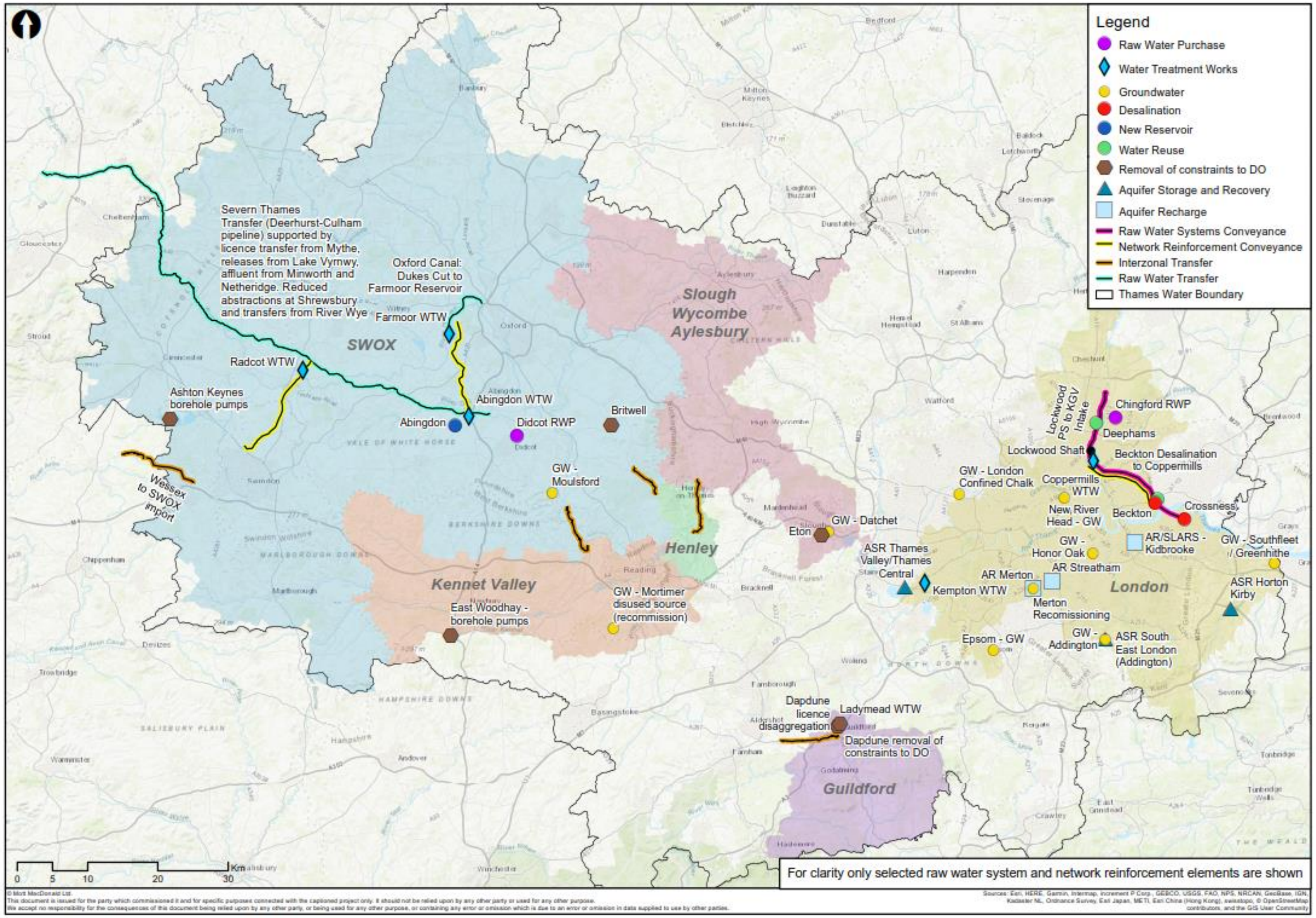
Option Type	Resource Element		Conveyance Element		Raw Water System	Treatment Element		Network Element
	Location	DO* (DYAA) Ml/d	Location	Nominal Capacity Ml/d		Location	Nominal Capacity Ml/d	
Water reuse	Deephams	45	Deephams to KGV	60		East London	100	See network reinforcement matrix - Section 7.D
			Deephams to TLT extension		See raw water system matrix - Section 7.D			
	Beckton 100 Ml/d	95	Beckton to Lockwood shaft	800		East London	100	
	Beckton 150 Ml/d	138					150	
	Beckton 200 Ml/d	183					200	
	Beckton 300 Ml/d	268					300	
Raw Water Transfer	Vyrnwy	60/148/180*	Deerhurst to Culham	300/400/500	See raw water system matrix - Section 7.D	Kempton	300	See network reinforcement matrix - Section 7.D
	Mythe	15*					150	
	River Wye to Deerhurst	60*					100	
	Netheridge to River Severn	35*						
	Minworth to River Avon	115*						
	Redeployment of Shrewsbury abstractions	12/30*						
	Oxford Canal	11						
Desalination	Beckton (blended)	142	N/A		N/A	N/A		See matrix Section 7.D, plus **Beckton to Coppermills**
	Crossness 100 Ml/d	95			Beckton-Crossness			As above plus **Crossness to Beckton**
	Crossness 200 Ml/d	189						
	Crossness 300 Ml/d	284						
New Reservoir	Abingdon 75Mm3	142	N/A		See raw water system matrix - Section 7.D	Kempton	300	See network reinforcement matrix - Section 7.D
	Abingdon 100Mm3	190					150	
	Abingdon 125Mm3	234					150	
	Abingdon 150Mm3	275						
	Abingdon 30+ 100Mm3	49+199						
	Abingdon 80+ 42Mm3	151+83						
Aquifer Recharge	AR/SLARS - Kidbrooke (SLARS1)	7	N/A		N/A	N/A		N/A
	AR Merton (SLARS3)	5						
	AR Streatham (SLARS2)	4						
Aquifer Storage and Recovery	ASR South East London (Addington)	3	N/A		N/A	N/A		N/A
	ASR Thames Valley/Thames Central	3						
	ASR Horton Kirby	5						
Groundwater	GW - Addington	1	N/A		N/A	N/A		N/A
	GW - London Confined Chalk (north)	2						
	GW - Southfleet/Greenhithe (new WTW)	8						
	GW - Honor Oak	1						
	GW - Merton recommissioning	2						
	Epsom removal of constraints	2						
	New River Head	3						
Inter-company transfer	Chingford raw water purchase	20	N/A		N/A	N/A		N/A
	Didcot raw water purchase	18	N/A		N/A	N/A		N/A

* For the Severn Thames Transfer (STT) support elements the volumes shown represent the gross volumes released for the River Severn before allowance for losses. Actual deployable outputs depend upon the combination of support elements selected and the size of the transfer pipeline.

Table 7-9: Constrained List for Thames Valley WRZs

WRZ	Option Type	Resource Element		Conveyance Element		Raw Water System	Treatment Element		Network Element	
		Location	DO Ml/d ADPW	Location	Nominal Capacity Ml/d		Location	Nominal Capacity Ml/d	Location	Nominal Capacity Ml/d
Swindon & Oxfordshire (SWOX)	**Raw Water Transfer**	**Severn Thames Transfer** (See London WRZ for support elements)	See Table 7.3	**Deerhurst to Culham**	300 400 500	N/A	**Radcot WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
		Oxford Canal	12	**Dukes Cut to Farmoor**	15					
	New Reservoir	**Abingdon 75Mm3** **Abingdon 100Mm3** **Abingdon 125Mm3** **Abingdon 150Mm3** **Abingdon 30+ 100Mm3** **Abingdon 80+ 42Mm3**	161 210 253 294 69+199 170+83	**Abingdon to Farmoor Reservoir** (if treatment capacity not required)	24	N/A	N/A		N/A	
							Abingdon SWOX WTW (if treatment capacity required)	24 each phase	Transfers to service reservoir included in WTW elements	
	Groundwater	**GW - Moulsford 1**	3.5	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**Ashton Keynes borehole pumps** **Britwell**	1.5 1.3	N/A		N/A	N/A		N/A	
	Inter-zonal transfers		2.4 5	**Henley to SWOX**	2.4 5	N/A	N/A		N/A	
		GW - Mortimer disused source	4.5 2.3	**Kennet Valley to SWOX**	6.7 2.3					
	Inter-company transfer		2.9	**Wessex Water to SWOX (Flaxlands)**	2.9	N/A	N/A		N/A	
Slough, Wycombe & Aylesbury (SWA)	**Raw Water Transfer**	**Severn Thames Transfer#** (See London WRZ for support elements)	See Table 7.3	**Deerhurst to Culham**	300/400/500	N/A	**Abingdon SWA WTW**	24 each phase	**Abingdon to north SWA**	**72 / 48**
						New intake 80 / 53	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
		Oxford Canal	12							
	New Reservoir#	**Abingdon 75Mm3** **Abingdon 100Mm3** **Abingdon 125Mm3** **Abingdon 150Mm3** **Abingdon 30+ 100Mm3** **Abingdon 80+ 42Mm3**	161 210 253 294 69+199 170+83	N/A		N/A	**Abingdon SWA WTW**	24 each phase	**Abingdon to north SWA**	**72 / 48**
						New intake 80 / 53	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
	Raw Water Purchase	**Didcot**	18	N/A		**New intake 80 / 53**	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
	Groundwater	**GW - Datchet**	5.4	N/A		N/A	N/A		N/A	
	Inter-zonal transfers		2.4/5	Henley to SWA	2.4 / 5	N/A	N/A		N/A	
Guildford	**Groundwater**	**Dapdune licence disaggregation**	7.8	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**Dapdune removal of constraints** **Ladymead WTW removal of constraints**		N/A		N/A	N/A		N/A	
	Inter-co. transfers		10	SouthEast Water to Guildford	10	N/A	N/A		N/A	
Kennet Valley	**Groundwater**	**GW - Mortimer disused source (recommission)**	4.5	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**East Woodhay borehole pumps**	2.1	N/A		N/A	N/A		N/A	

Figure 7-5: Map of Constrained List options



F. Further option development for the Constrained List

Conceptual design

7.56 For water resource elements on the Constrained List, Conceptual Design Reports (CDRs) have been prepared. The CDRs provide information on the location of the works, engineering and land requirements, dependencies with other elements, construction impacts, environmental and social mitigations, DO, programme assumptions and risks.

7.57 The information gathered from the CDRs was used as the basis for updating cost estimates, developing a risk register, and for conducting the Strategic Environmental Assessment of options (SEA).

Cost and risk

7.58 For all elements on the Constrained List a review of feasibility stage costs was conducted. Costs were updated to reflect conceptual designs, where these have changed from the feasibility stage. Unit rates were updated for material cost items where confidence in the feasibility stage estimates was low.

7.59 For all large resource elements on the Constrained List (i.e. resources with a capacity of more than 50 Ml/d) a risk register was developed and estimates of likelihood and consequence of risks occurring were assigned. Monte Carlo analysis was used to combine these estimates to provide a probability distribution for risk.

7.60 An allowance for optimism bias was applied to all elements at feasibility stage, and this was scaled back to reflect the level of confidence around solution delivery at conceptual design stage. For elements where a risk allowance was applied from the risk register, the scaling back of optimism bias was revisited following completion of the risk register so as to avoid double counting of risk between optimism bias and the bottom-up allowance of risk identified through the risk register.

Strategic environmental assessment

7.61 For all elements on the Constrained List a SEA was conducted. Further information on the Strategic Environmental Assessment appraisal can be found in WRMP19 Section 9: Environmental appraisal.

Further investigations into Constrained List options

7.62 The options on the Feasible List and Constrained List are assessed as being feasible based upon existing knowledge. Additional information on further work can be found in Appendix XX. At this stage of project development, it is inevitable that uncertainties will exist and a number of investigations are ongoing to further reduce uncertainty.

7.63 The major option on the Constrained List with the most significant uncertainties is the Severn Thames Transfer. In responding to the consultation on the Statement of Response a number of stakeholders requested that investigations into the feasibility of the Severn Thames Transfer should continue. A programme of investigations is proposed that includes investigations into losses that would occur in the River Severn associated with supporting resource options for the Severn Thames Transfer from Lake Vyrnwy, redeployment of the River Severn abstractions at Shrewsbury and Minworth STW discharges to the River Avon. Associated with these investigations are discussions through the River Severn Working Group on potential future abstraction arrangements. The EA has indicated that existing information/data does not allow a definitive estimate of losses to be agreed and that they would not agree to a put and take licensing arrangement based on currently available information. Instead they would apply the published abstraction licensing policy (currently no abstraction when River Severn flow is below 1800Ml/d and restricted abstraction when flow is between 1800Ml/d and 2400Ml/d) to any new licence at Deerhurst in order to protect the Severn Estuary Special Area of Conservation (SAC). The loss assumption has, accordingly, been increased from 10% to 20% for the revised draft WRMP. Further work and consultations are ongoing; however, the issues described above pose a significant risk that water released to the River Severn from 3rd party support options would not be available for transfer when required by Thames Water.

7.64 The Mogden South Sewer option was rejected at Fine Screening in the draft WRMP as being mutually exclusive with the Teddington DRA option. The Teddington DRA option has now been removed from the Feasible List due to environmental concerns raised by the Environment Agency and the Mogden South Sewer option has now been assessed as passing Fine Screening. Details of the concerns can be found in Appendix L: Water Reuse. However, it has not been possible to further develop the Mogden South Sewer option sufficiently to include it in the Constrained List for this revised draft WRMP, but initial review suggests that the option, if included, would not have impacted the preferred programme. Further work is needed to develop the option for inclusion in the Constrained List in future and to confirm this assessment.

G. Drought permits

7.65 We have identified a number of drought permit options that would be used to augment existing water supplies in the event of a severe drought. Drought permits are options that enable water companies to abstract more water than permitted by their abstraction licences. These options are only available in drought situations and require the water company to demonstrate that there has been an exceptional shortage of rainfall. They are initially issued for a six month period but may be extended for a further six months if the drought persists. These drought permit options are set out in more detail in our Drought Plan and its appendices[12].

7.66 The volumes associated with each drought permit are uncertain because the yields will be subject to the impact of the severe drought that would trigger their implementation. The

[12] Thames Water draft Drought Plan, 2017

Drought Plan provides an indication of the yield that would be expected from each option. An estimate of this yield has been produced and the associated resource benefit volumes used for modelling of scenarios by WRSE. The yields for each WRZ under the worst droughts from the historic record and the worst droughts from a 1:200 stochastic record are shown below in Table 7-10. The historic record is the period for which data is available and is used to calculate the deployable output for our water resources. The 1 in 200 year estimate has been derived from stochastic analysis to provide a longer period than the historic record which can then be used to examine the impact of more severe droughts than those that occur in the historic record.

Table 7-10: Yields for each WRZ under the worst droughts from the historic record and the worst droughts from a 1:200 stochastic record[13]

WRZ	Historic record	1:200
London	240 Ml/d	126 Ml/d
SWOX	81 Ml/d	42 Ml/d
Kennet Valley	61 Ml/d	9 Ml/d
SWA	14 Ml/d	11 Ml/d
Guildford	12 Ml/d	9 Ml/d
Henley	6 Ml/d	6 Ml/d

7.67 The drought permit options generally exist where we have water sources that are restricted or have been closed because of their potential to exacerbate low flows in rivers. Therefore, the options, in most cases, would have some adverse environmental impact if implemented, although in most cases it would be temporary and reversible in that the ecology would recover after drought conditions ceased if permits are implemented for up to six months. In each case the environmental impact has been assessed and Environmental Assessment Reports produced and these have been used in the production of a Habitats Regulations Assessment and a SEA for the Drought Plan. The prolonged use of drought permits during severe drought events would be likely to cause significant environmental damage. This is discussed in our Drought Plan and Appendices.

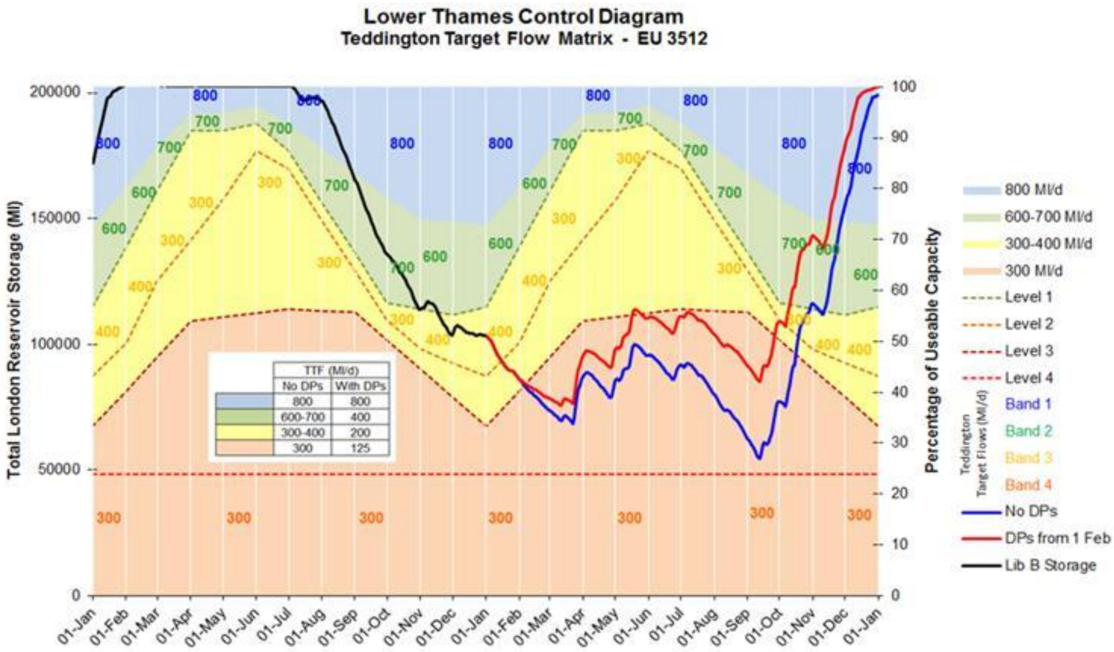
7.68 These drought permit options provide an important resource to ensure continuity of supply in the event of severe drought. The longer a drought permit option is used the greater the environmental impact is likely to be. It is also important to consider that the yield of these options would decrease through time as the drought severity intensifies and this is shown above in Table 7-10 for a 1:200 year drought. In addition, there is a risk that drought permits may not be renewed for a further period of six months if the Environment Agency / Secretary of State consider the actual or potential environmental impact would be too great.

7.69 We have assessed the impact of more severe droughts for our Drought Plan using stochastically generated data to provide a much longer time series which gives a greater range of droughts for assessment. Figure 7-6 and Figure 7-7 show the impact of droughts of severity of 1:300 for London using the Lower Thames Control Diagram (LTCD) and demonstrate the importance of drought permits in preserving reservoir storage. A full

[13] These estimates are for yield, not the associated deployable output figure which would be lower.

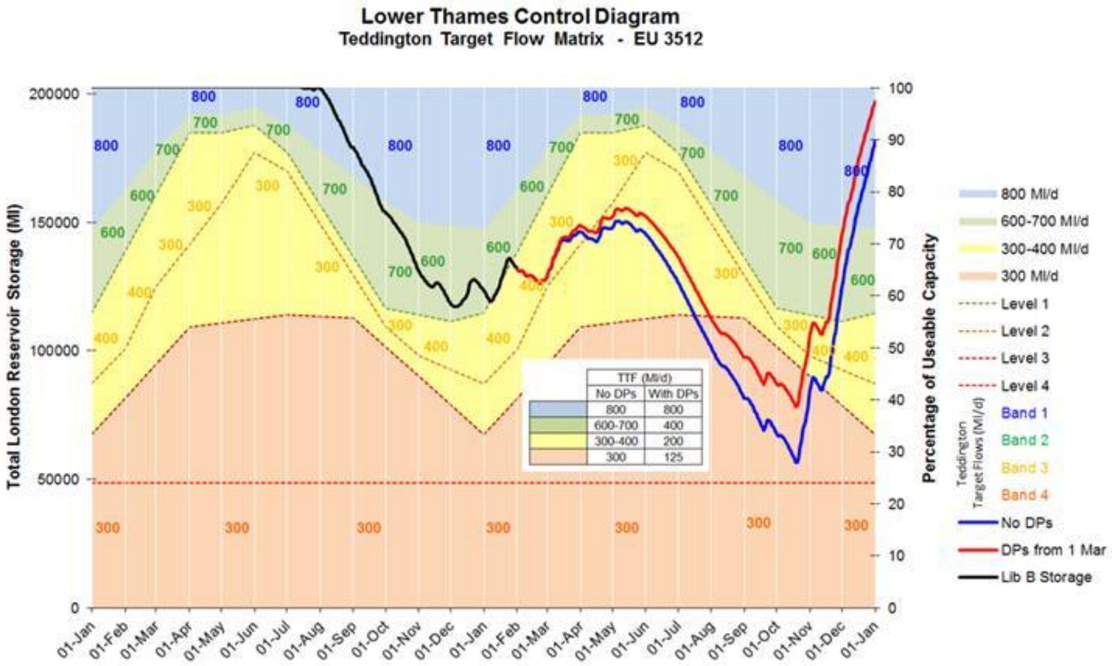
explanation of the LTCD is provided in Appendix I sections D and F. In the first example we would need to implement drought permits from 1st February until the end of September. In the second example we would need drought permits from 1st March until the end of October. In each case drought permits would have been needed for longer than six months and so a reapplication would be necessary. The reapplication would be subject to significant uncertainty in yield, because of the impact of a more severe drought on water resource availability, and environmental impact and would be likely to be strongly opposed by regulators and stakeholders concerned with impact on the environment.

Figure 7-6: Impact of the Generated 'Severe' Drought Event 1 (modelled 1 in 300 Return Period) on Aggregated London Reservoir Storage – example 1[14]



---
[14] Thames Water draft Drought Plan, 2017

Figure 7-7: Impact of the Generated 'Severe' Drought Event 2 (modelled 1 in 300 Return Period) on Aggregated London Reservoir Storage – example 2



7.70 We do not consider the prolonged use of drought permits to be a sustainable use of water resources for a resilient 1:200 water supply system. That does not mean that we would only use drought permits with an expected drought frequency of 1 in 200 years; their use is likely to be significantly more frequent than this. Our aspiration is not to abstract from these sources apart from in very severe drought events. As a drought begins to unfold it is impossible to say at the time how severe the event will be. It is only with hindsight that it is possible to look back and state what the severity of the event was. Therefore during an emerging drought event that has the potential to be very severe, it is inevitable that drought permits will be requested, and if granted, implemented much more frequently than once in every 200 years. Figure 7-8 and Figure 7-9 below show two emerging drought events from the historical record; drought permits would have been requested from the EA given the pending severity of the event. Figure 7-10 and Figure 7-11 show how these two events subsequently unfolded; neither event was subsequently shown to be a 1 in 200 year event, the frequency was approximately 1 in 100 year. Under climate change scenarios, where drought events are forecast to become more extreme with less summer rainfall, it is inevitable that the frequency and occurrence of such events will increase and consequently that drought permits requests to the EA and subsequent implementation will be much more frequent than once every 200 years, indeed they will be significantly more frequent than once every 100 years.

7.71 We have undertaken analysis of the frequency of Level 3 and Level 4 events under 1 in 100 and 1 in 200 year droughts. This work is based on the analysis of stochastically generated records used to assess the likelihood of greater drought severity than experienced in the historic record and is presented in Appendix I.

7.72 To plan for a resilient water supply system that relies on the frequent use of drought permits is not appropriate due to their association with environmental damage. Therefore, these temporary supply options are not taken forward for inclusion in our programme appraisal. However, they do provide a short term unsustainable option which would need to be implemented in the event that a severe drought occurs. We believe that, in the long term, alternative options should be developed to provide resilience to more severe droughts such as those with a level of severity of 1:200. In this respect our approach is consistent with that adopted by other water companies.

7.73 Our WRMP19 ensures a reduction in the frequency of reliance on drought permits by increasing resource availability and becoming resilient to a 1 in 200 year drought event. The company will only rely on drought permits during severe drought events, i.e. events which, as they begin to unfold, suggest that they could be very severe in terms of the incidence of occurrence. The analysis presented in WRMP19 Appendix I, Table I-7, shows that the frequency of drought permit implementation improves to 1 in 40 years post 2030 when new resources are introduced to deliver 1 in 200 year level 4 resilience.

7.74 We have considered whether our Drought Permit options would be suitable as water resource options and we do not consider these options as feasible because of the adverse environmental impact that they would have, which would preclude the Environment Agency from licensing them. In support of our Drought Plan Thames Water has undertaken work to assess the impact of abstraction at Drought Permit sources over a sustained period to meet potentially severe droughts in the future. This work led to the production of a report 'Environmental Assessment of Severe Droughts – Summary Report', which undertook a high level assessment of the impact of use of Drought Permit options to address prolonged drought of greater than 6 months. The report included the following conclusions: 'The implications of severe droughts on the WFD of the Drought Plan has been considered. Extreme low flows as a result of an environmental drought (without drought permits) may have major effects on aquatic habitats, biota, and consequently ecosystem functions. It is generally recognised that multi-season droughts in sensitive water bodies could result in impacts on the ecological communities of a high magnitude with communities only recovering in the long-term. Most water bodies within the Thames Water operational area have been physically modified. As such, these water bodies are less resilient to the impacts of environmental drought and sensitive to the extended implementation of drought permits. The re-application of some drought permits could result in some local populations being lost due to a lack of suitable habitat. As the duration and impacts associated with drought and drought permits increase, the effect on biota is likely to increase in severity from the individual to a catchment/regional level. As such, there is a high risk that temporary deterioration in WFD status associated with a severe environmental drought will be exacerbated through the re-application of individual drought permits, affecting several WFD elements with recovery only expected over the long term.' In light of this we do not consider that the options identified above could be considered as WRMP options as to implement them would lead to unacceptable environmental impact with likely breach of WFD standards.

Figure 7-8: Emerging drought event (1921/22)

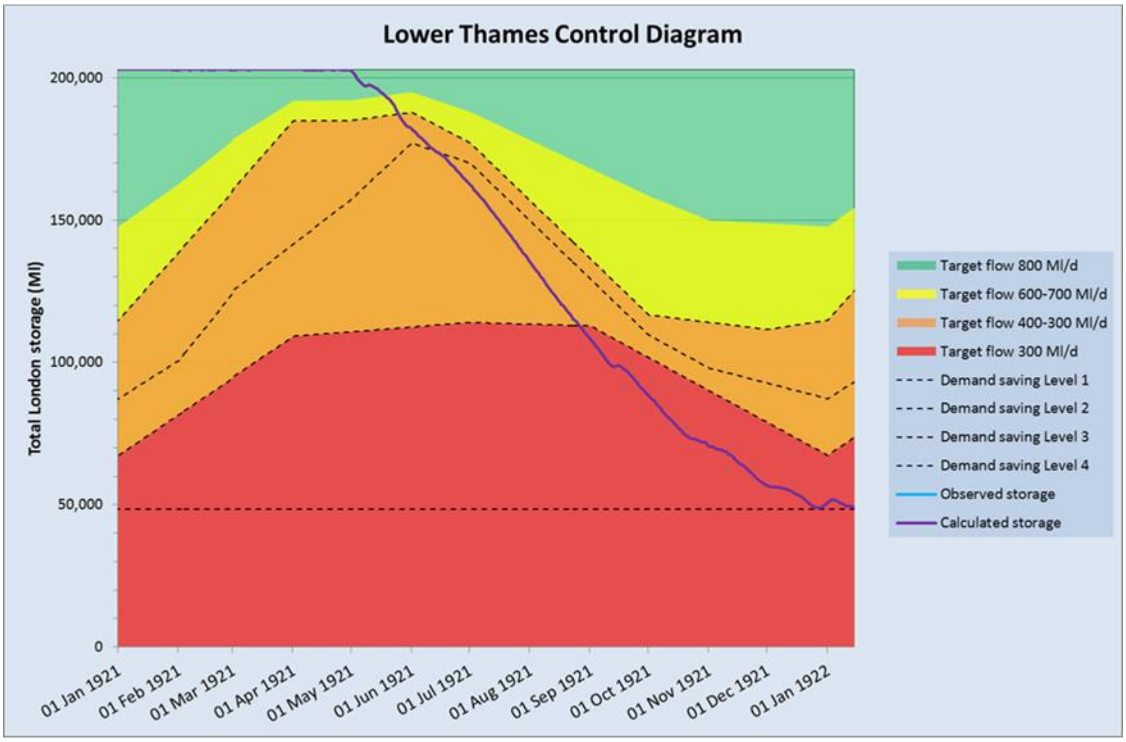


Figure 7-9: Emerging drought event (1976)

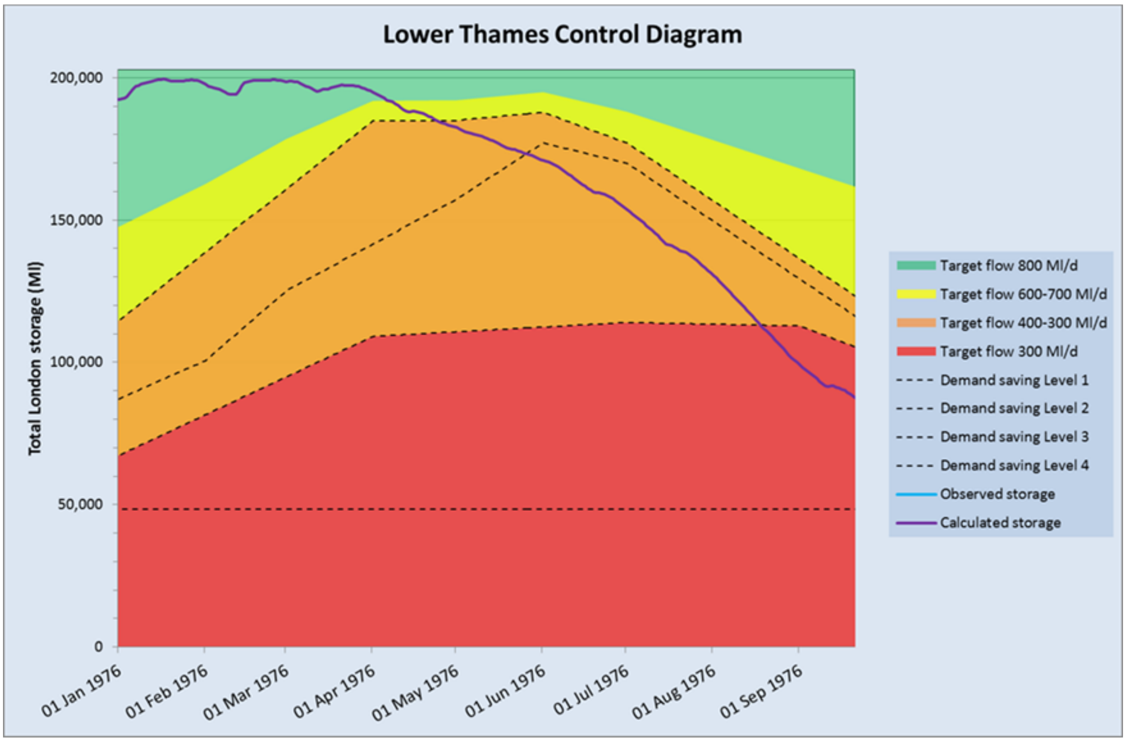


Figure 7-10: How the drought subsequently unfolded (1921/22)

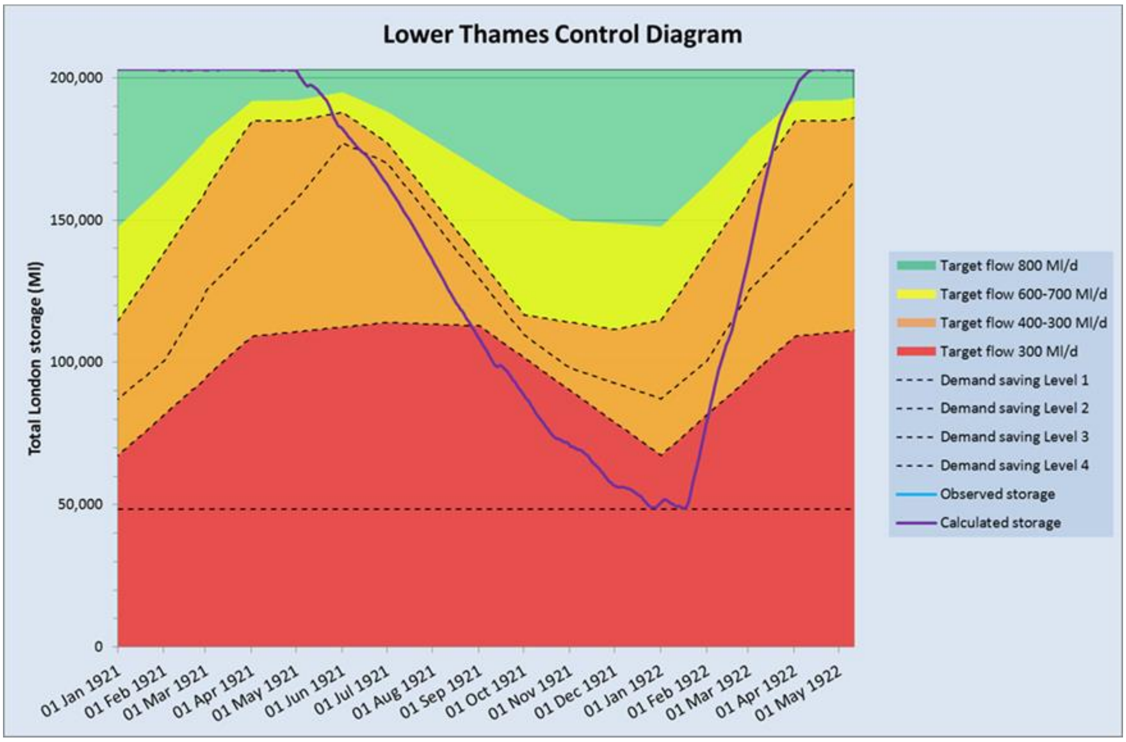
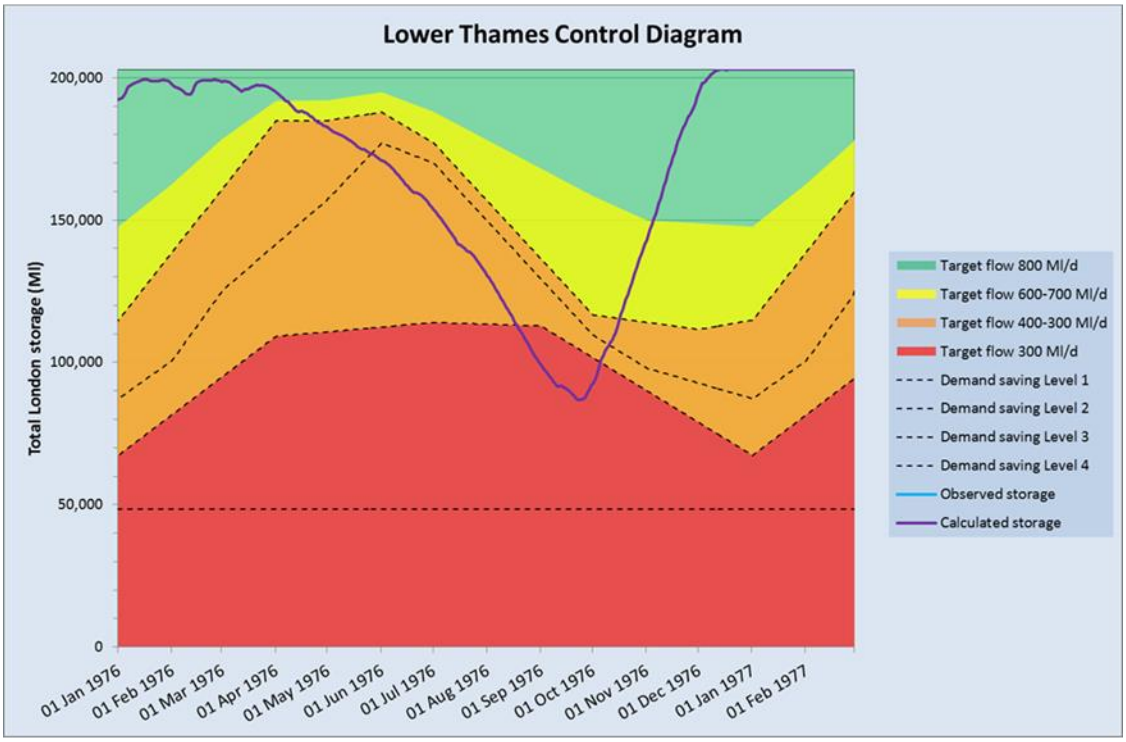


Figure 7-11: How the drought subsequently unfolded (1976)



H. Sources of further information

7.75 The following information is available on the Constrained List options.

- Fine screening report, Mott MacDonald, September 2018
- Feasibility reports
  - Raw Water Transfer Feasibility report, Mott MacDonald, September 2018
  - Groundwater Feasibility report, Mott MacDonald, September 2018
  - New Reservoirs Feasibility report, Mott MacDonald, July 2017
  - Water Reuse Feasibility report, Mott MacDonald, September 2018
  - Desalination Feasibility report, Mott MacDonald, February 2018
  - Direct River Abstraction Feasibility report, Mott MacDonald, September 2018
  - Catchment Management Feasibility report, Mott MacDonald, March 2018
  - Inter-Zonal Transfer Feasibility report, Mott MacDonald, February 2018
- Risk methodology, Mott MacDonald, March 2018
- Cost and Carbon and Whole Life Cost Methodology reports, Mott MacDonald, March 2018
- Network Reinforcement Cross Option study, Mott MacDonald, January 2018
- Raw Water System Cross Option study, Mott MacDonald, January 2018
- Water Treatment Cross Option study, Mott MacDonald, January 2018
- Discharge Design Standards Cross Option study, Mott MacDonald, February 2018
- Operating Philosophy, Mott MacDonald, February 2018
- Stochastic Resource Modelling, Stage 2 & 3 Report, Atkins, July 2018
- Conceptual Design Reports – these are available in CWC by appointment
- Constrained List Scheme Dossiers, Appendix R

7.76 Please contact consultations@thameswater.co.uk for access to any of these documents