Annex A2: Mogden Water Recycling Conceptual Design Report

Standard Gate two submission for London Water Recycling SRO

Notice – Position Statement

This document has been produced as the part of the process set out by RAPID for the development of the Strategic Resource Options (SROs). This is a regulatory gated process allowing there to be control and appropriate scrutiny on the activities that are undertaken by the water companies to investigate and develop efficient solutions on behalf of customers to meet future drought resilience challenges.

This report forms part of suite of documents that make up the 'Gate 2 submission.' That submission details all the work undertaken by Thames Water in the ongoing development of the proposed SRO. The intention at this stage is to provide RAPID with an update on the concept design, feasibility, cost estimates and programme for the schemes, allowing decisions to be made on their progress.

Should a scheme be selected and confirmed in the Thames Water final Water Resources Management Plan (WRMP), in most cases it would need to enter a separate process to gain permission to build and run the final solution. That could be through either the Town and Country Planning Act 1990 or the Planning Act 2008 development consent order process. Both options require the designs to be fully appraised and, in most cases, an environmental statement to be produced. Where required that statement sets out the likely environmental impacts and what mitigation is required.

Community and stakeholder engagement is crucial to the development of the SROs. Some high-level activity has been undertaken to date. Much more detailed community engagement and formal consultation is required on all the schemes at the appropriate point. Before applying for permission Thames Water will need to demonstrate that they have presented information about the proposals to the community, gathered feedback and considered the views of stakeholders. We will have regard to that feedback and, where possible, make changes to the designs as a result.

The SROs are at a very early stage of development, despite some options having been considered for several years. The details set out in the Gate 2 documents are still at a formative stage.

Disclaimer

This document has been written in line with the requirements of the RAPID Gate 2 Guidance and to comply with the regulatory process pursuant to Thames Water's statutory duties. The information presented relates to material or data which is still in the course of completion. Should the solutions presented in this document be taken forward, Thames Water will be subject to the statutory duties pursuant to the necessary consenting process, including environmental assessment and consultation as required. This document should be read with those duties in mind.

Annex A2: Mogden Water Recycling Scheme Conceptual Design Report

Document no: J698-MR-DOC-220001-0D

Thames Water Utilities Ltd
J698

London Water Recycling
13 October 2022

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Executive Summary

This report sets out the conceptual design for the Mogden Water Recycling scheme. This scheme was identified in the Water Resources Management Plan 2019 (WRMP19) Water Reuse Feasibility Study and WRMP19 Fine Screening process by Thames Water Utilities Limited (TWUL) and selected as a part of the Strategic Resource Option (SRO) London Effluent Reuse by the Regulators' Alliance for Progressing Infrastructure Development (RAPID).

As a part of London Effluent Reuse SRO, Mogden Water Recycling scheme was submitted for the standard Gate 1 assessment by RAPID, and it was agreed that it would continue to be funded to Gate 2 as part of the standard gate track.

The SRO Gated process by RAPID, working alongside the regional planning stakeholder groups, will provide regulatory oversight of a set of regional water resource management plans that will adopt consistent assumptions to form a nationally coherent view.

The design elements in this report are listed below:

- 50Ml/d Advanced Water Recycling Plant at site near Kempton WTW (AWRP site) (WRSE Ref. TWU_WLJ_HI-REU_reuse mogden 50)
- 100Ml/d Advanced Water Recycling Plant at site near Kempton WTW (AWRP site) (WRSE Ref. TWU_WLJ_HI-REU_reuse mogden 100)
- Final Effluent Transfer Tunnel from Mogden Sewage Treatment Works (STW) to AWRP site (WRSE Ref. TWU_WLJ_HI-TFR_reuse mogden/walton)
- Waste Stream Return Pipelines (2 no.) from AWRP site to Mogden STW (WRSE Ref. TWU_WLJ_HI-TFR_reuse mogden/walton)
- Recycled Water Transfer Pipeline from AWRP site to the River Thames (WRSE Ref. TWU_WLJ_HI-TFR_reuse mogden/walton)

Table S.1: Scheme Summary

Name	Mogden Water Recycling
Gate-2/WRSE Reference	TWU_WLJ_HI-REU_reuse mogden 50, TWU_WLJ_HI-REU_reuse mogden 100, TWU_WLJ_HI-TFR_reuse mogden/walton
Scheme Type	Resource and Conveyance
WRZ	London. Potentially, Affinity Water's WRZ if Mogden Water Recycling supplies water to Thames to Affinity Transfer (T2AT) SRO.
Engineering Scope	A portion of final effluent from Mogden STW would be conveyed to a new Advanced Water Recycling Plant (AWRP). The Recycled Water would be discharged into the River Thames upstream of the existing Thames Water Walton WTW Intake. The waste streams would be conveyed back to Mogden STW.
Benefit	46Ml/d, 88Ml/d and 169Ml/d Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP) Deployable Output for the capacities of 50Ml/d, 100Ml/d and 200Ml/d, respectively
Mutual exclusivities	Teddington DRA and Mogden South Sewer up to a combined capacity of 200Ml/d. If Mogden Water Recycling scheme and Mogden South Sewer scheme are using same site for AWRP, there may be mutual exclusivities depending on scheme sizes and area of selected site.
Interdependencies	Mogden Water Recycling scheme would possibly support Thames to Affinity Transfer (T2AT) SRO. Mogden Water Recycling scheme does not have dependencies on other options. To provide an additional resource to London WRZ, the following elements may also be required: ▪ Additional capacity to abstract from the River Thames and convey to Kempton WTW. Increase in abstraction would also be considered as an upgrade to raw water systems in West London. ▪ Additional treatment capacity at Kempton WTW ▪ Potential network reinforcements

1 Introduction

1.1 Background

Thames Water Utilities Limited (TWUL) are engaged in development of Strategic Regional Water Resource Options (SROs) under the guidance of the Regulators' Alliance for Progressing Infrastructure Development (RAPID). RAPID was formed to help accelerate the development of new water infrastructure and design future regulatory frameworks, with collaboration between Ofwat, the Environment Agency (EA) and the Drinking Water Inspectorate (DWI).

Water resource options were developed for the reuse of Sewage Treatment Works (STW) effluent or blackwater (untreated sewage) reuse and direct river abstractions in London as part of TWUL's Water Resource Management Plan 2019 (WRMP19). London Effluent Reuse has been identified as SRO in the Price Review 2019 (PR19) Final Determination (London Effluent Reuse SRO). At PR19, Ofwat announced a development fund for strategic water resource solutions linked to "Gates" to ensure efficient delivery and to protect customers. TWUL has been allocated funds to investigate and develop integrated strategic regional water resource solutions, including London Effluent Reuse SRO, between 2020 and 2025 to support long term resilience. The London Effluent Reuse SRO solution was submitted for the standard Gate 1 assessment by RAPID in 2021, and it will continue to be funded to Gate 2 as part of the standard Gated process in 2022.

London Effluent Reuse SRO incorporates four schemes that need to progress through a formal gated process of review and approval by RAPID: two schemes for reuse of final effluent from Mogden STW (Mogden Water Recycling scheme) and Beckton STW (Beckton Water Recycling scheme), a direct river abstraction scheme (Teddington Direct River Abstraction (DRA) scheme) and a fourth, blackwater or sewer mining treatment option within the Mogden STW catchment (Mogden South Sewer scheme). Abstracted effluent or sewage in these schemes is to be treated in each case through an Advanced Water Recycling Plant (AWRP) or a Tertiary Treatment Plant (TTP) and discharged to the River Thames or the River Lee Diversion for abstraction as a water resource.

This report sets out the conceptual design for the Mogden Water Recycling scheme. The proposal for the Mogden Water Recycling scheme is summarised as:

- A portion of final effluent from Mogden STW will be pumped to a new Advanced Water Recycling Plant (AWRP) at a site near Kempton Water Treatment Works (WTW).
- The Recycled Water is then to be discharged into the River Thames upstream of the existing Thames Water Walton WTW Intake. The waste streams will be conveyed back to Mogden STW.
- Definitions of glossary and abbreviations in this report could be found in section 6 Glossary and Abbreviations.

1.2 Scheme Overview and Location

Mogden STW is located in Isleworth, West London. This scheme would abstract and treat the final effluent from Mogden STW (see (1) Figure 1-1).

Accordingly, the scheme would include locating a new Advanced Water Recycling Plant (AWRP) near Kempton WTW, which is approximately 6 km to the Southwest of the Mogden STW (see (2) Figure 1-1). Potential sites for the new AWRP are currently being investigated. Final effluent from Mogden STW would be transferred to the new AWRP and treated to sufficient standard for reuse to allow its discharge to the River Thames as a source water for drinking water abstraction.

The Recycled Water would be discharged into the River Thames upstream of the existing Thames Water Walton WTW Intake (see (3) Figure 1-1). A route optioneering study is being carried out to determine a suitable site and discharge conditions. The waste stream from the AWRP would be conveyed from AWRP site back to Mogden STW to return to the inlet works of the STW for treatment.

The Mogden Water Recycling scheme would supply the London Water Resource Zone (WRZ) (see (4) and (5) Figure 1-1).

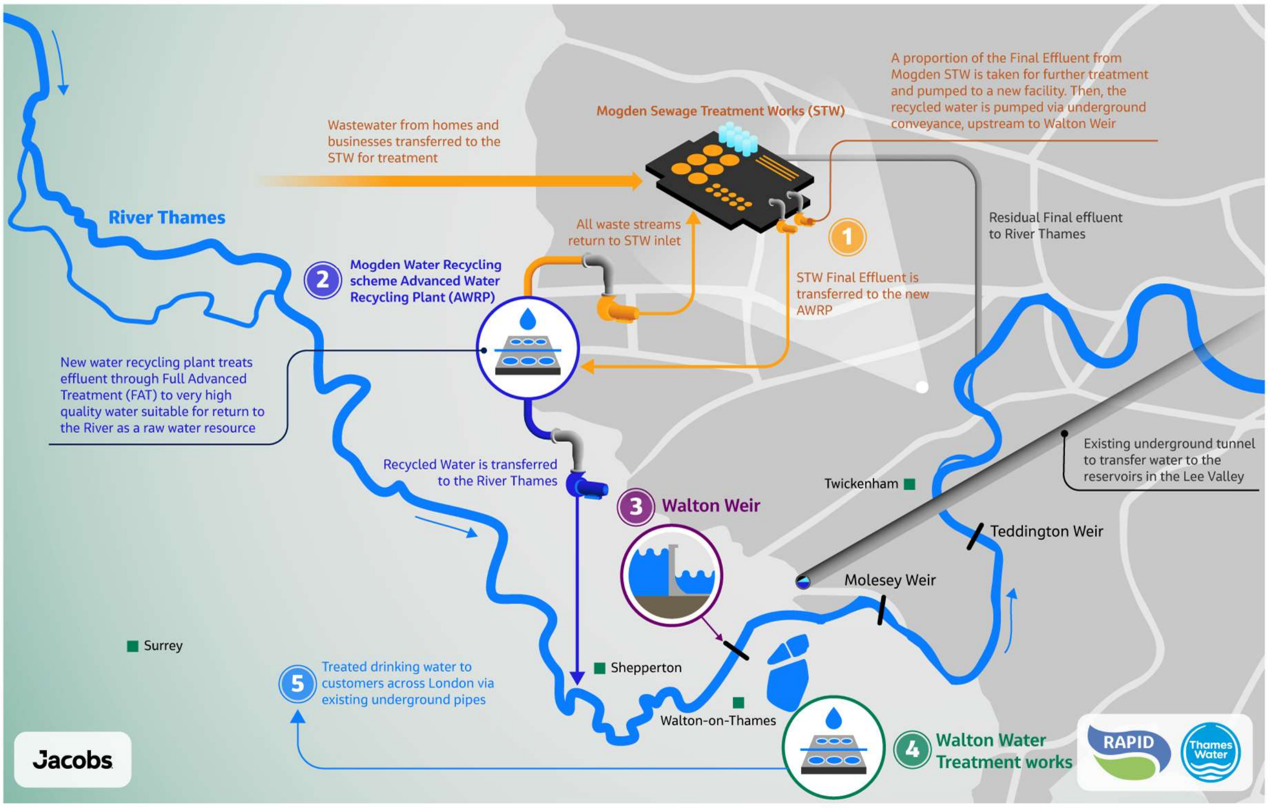

Figure 1-1: Mogden Water Recycling Scheme Overview.

1.2.1 Gate 1 Development

Maximum size for Mogden Water Recycling scheme at Gate 1 was recommended to be at 200Ml/d based on source flow availability (i.e. Final Effluent from Mogden STW). Therefore, engineering design in Gate 2 design development assumed 200Ml/d as the scheme maximum size. However, the results of Gate 2 environmental investigation showed a significant risk from a 200Ml/d scheme causing thermal plume in Recycled Water discharge on the River Thames. At 150Ml/d capacity, thermal plume would occur in only in winter months when the scheme would not be likely in use, whereas at 100ML/d the assessment showed no risk of significant impacts on the River Thames. Details of Gate 2 environmental investigations could be found in Annex B of Gate 2 Report.

Therefore, for future scheme investigations into Gate 3, the maximum capacity of the Mogden Water Recycling scheme would be capped at 150Ml/d.

In Gate 1 conceptual design, the conveyance routes were reviewed to reduce the costs associated with the long conveyance routes. Most of Recycled Water Transfer Pipeline and some sections of Final Effluent transfer conveyance were proposed to be in trenched installation in Gate 1. However, Gate 2 option appraisal showed a combination of trenched installation and trenchless installation for the Final Effluent transfer conveyance between Mogden STW and the AWRP site would not be practicable due to restriction of land use and change of conveyance profiles.

In Gate 2, it would be proposed that the entire section of the Final Effluent Transfer Tunnel would be installed in trenchless method.

The conveyance route and designs proposed in Gate 1 were further reviewed in conjunction with various aspects such as environmental, planning and engineering for Gate 2. Gate 2 design development includes walk-over surveys, scheme operational philosophy and hydraulic and pumping strategy development and incorporation of planning strategy. This has enabled a greater understanding of the constraints and reduced uncertainty in delivery of the schemes.

Table below list the key design changes from Gate 1 to Gate 2.

Table 1-1: Key Design Changes from Gate 1 to Gate 2

Gate 1 Conceptual Design	Gate 2 Conceptual Design
Maximum scheme size had been assumed to be at 200Ml/d.	Environmental studies during Gate 2 showed impacts on river temperature would be acceptable only up to 150Ml/d. Maximum scheme size of 150Ml/d is recommended for Gate 3, though Gate 2 design for engineering components has been performed assuming a maximum scheme size of 200Ml/d.
A combination of trenched and trenchless section had been proposed for Final Effluent conveyance between Mogden STW and the AWRP site.	Final Effluent conveyance between Mogden STW and the AWRP site was assumed to be installed entirely in trenchless method.

1.3 Sizing and Phasing

This section provides an overview of the sizing and phasing of the Mogden Water Recycling option.

The table below shows the scheme sizes (Recycled Water yielded in AWRP) considered at Gate 2.

Table 1-2: Mogden Water Recycling Scheme Sizes Considered in Gate 2 Design Development

Scheme Name	Description of Scheme	Constraint	Scheme Sub-Options	
Mogden Water Recycling scheme	Final effluent harvest, reuse, convey recycled water to River Thames at Walton	Combined maximum capacity of 200Ml/d	AWRP options	50 Ml/d
				100 Ml/d
			Conveyancing (e.g., tunnel, pipes and outfall)	

1.3.1 Constraints Impacting Solution Sizing and Phasing

The key constraints impacting the solution sizing and phasing are:

- **Availability of land at Mogden STW for development**: The site is very developed with little available land, thus necessitating a solution which uses alternative land near Kempton WTW, the exact potential site locations are currently being evaluated.
- **Availability of land for conveyance or tunnel shafts**: The nature of the urban/sub-urban environment, and designated sites limits open-cut trenching pipeline options. It also constrains the potential shaft locations. A combination of tunnel and pipeline conveyance would be required for the option to be considered feasible.
- **Increases to receiving water body temperature**: Increases to receiving water-body temperature that would not achieve Environment Agency permitting requirements and pose risk to passage of migratory fish species.

1.4 Links with Other Options, Schemes and Elements

1.4.1 Dependencies

Water resource options require several different elements (from source to treated water transmission) to be implemented for the resource option to deliver benefit. Table 1-3 lists system elements that may be required to deliver a full water resource utilisation for this scheme. Water network reinforcements required irrespective of the specific scheme selected, have not been included.

Table 1-3: Interdependent Elements

Type	Interdependent Elements
Water Sources	N/A
Abstraction and Conveyance	▪ Additional capacity to abstract from the River Thames and conveyed to Kempton WTW
Water Treatment Works	▪ Additional treatment capacity at Kempton WTW
Drinking Water Network Reinforcement	▪ Potable network reinforcements.
Others	▪ Mogden Water Recycling scheme is identified as one of the potential water source options for T2AT SRO.

1.4.2 Mutual Exclusivities

The combined capacity/yield of Teddington DRA, Mogden Water Recycling and Mogden South Sewer is limited to 200Ml/d because the three schemes use final effluent of Mogden STW or sewage from the Mogden STW catchment as a water source as detailed in section 1.3. These three schemes could be mutually exclusive when the cumulative capacities exceed the limit.

2 Conceptual Design

2.1 Design Principles

2.1.1 Overview

During the Gate 2 Conceptual Design process, the All Company Working Group (ACWG) issued "ACWG Design Principles, Process and Gate 2 Interim Guidance" to maintain consistency throughout SROs.

The ACWG Design Principles comprise the four principles of the National Infrastructure Commission (Climate, People, Place, Value) with two cross-cutting principles that apply across all four categories. Table 2-1 summarises an overview of approaches in Mogden Water Recycling scheme to the ACWG Design Principles.

2.1.2 London Effluent Reuse SRO Design Vision

For the London Effluent Reuse SRO, Thames Water have set out their design vision: to create a resilient water future for customers in Greater London and the Southeast. This design vision focuses on the key principles of climate, people, places and value. Thames Water supports the need to protect the environment and our climate through the principles of sustainability, while ensuring the water supply, to our people, is resilient in terms of quality and quantity. Thames Water endeavours to create this resource supply in ways that meet the needs and expectations of our customers and all stakeholders. The projects will protect and enhance the natural environment whilst providing the best value to customers.

Growing populations, climate effects and reduction in suitable raw water supply for the region mean there will be a significant supply deficit in future periods of dry weather.

Conventional water resources are becoming strained and so innovative, sustainable solutions such as water recycling are increasingly important. Thames Water is committed to delivering a new water recycling strategic resource option (SRO) to meet the future needs by the early 2030's.

The scale of the challenge is reflected in the extent of the supply deficit the region will see in drought conditions. This will require scheme sizes having the potential to deliver an additional 300Ml/d of new water. By employing water reuse schemes in the region, Thames Water can avoid reliance on additional river abstraction thereby protecting local rivers and reservoir habitats.

As a company, Thames Water needs to deliver wide-ranging solutions, including demand management and leakage reduction, new storage facilities, new transfers from other companies and enhanced network capacity. These present challenges in terms of protecting the environment and providing best value to customers, but also offers opportunities to take significant steps in delivering a design vision to create a resilient water future. The London Effluent Reuse SRO presents an opportunity to deliver this vision, that is regionally focused, resilient for the future and supporting us in protecting the environment.

Thames Water's starting point is that it will deliver value for money by applying the best in worldwide design and construction. It is recognised that good design saves resources and reduces carbon footprint; therefore, our commitment through the early design stages will ensure that all viewpoints are considered.

Thames Water's design vision commitment is:

- To provide a secure, resilient and high-quality new resource of raw water to Greater London and supplement the water supply to the region, ensuring beautiful and functional design with a pride of being a part of the community.
- Through robust and detailed environmental and ecological assessments, to protect and promote the recovery of nature and achieve Environmental Net Gain, while limiting and mitigating any effects on the local environment.
- To develop solutions that provide social amenity value, environmental benefits and any additional values to the region.
- To work collaboratively with all stakeholders to ensure the best value for the customer and the environment, meeting needs of the communities.
- To create a long-term, sustainable solution that recycles an existing resource to reduce the water footprint.

Table 2-1: Overview of Gate 2 Design Approaches to ACWG Design Principles

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
Cross Cutting Design Principles 1. Be specific: Develop project-specific design vision and principles based on an understanding of the objectives of each project and the people and places it will affect.	1. Draft Design Vision, Narrative and Principles.	See section 2.1.2 for Design Vision of London Effluent Reuse SRO. The Gate 2 Report content gives an overview of the design vision for this scheme and the London Reuse SRO as a whole.	CDR section 2.1.2. Gate 2 Report	1.1. Development of project specific vision and principles mapped against the NIC and ACWG Principles. 1.2. Development of a clear, concise narrative describing the story behind your Vision and Principles.
2. Safe and well: Actively and collectively develop designs that can be built, used, and maintained without unacceptable risks to the health and safety of workers - particularly during hazardous construction and operational activity. Manage risks to members of the public thoughtfully with an approach that balances maximising wellbeing benefits with protection from risks that could cause significant harm.	2. Outline Designers Risk Assessment highlighting potential significant and/or unusual risks with potential mitigations.	Principal Designer was appointed in conformance with the CDM Regulations 2015. Please see section 3.1.3 for CDM implementation and outline of the potential significant and/ or unusual risks in the scheme. Drinking Water Safety Plans have been created for this scheme to ensure the customer's and environment's safety is paramount for the design vision.	CDR section 3.1.3 Gate 2 Report - Annex C: Water Safety Plan	2.1. No accidents, incidents or harm to people during construction and operation. 2.2. Use of best practice procedures in design risk management following HSE Guidance and CDM Legislation. 2.3. Design informed by understanding potential risks to the public and management of these so far as reasonably practicable. Use of appropriate guidance including but not limited to: a. RoSPA and the National Water Safety Forum's Guiding Principles for Managing Drowning and Water Safety Risks. b. Visitor Safety in the Countryside. 2.4. Consideration of security early in the design of fence, gate and boundary treatments.
Climate 1. Nature knows no boundaries: Water is essential to all life and managing our response to climate change is a collective and urgent activity. Projects must be developed to work across companies and/or legislative boundaries to develop sustainable solutions and environmental	1. Evidence of collaborative working across companies. 2. Evidence of working with Regulatory, Statutory (and, where practicable, local) stakeholders including Catchment Partnerships where appropriate.	Design work, cost estimate and carbon analysis have been carried out in coordination with ACWG to ensure collaboration across companies. Regular meetings have been held with Environment Agency (EA), Natural England (NE) and Port of London Authority (PLA) to discuss scheme	Gate 2 Report – section 7 Gate 2 Report – Annex D: Engagement Report	1.1. Collaborative working across companies and with stakeholders. 1.2. Timely - preparation of proposals ready to construct in 2025-2030 will involve early and rigorous development of design objectives followed by proposals. 1.3. Alignment with other relevant environmental policy, plans and strategies

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
enhancement for the wider benefit of society.	3. Design Vision and Principles informed by this engagement (Stages 1-6 of design process).	benefits and impacts, and opportunities for enhancement. Local Councils (Hounslow, Richmond upon Thames, and Spelthorne LPAs) have also been contacted for discussion.		such as Catchment Management and Local Nature Recovery Plans (see also Place 2).
2. Resource and carbon efficient throughout: Projects shall seek to reuse existing assets, eliminate waste (including waste of water) and make efficient use of materials and transport across the whole of the project lifecycle.	1. Submissions to meet expectations of RAPID Gate 2 Guidance. 2. Narrative on the SRO approach to avoiding and reducing the use of carbon and other resources and Inclusion of the approach in the Design Vision and Principles.	In Gate 2, it was attempted to establish carbon efficient strategies based on Net Zero 2030 route map, as well as PAS 2080. Opportunities of increasing efficiency of transportation were investigated, considering use of barges for shipping spoils from pipeline construction. Details of carbon efficient strategies are in section 2.2.8 of this CDR, and environmental reports are in Annex B of the Gate 2 Report. Optimised design to reduce material waste and carbon use have been accounted for, including the main design principle to reuse Thames Water land for the AWRP location.	Gate 2 Report – section 6.5 Gate 2 Report - Annex B: Environmental and Regulatory Assessment . CDR section 2.2.8	2.1. Lifecycle Carbon: Projects shall support the water industry commitment to achieve Net-Zero in terms of operational carbon in accordance with the industry roadmap. Projects must be efficient in embodied carbon in both construction and operation. 2.2. Projects should investigate if existing infrastructure assets could be repurposed and reused. 2.3. Projects should look to avoid unnecessary construction and minimise use of materials. 2.4. Projects should seek to minimise the use and waste of water.
3. Resilient and adaptable: Design for anticipated future demand at the appropriate scale. Build in the resilience to absorb and recover from the impacts of the extreme events and incremental stresses likely to arise from climate change.	1. Submissions to meet expectations of RAPID Gate 2 Guidance noting the climate change scenario(s) the schemes have been designed to cope with. 2. Review of local plans and strategies that may impact resilience*	DO analysis was carried out for climate change scenarios. The maximum capacity of Mogden Water Recycling was determined based on drought conditions/ scenario, excluding infiltration and trade flow from the available flow (see section 1.1). As per the Drinking Water Safety Plan, this scheme has had a detailed assessment to allow for mitigation of any effects caused by discharge of flows at the River Thames, and any effects due to a reduction of final effluent discharge into the River Thames downstream from the existing Mogden STW outfall.	CDR section 2.2.1. Gate 2 Report - Annex C: Drinking Water Safety Plan	3.1. Designs should be developed to include proportionate measures to anticipate future extreme events and stresses so that they can resist, absorb, recover and, where necessary, be adapted. 3.2. Designs would support the digitisation of the network at a catchment level using data to inform design, optimise solutions and improve operational efficiency in real time. 3.3. Where proposals add to the resilience of the broader system this should be accounted for in its social value (see Value 3). 3.4. The layout and design of specific elements of infrastructure should be taken in

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
				cognisance of planned future development of the immediate area. 3.5. Deploy nature-based approaches to resilience wherever possible (see also Place 2).
People 1. Understand and respond to your Community's needs: Develop a full understanding of the social context that will be impacted by the project over its lifecycle. Design for how local communities will encounter the infrastructure in their everyday lives during both construction and operation.	1. Indicator for Target 1.1 to be decided by others. 2. Initial appraisal of the scheme and its potential to contribute to the UN's Sustainable Development Goals - or other Social Value evaluation process (see also Value 2 and 3). 3. Review of relevant regional/local policy and demographic information and narrative around how it has shaped the draft Vision and Principles for the option.	The Design Vision sets out the key principle of customer engagement to demonstrate the quality and security that water reuse brings. Drinking Water Safety Plans were carried out at these early stages and a Planning Consultant has provided detailed input and direction to meet the requirements of regional/local policy. As part of the scheme site and conveyance route appraisal potential options under a multi-criteria framework (section 3.4, Gate 2 Report).	Gate 2 Report – section 3.4 Gate 2 Report – Annex C: Drinking Water Safety Plan Gate 2 Report – Annex D: Engagement Report Gate 2 Report – Annex G: Planning Report	1.1. Reliable supply of water to customers 1.2. Designs developed to maximise their social value. 1.3. Proposals reflect local community views as to how they interact with and experience the infrastructure as far as possible.
2. Engage widely, early and meaningfully: Work with stakeholders and local communities to develop their understanding of the importance of nature and water conservation. Develop co-design approaches to aspects of the design of infrastructure and associated landscape where practicable.	1. Summary of feedback from stakeholders (either project specific or received to date through the WRMP/Regional Plan process) and narrative around how it has shaped the draft Vision and Principles for the option. 2. Inclusion of engagement activities within the design programme of the project plan for Gate 3 and beyond showing adequate time for community (public) consultation to inform both site selection (where possible) and developed design.	Continuous and open communication between stakeholders has been carried out with stakeholders such as the EA, NE, PLA, DWI, NAU and Ofwat. Digital 3D graphics of the proposed outfall at River Thames are being prepared in to enhance effective communication with stakeholders, in addition to scheme schematic diagrams (section 1.2). Early and collaborative engagement has been undertaken with regulators and key stakeholders (as above) to identify key issues, agree approaches to monitoring and assessment, and then review findings and consider mitigation requirements.	Gate 2 Report – section 7 Gate 2 Report – Annex D: Engagement Report Gate 2 Report – Annex G: Planning Report	2.1. Stakeholders and communities understand the need for the scheme and the nature/appearance of the proposed solution(s). 2.2. The views of local stakeholders have shaped the design, where possible. 2.3. Engagement and consultation with communities has influenced the design (including but not limited to site selection, layout, materials, detailing) making it more acceptable to them. 2.4. The project provides the public with information on the importance of water and/or nature conservation (e.g. through information boards, artwork or digital information)).

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
	3. The development of tools that will enable successful engagement (e.g. digital models for visualisation/animation, GIS systems, precedent pictures of similar schemes/components) *. 4. Survey information on local needs and preferences in design*			
3. Improve access and inclusion: Consider how people move around your works. Maximise opportunities to support active travel and improve recreational access to waterside and green spaces that can improve outcomes for wellbeing, health, local economy, social inclusion and education.	1. Mapping of interface with PRoW network* 2. Evidence of engagement with local access groups* 3. Review of Local Cycling and Walking and Infrastructure Plans (LCWIPs) information or similar and note of how the project may impact/enhance it.*	The Gate 2 Planning Consultants have prepared plans for engaging the community and accounting for their concerns and desires. Considerations were made in option designs to minimise negative visual and auditory effects for the local community, such as keeping most of the engineering assets in public areas below ground, with above-ground assets blended into the local surrounds. A dedicated Navigation Assessment has been undertaken to determine potential for impacts on river users in the Thames Tideway at key locations identified by the PLA. Further engagement and community activities will occur at Gate 3 and onward.	Gate 2 Report – Annex D: Engagement Report Gate 2 Report – Annex G: Planning Report	3.1. Find opportunities to improve people's health, wellbeing and understanding of the natural environment, through access to waterside and green spaces for recreational and other purposes (see Note 1). 3.2. Maximise opportunities for workers to access sites via sustainable transport during construction and operation. Minimise disruption to travel routes in areas affected by a project during construction and operation.
Place 1. Take care: Develop proposals in the spirit of stewardship looking to both the past and future of each context to understand and develop its landscape, cultural heritage, health and sustainability. Work with partners to secure the	1. Evidence of place-based balanced, holistic and long-term decision making in the description of design considerations and development of design vision and principles.	The Gate 2 options appraisal includes detail of frequent collaborative reviews between the engineering, environmental, planning and commercial designers for this scheme. These reviews significantly influence the design development of the schemes in line with the place-based principles.	Gate 2 Report – section 3.4 CDR section 2.1.2. Gate 2 Report – Annex B: Environmental and Regulatory Assessments	1.1. Achieve Environmental Net Gain (ENG). 1.2. Adopt measures in the design that enhance the environment and help avoid future problems - e.g. adoption of SuDS solutions that improve cooling, attenuate surface water run-off and improve infiltration and biodiversity.

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
long-term success of all measures.	2. Statement on SRO approach to achieving Environmental Net Gain within the Design Vision and Principles. 3. Evidence of review of adopted (or emerging) spatial plans, strategies for the areas impacted by your works*. 4. Landscape/townscape character assessments and approach to design specific to context.*	The majority of permanent land requirements for this SRO are on land currently owned by Thames Water, with minor land acquisition required for things such as conveyance shafts, which would be entirely below-ground post-construction. Planning reviews and engagement with local authorities are underway to best mitigate any new developments.	Gate 2 Report – Annex D: Engagement Report Gate 2 Report – Annex G: Planning Report	1.3. Have clear and realistic long-term strategies for how operational and mitigation proposals will be managed and maintained. Develop partnerships with local communities where this has a mutual benefit. 1.4. Develop proposals in light of a clear understanding of the area's landscape and history.
2. Protect and promote the recovery of nature: Focus on the role of landscape, its capacity to accommodate infrastructure and shape places. Work collaboratively and employ holistic, landscape-scale approaches that support and deliver biodiversity net gain as well as multiple other benefits.	1. Statements on your approach to achieving BNG and aspirations to contribute to the recovery of nature within Design Vision and Principles. May include specific reference to local Green-Blue Infrastructure Strategies/ (emerging) Local Nature Recovery Plans, catchment management plans and other measures to improve watercourse quality.	In Gate 2, baseline ecological surveys have been carried out in the potential plant sites and conveyance routes where the project could impact the local ecosystem and the nature. The findings of surveys are being considered in the option appraisal process to select the optimum locations and conveyance routes. Measures to protect and promote the nature and ensure the BNG target will be established in the future design stage based on the ecological survey data and characteristics of the sites/ routes selected through the option appraisal process. Engagement with local EA and NE officers on potential BNG opportunity sites further supported this work.	Gate 2 Report – Annex B: Environmental and Regulatory Assessments Gate 2 Report – Annex D: Engagement Report	2.1. Achieve at least 10% Biodiversity Net Gain (BNG). 2.2. Deploy nature-based approaches to integration and mitigation as the first-choice solution where possible. 2.3. When looking at options to provide compensation or enhancement prioritise measures that support achieving good ecological condition for affected watercourses and bodies as a whole. When making an intervention, mitigate infrequent impacts by developing proposals that keep them local and short lived. 2.4. Work with landowners and land managers to develop mutually beneficial solutions where practicable.
3. Design all features beautifully, with honesty and creativity: Our utility infrastructure can be a source of pride and a positive contribution to its context. Develop proposals that reveal	1. Set out with opportunities and aspirations for high quality design within Design Vision and Principles. 2. Development of a project plan stating how these	The proposed Recycled Water outfall would be located on the River Thames which is an iconic natural heritage location for Londoners and for the world. Ensuring engineering and functional integrity, the London Effluent SRO will deliver designs of	CDR section 2.2.4	3.1. Develop a utilities architecture that speaks to its purpose and enhances its context. This applies to buildings, structures and landscape. 3.2. Develop designs and, where appropriate, artworks that bring narrative (meaning), beauty and interest to the proposals.

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
and celebrate its importance, provide visual delight and leave a positive legacy.	aspirations will be developed/achieved. 3. Favourable independent design review outcomes* 4. See also Place 1.	these components beautifully with a pride of being a part of the community. It is planned that architects and landscaping specialists will be engaged in design work at the future stages, with minimal consequences visually and for local access.		3.3. Consideration of context in every aspect of design including its location, layout, form, scale, appearance, landscape, materials and detailing.
Value 1. Maximise embedded value: Work collaboratively across specialisms and with stakeholders to maximise the benefits of the scheme by being smart with the location and arrangement of elements and design of mitigation within the project scope and budget.	1. Evidence of multi-disciplinary input into site selection* (See Note 2). 2. Initial project and, where appropriate, site appraisals (including constraints and opportunities) undertaken by a multi-disciplinary team (steps 1-5 in design development process). 3. A statement within the Design Vision on the SRO's aspirations and capability to deliver embedded value which should include Social Value, BNG and ENG.	Planning professionals, terrestrial habitat ecologists, carbon and energy analysts joined the Gate 1 design team which consisted of engineering and environmental consultants. As for engineering designs, inputs from an outfall/abstraction design specialist, a high-voltage electrical overhead line specialist, geotechnical engineers and a structural engineer were introduced at Gate 2 to improve design development. Site and conveyance route appraisal have been started in Gate 2, and it is expected to be completed in Gate 3.	Gate 2 Report – section 3.4	1.1. Early multidisciplinary input informing a design that solves multiple problems at once. 1.2. Design of infrastructure capable of adaptation to reasonable future demands (see also Climate 3). 1.3. Site selection processes and layouts that assist (or as a minimum, do not prevent) local development except where absolutely necessary. 1.4. Reinstatement, landscape and mitigation proposals that improve the existing situation, - e.g. through better biodiversity, carbon sequestration, surface water infiltration and reduced run-off. 1.5. Deliver benefits efficiently by exploiting the two-way relationship between infrastructure and natural capital to enable multiple benefits to be delivered simultaneously.
2. Understand how you could provide additional value: Identify opportunities to contribute wider regional benefits outside of the project scope. In particular look for synergies with relevant catchment management plans and proposals that support the	1. A description of potential opportunities to work with other projects/partners to achieve wider benefits. 2. A statement within the Design Vision on the SRO's aspirations and capability to deliver additional value.	The Mogden Water Recycling scheme is identified as one of the potential water source options for T2AT SRO	CDR section 1.4	2.1. Strategic project selection is informed by cross-sectoral engagement to maximise social benefit and reduce the use of customers money (see note 3). 2.2. Work closely with partners and focus on landscape scale schemes that improve hydrology, aquatic ecology and reduce/sequester carbon and provide opportunities for access to recreation and visual delight.

ACWG Design Principles	ACWG Gate 2 Indicators	Approach in Mogden Water Recycling Gate 2 Designs	Documentation in Gate 2 Submission	Targets
delivery and enjoyment of a healthy water environment.				2.3. Be honest and realistic with partners as to what you might be able to offer as an organisation.
3. Capture and measure embedded and additional value: Have clear narratives about how you are contributing to society beyond the core scope of your project. Quantify these benefits so they can be considered meaningfully in conversations on value, financing and risk. Share your experience and knowledge widely.	1. Details of the best-value metrics used in determination of the Regional Plans and WRMPs and a clear narrative on how these have influenced option selection so far. 2. Inclusion of a description within the project plan of how these will be developed and monitored at subsequent gates. 3. Initial narrative (description) of the value of the scheme in plain English.	WRSE is progressing further assessments of the options, considering factors beyond cost to deliver additional value, improve the region's environment further and benefit wider society. Wider resilience benefits of each solution have been reassessed. Details of the best-value metrics used are described in section 4.3 in Gate 2 Report.	Gate 2 Report - section 4.3	3.1. Gathering of project specific data and improvement in the tools we have to measure and monitor added and additional value across the sector. 3.2. Full consideration of potential benefits in the Cost Benefit analysis and investment case for the SRO. 3.3. Clear communication of value of the scheme to stakeholders, communities and within the industry.

*Activity may occur at Gate 2 or Gate 3 depending on maturity of the proposals.

2.2 Scheme Components and Operating Philosophy

The conceptual design for each of following option components are developed in this report:

- Mogden STW Final Effluent abstraction
- Final Effluent Transfer Tunnel from Mogden STW to Advanced Water Recycling Plant (AWRP)
- Advanced Water Recycling Plant (AWRP)
  - 50Ml/d AWRP Process unit
  - 100Ml/d AWRP Process unit
- Recycled Water Transfer Pipeline from AWRP to the River Thames
- Waste Stream Collection and Discharge
  - Reverse Osmosis (RO) Concentrate Pipeline (to be conveyed from AWRP to existing Inlet Works in Mogden STW)
  - Wastewater Pipeline (to be conveyed from AWRP to the existing Inlet Works in Mogden STW)
- Recycled Water Discharge to the River Thames

2.2.1 Assessment of Source Flow Availability

In Gate 1 conceptual design, a check of final effluent flow recorded in Mogden STW from 2016 to 2020 was carried out, and it was found that the Dry Weather Flow (DWF), as a nonparametric 80% exceeded daily flow, during this period was 420Ml/d and the Average Daily Flow (ADF) was 494Ml/d at the proposed final effluent abstraction location.

However, these values include infiltration and trade flows which may reduce significantly in drought conditions. Therefore, availability of source flow was considered further in Gate 2, and a review was undertaken of projected flows received by the Mogden STW in Strategic Overview of Long term Assets and Resources (SOLAR) analysis (SOLAR, AMP6 ver. 4.2 updated on 10 July 2019).

SOLAR estimates STW influent in the future, utilising predicted population growth. All flows into Mogden STW essentially leave the site as final effluent though there is a small amount of volume loss during treatment which account for sludge and evaporation.

According to SOLAR, projected domestic flow to be received by Mogden STW in 2031 would be 305Ml/d. Domestic flow does not include infiltration or trade flows, and it is assumed that domestic flow would not reduce significantly during periods of drought. Therefore, this value would provide a conservative estimate of available effluent from Mogden STW during drought conditions.

Table below lists approximate source flows required for different option sizes in Mogden Water Recycling, Teddington DRA and Mogden South Sewer schemes. These three schemes would use final effluent from Mogden STW as their water source. For example, an approximately 252Ml/d of final effluent would be required for a 200Ml/d capacity of Mogden Water Recycling scheme. Because the projection of available final effluent from Mogden STW would be 305Ml/d, it would be recommended that combined maximum capacities (total yield of Treated Effluent/ Recycled Water) of Teddington DRA, Mogden Water Recycling and Mogden South Sewer would be 200Ml/d.

Table 2-2: Yields of Treated Effluent/ Recycled Water and Abstraction of Final Effluent/ Sewage in Mogden Water Recycling, Teddington DRA and Mogden South Sewer Schemes

Flow	Units	Yield of Treated Effluent	Required Abstraction of Final Effluent or Sewage*
Mogden Water Recycling	Ml/d	50	63
	Ml/d	100	126
Teddington DRA	Ml/d	50	58
	Ml/d	75	87
Mogden South Sewer	Ml/d	50	60

*Mogden Water Recycling and Teddington DRA schemes would abstract final effluent from Mogden STW, while South Sewer scheme would abstract untreated sewage from the catchment of Mogden STW.

2.2.2 Source Water (Mogden STW Final Effluent) Abstraction Design Components

The existing 3m-wide, 2m-deep final effluent channel runs along the South edge of the Mogden STW from West to East, and to the North along the existing storm tanks on the East side of the STW. Overflows from the existing storm tanks directly discharge into the final effluent channel along the eastern perimeter of the storm tanks. Therefore, final effluent would be abstracted upstream of the storm tank overflow along the southern edge of the existing storm tank to prevent untreated stormwater overflows being transferred to the AWRP. Abstracted final effluent would be treated in the new AWRP near Kempton WTW.

2.2.3 Treatment Design Components

The AWRP conceptual design proposes treatment process which is globally referred to as Full Advanced Treatment (FAT). FAT is globally accepted for Indirect Potable Reuse (IPR) and uses Reverse Osmosis (RO) and UV Advanced Oxidation Process (UVAOP) for treatment. There are alternative non-FAT treatment options for IPR; however, at this stage the RO based process is proposed because Thames Water have experience operating similar membrane-based treatment trains, for example, in the Beckton Desalination and in the Old Ford Water Recycling plant.

The FAT process would produce ultra-pure/ deionised water which is corrosive and aggressive to transfer and discharge to the receiving water course. Therefore, a remineralisation process using Lime and CO_2 dosing would be required downstream of the FAT process.

Design work has developed a methodology for the required treatment, based on compliance with discharge under the Water Framework Directive.

2.2.3.1 Water Quality

2.2.3.1.1 AWRP Feed Quality

A summary of the key water parameters in the AWRP feed water (i.e., Mogden STW final effluent) is presented in Table 2-3. The Prescribed Concentration or Values (PCV) for drinking water, where applicable, are also included for reference.

Table 2-3: Key AWRP Feed Water Quality Parameters

Parameter	Unit	Average	95%ile	Drinking Water Regulatory PCV
General				
BOD	mg/l	5.4	12.2	
Total Organic Carbon, TOC	mg/l	12.8	44.4	No abnormal change
Suspended Solids	mg/l	15.7	36.0	
Total Dissolved Solids, TDS	mg/l	676.7	899.2	
Turbidity	NTU	8.76	58.00	4.0

Parameter	Unit	Average	95%ile	Drinking Water Regulatory PCV
Ammonia. NH_3	mg/l	0.4	1.7	
Total Nitrogen, TN	mg/l	22.4	31.9	
pH	ph Unit	7.4	7.6	6.5-9.5
Alkalinity (as $CaCO_3$)	mg/l	201.2	230.4	
Salts & Anions				
Chloride, Cl	mg/l	109.0	125.3	250
Nitrate, NO_3	mg/l	18.8	26.2	50
Nitrite, NO_2	mg/l	1.27	2.15	0.5
Phosphate, PO_4	mg/l	7.8	11.2	
Sulphate, SO_4	mg/l	84.2	104.9	250
Silica, SiO_2	mg/l	10.5	15.0	
Microbiological				
Cryptosporidium	No./l	1.2	2.0	
E. Coli	mpn/100ml	12,223.5	25,440.0	0
Metals				
Aluminium	µg/l	169.0	385.0	200
Barium	µg/l	14.4	22.8	
Boron	µg/l	117.63	226.70	1000
Manganese	µg/l	35.4	67.8	50
Iron	µg/l	214.0	588.8	200
Calcium	mg/l	105.5	127.5	
Chromium	µg/l	2.4	5.0	50
Copper	µg/l	11.9	34.6	2000
Magnesium	mg/l	8.6	11.8	
Strontium	mg/l	0.3	0.4	
Human made organics				
1,4-Dioxane	µg/l	0.5	0.6	
Benzo(α)pyrene	µg/l	0.004	0.02	1
Disinfection By-products				
NDMA	µg/l	0.004	0.012	
Total THM	µg/l	9.8	10.0	100
Per- and Polyfluoralkyl Substances (PFAS)				
Perfluorooctanoic acid (PFOA)	µg/l	0.011	0.017	$0.1^{\dagger}$
Total PFAS*	µg/l	0.083	0.178	$0.5^{\dagger}$
*Based on Perfluorodecanoic acid, Perfluorododecanoic acid, Perfluoroheptanoic acid, Perfluorohexanoic acid, Perfluorononanoic acid, Perfluorooctanoic acid, Perfluorooctanesulfonic acid and Perfluoropentanoic.				
†The proposed EU Directive recasting recommends a parametric (limit) value for individual PFAS compounds of 0.1 µg/l and 0.5 µg/l for PFAS in total.				

Total Organic Carbon (TOC)

The feed water has a 95%ile TOC concentration of 44mg/l which indicates a high level of organics and would constitute a risk of Trihalomethane (THM) formation in chlorine disinfection. It could be proposed to dose pre-formed monochloramine to control biological fouling of the membranes, which mitigates the risk of disinfection by-product formation. RO provides excellent removal of TOC typically, in excess of 95% removal in potable reuse applications.

Nitrogen and Phosphorous

Assessed Mogden STW final effluent indicates high levels of Total Nitrogen (TN) (95%ile concentration of 31.9mg/l). High nitrogen concentrations could result in greater fouling to membranes because of the higher level of organics associated with the water.

The high phosphate levels (95%ile concentration of 11.2mg/l) within the feed water is likely to require pre-treatment to prevent the accumulated build-up of scalants within the RO membranes that could also reduce the recovery of the system. Sulphuric acid dosing to lower the pH ahead of the RO membranes would be provided to address this.

Suspended Solids

The feed water has 95%ile suspended solids concentration of 36mg/l which may be problematic for UF operation. Design development will further consider the risk that this may pose, recognising the upgrade works ongoing at the Mogden STW and likely future performance. In correlation, turbidity levels at the 95%ile are also high which may affect pre-strainer and UF membrane design.

Solvents and Industrial Chemicals

Industrial chemicals are not present in the Mogden final effluent at significant levels and no specific treatment is expected to be required, subject to further water quality analysis ongoing.

The final effluent quality data shows low levels of 1,4-Dioxane, an industrial chemical which could provide treatment challenges, with a 95%ile of 0.62µg/l. A common target in potable reuse applications is to achieve a finished water quality concentration of 1µg/l, which would be accomplishable given the low feed concentration. Most potable reuse applications assume 0.5-log removal (68%) of 1,4-Dioxane through UVAOP to ensure good oxidation of a variety of chemicals.

Microbiological

There are significant microbiological levels in the Mogden STW final effluent. The AWRP treatment train would provide a multi-barrier disinfection and removal of pathogens, including bacteria, viruses and protozoa. Indicative treatment log removals have been summarised in Table 2-4.

Table 2-4: Indicative Pathogen Log Removal Credits for Proposed AWRP Treatment Processes

Pathogen	Mogden STW*	UF	RO	UVAOP	Pipeline Cl_2†	Total
Virus	0	0	1.5	6	6	13.5
Giardia	0	4	1.5	6	0	11.5
Cryptosporidium	0	4	1.5	6	0	11.5

*Pathogen reduction across the Mogden STW is expected but has not been quantified in this table until site specific pathogen testing at Mogden STW is conducted.

†Level of pathogen log removal from conveyance disinfection using sodium hypochlorite or other preferred disinfectant chemical.

Metals

Although 95%ile concentrations of Iron, Manganese and Aluminium in the final effluent are all above the PCV values, the treatment train would reduce these parameters to concentrations well below the PCV.

Pesticides and Other Organics

A large number of organic chemicals are present in the final effluent, and the most significant ones are pesticides – including aminomethylphosphonic acid (AMPA), metaldehyde and glyphosate. While individually none of these exceed the PCV limit, it is possible that on occasions their combined total may exceed the PCV limit for total pesticides. The full advanced treatment processes are effective in removing pesticides. In addition, it is envisaged that catchment and abstraction management schemes would control metaldehyde contamination. The use of metaldehyde has been banned by Defra in March 2022. It is expected environmental levels of the chemical will reduce over time.

Endocrine Disrupting Compounds (EDCs) and other Contaminants of Emerging Concern (CECs)

These include several contaminants such as nonylphenols, per and polyfluoroalkyl substances (PFAS) and N-Nitrosodimethylamine (NDMA). There is limited sampling data and, in most cases, no PCV limits have been set by the regulators in the UK. A multibarrier treatment process could be proposed, in alignment with global best practice, to remove these compounds.

2.2.3.1.2 Advanced Recycled Water Quality

A high-level mass balance has been completed to project the potential Recycled Water quality concentrations. The assessment has been completed using Mogden STW final effluent (95%ile) data to make projection with the worst-case feed water quality. Parameters for metals, disinfection by-products, organic compounds and microbiological components have been determined using assumed removal efficiencies.

As shown in Table 2-5, the projected Recycled Water quality would not exceed the Water Supply Regulations PCVs and would also be below 50% of the PCV, which is a common internal target for the water industry.

Table 2-5: Projected AWRP Recycled Water Quality Parameters

Parameter	Unit	Average	95%ile	Drinking Water Regulatory PCV
General				
BOD	mg/l	1.69	3.84	
Total Organic Carbon, TOC	mg/l	0.29	1.01	No abnormal change
Suspended Solids	mg/l	0.02	0.06	
Turbidity	NTU	0.01	0.01	4.0
Ammonia. NH_3	mg/l	0.05	0.22	
Total Nitrogen, TN	mg/l	2.81	4.01	
pH	ph Unit	8.41	8.44	6.5-9.5
Alkalinity (as $CaCO_3$)	mg/l	60.00	60.00	
Salts & Anions				
Chloride, Cl	mg/l	13.72	2.54	250
Nitrate, NO_3	mg/l	1.55	2.60	50
Nitrite, NO_2	mg/l	0.16	0.27	0.5
Phosphate, PO_4	mg/l	0.02	0.04	
Sulphate, SO_4	mg/l	0.29	0.52	250
Silica, SiO_2	mg/l	0.13	0.27	
Microbiological				
Cryptosporidium	No./l	1.5E-12	2.5E-12	
E. Coli	mpn/100ml	1.5E-08	3.2E-08	0
Metals				
Aluminium	µg/l	21.27	48.45	200
Barium	µg/l	1.81	2.86	
Boron	µg/l	14.80	26.41	1000
Manganese	µg/l	4.45	8.53	50
Iron	µg/l	26.94	74.09	200
Calcium	mg/l	22.80	22.20	
Chromium	µg/l	0.30	0.63	50
Copper	µg/l	1.49	4.35	2000
Magnesium	mg/l	0.01	0.01	
Strontium	mg/l	0.04	0.05	

Parameter	Unit	Average	95%ile	Drinking Water Regulatory PCV
Human made organics				
1,4-Dioxane	µg/l	0.18	0.25	
Benzo(α)pyrene	µg/l	0.001	0.01	1
Disinfection By-products				
NDMA	µg/l	0.002	0.005	
Total THM	µg/l	6.18	6.29	100
Per- and Polyfluoralkyl Substances (PFAS)				
Perfluorooctanoic acid (PFOA)	µg/l	0.003	0.004	0.1†
Total PFAS*	µg/l	0.02	0.04	
*Based on Perfluorodecanoic acid, Perfluorododecanoic acid, Perfluoroheptanoic acid, Perfluorohexanoic acid, Perfluorononanoic acid, Perfluorooctanoic acid, Perfluorooctanesulfonic acid and Perfluoropentanoic.				
†The proposed EU Directive recasting recommends a parametric (limit) value for individual PFAS compounds of 0.1µg/l and 0.5µg/l for PFAS in total.				

2.2.3.2 Treatment Technology Options

Full Advanced Treatment (FAT) process using UF, RO and UVAOP is proposed for Mogden Water Recycling scheme in Gate 2 conceptual design. Another potable reuse treatment technology which is globally accepted would be Ozonation with Granular Activated Carbon (GAC) treatment process. The following sections discuss advantages and disadvantages of these two alternatives.

2.2.3.2.1 Full Advanced Treatment (FAT) with UF, RO and UVAOP Option

Full Advanced Treatment (FAT), using UF, RO and UVAOP systems, is a globally accepted and implemented treatment process for indirect potable reuse treatment schemes. The outline of indicative FAT process is shown in Figure 2-1 below.

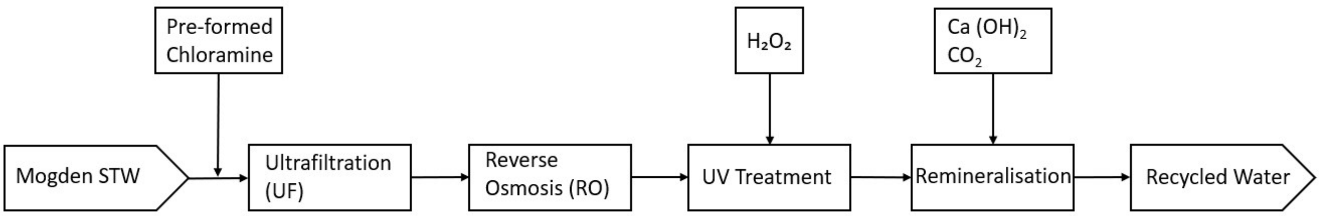

Figure 2-1 Outline of Indicative Full Advanced Treatment (FAT) Process

Note: This diagram shows outline treatment process outline only. Additional chemical dosing and other auxiliary processes are likely to be required.

This treatment process can effectively remove and/or inactivate pathogens and organic chemicals that can be dangerous to human health, including pathogens such as protozoa, bacteria, and viruses, and organic chemicals often referred to as Contaminants of Emerging Concern (CEC) such as PFAS, NDMA and THMs. The use of a FAT system could remove up to 7.5 and 11.5-log of viruses and cryptosporidium, respectively.

However, it presents several drawbacks as highlighted below:

- The use of RO membranes generates a concentrated brine which would need to be treated or disposed of. This could be problematic for inland treatment facilities where ocean disposal is unavailable and expensive brine treatment would be required.
- A large footprint is generally required for the treatment streams and conditioning processes.
- Operation could be energy and chemical intensive.

In the case of Mogden Water Recycling scheme, there is a potential that the Mogden STW could receive and treat the RO concentrate brine. Thus, high-cost brine treatment systems may not be required to mitigate environmental impacts from RO concentrate discharge.

Energy saving and chemical reducing practices, such as Energy Recovery Devices, optimised chemical cleaning practices and Chemical Dose Optimisation, could be used to mitigate high cost and carbon emissions.

2.2.3.2.2 Ozonation with Granular Activated Carbon (GAC) Option

The alternative treatment system involving use of Ozonation with Granular Activated Carbon (GAC) includes Nitrifying Sand Filters (NSF) with ferric dosing, ozonation/GAC and Ion Exchange (for nitrate removal). Outline of indicative treatment process is shown in Figure 2-2 below.

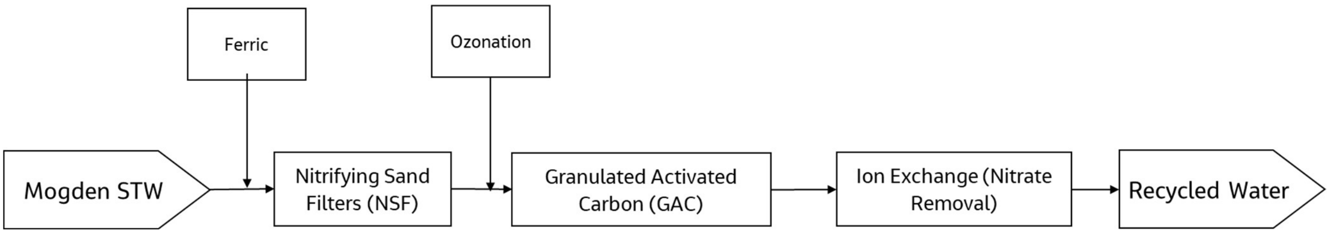

Figure 2-2 Outline of Alternative Ozone/GAC Treatment Process

Note: This diagram shows Ozone/GAC treatment process outline only. Additional chemical dosing and other auxiliary processes are likely to be required.

It would be recommended to include a Biological Activated Carbon (BAC) filter system to provide nutrient removal upstream of the GAC. A flocculation/sedimentation stage may also be desirable upstream of the Ozonation process to lower TOC levels prior to the O_3, BAC and GAC stages. To provide a similar level of pathogen removal/reduction to the FAT process, the inclusion of a UV or UVAOP system would be preferred downstream of the GAC. In this case, the use of NSF and Ion Exchange systems could be omitted. Furthermore, upstream source reduction of ammonia/nitrates in STW would be preferable.

The use of ferric dosing upstream of NSFs provides reduction of carbonaceous organics, phosphate and ammonia. However, because of a high phosphate concentration in the Mogden STW final effluent, it is likely that a clarification stage for chemical sludge from ferric dosing would be required in addition to NSFs.

These solids from ferric dosing would ultimately be backwashed and transferred to the Mogden STW. Whilst it is envisaged the Mogden STW would have sufficient capacity, chemical sludges could be problematic for secondary biological treatment processes.

The ozonation/GAC process provides microbiological and pathogen reduction and disinfection. Dosing ozone (O_3) is advantageous as it oxidises heavy molecular weight organics. However, high concentrations of ozone could form disinfection by-products, most notably bromate and N-nitrosodimethylamine (NDMA). Additionally, nitrates exert a significant ozone demand which may be problematic with the NSF.

The GAC media could remove trace organics through adsorption mechanisms and resultingly the adsorption capacity of the media decreases over time. This is usually controlled through frequent sampling and media monitoring to replace GAC media prior to exhaustion. Without provision of an upstream BAC filter, GAC filter media is likely to require frequent replacement/regeneration due to heavy bulk organic matter loading

The Mogden STW final effluent has a 95%ile nitrate concentration of 26.2mg/l which must be significantly reduced. The use of the Ion Exchange process could provide a removal efficiency of up to 90%. In similar principle to the GAC filters, high nitrate loading to the Ion Exchanger leads to breakthrough and therefore requires monitoring and regular resin regeneration.

2.2.3.3 Proposed Treatment Scheme

Indicative treatment process for Mogden Water Recycling scheme would be:

- Upstream AWRP Equalisation Tank (to provide retention of final effluent flows from STW during operational disturbances which may occur at Mogden STW)
- Fine screening (as protection to the UF Membranes and RO system)
- Pre-formed monochloramine dosing (for prevention of bio-fouling on the UF and RO membranes)
- Ultrafiltration membrane treatment (for pathogen removal and as pre-treatment to the RO membranes)
- Anti-scalant and sulphuric acid dosing (for scale prevention on RO membranes and pH control prior to the membranes)
- Reverse Osmosis membranes (for the removal of pathogens, chemicals, anions, metals and some organics)
- Advanced Oxidation Process (AOP) consisting of UV irradiation and hydrogen peroxide addition (for removal of recalcitrant compounds such as metaldehyde and disinfection purposes)
- Remineralisation with lime (calcium hydroxide) and carbon dioxide

Remineralisation would be required to prevent corrosion of the Recycled Water conveyance by the demineralised water produced by the RO. This process is also required so that the water discharged into the environment would not have a detrimental impact on the ecology present in the River Thames at Walton.

Chlorination of the Recycled Water before conveyance, together with dechlorination prior to river discharge, may also be required for virus reduction, subject to further water quality analysis and development of pathogen removal targets.

2.2.3.3.1 Equalisation Tank

Final effluent from the Mogden STW would be fed into an equalisation tank. The purpose of the tank is to provide an operational buffer in the event of upstream STW operational issues, as well as during low flow STW influent periods.

The equalisation tank sizing would be optimised as the design progresses, considering diurnal flows, land limitations and STW operational conditions.

2.2.3.3.2 Pre-formed Chloramine Addition

Pre-formed monochloramines would be added upstream of the UF plant for the purpose of bio-fouling control. Monochloramine reduces the risk of disinfection by-products such as THMs or Halogenic Acetic Acid (HAA).

Monochloramines would be prepared on-site by batching sodium hypochlorite solution with liquid ammonium sulphate. Separate feed systems would be required for both chemicals involved.

2.2.3.3.3 Fine Screening and Ultrafiltration Membranes

The abstracted water would be screened using 100-200micron mesh filter strainers. The screens are designed to remove materials which could cause abrasive damage to the membranes downstream. Automatic self-cleaning through regular backwash sequences is recommended. The dirty backwash water would be transferred to the Wastewater Return Pumping Station.

The screened raw water would then fed to the Ultrafiltration (UF) plant. The plant could comprise pressurised UF membrane trains. A summary of indicative UF train configurations is provided in Table 2-6.

Table 2-6: Indicative UF Configurations

Scheme Design	50Ml/d	100Ml/d
Permeate Capacity	59Ml/d	118Ml/d
Total No. Trains	6 No. Duty + 1 No. Standby	12 No. Duty + 2 No. Standby
Membrane Flux Rate	60Lmh	60Lmh
Total No. Membrane Modules	1,120 (160 modules/train)	2,240 (160 modules/train)
Total Membrane Area	56,000m² (8,000m² per train)	112,000m² (8,000m² per train)

Standby trains would be included to achieve desired output flow during cleaning sequences. The membranes would be supplied with pressurised inlet flow from the UF Feed Pumping Station. The UF plant would also be supplied with a dedicated backwash plant, comprising duty/standby backwash pumps and a set of duty/standby air scour blowers. Each membrane cell should be backwashed frequently to remove fouling.

Waste from the backwash process would drain via gravity to a backwash holding tank and be transferred to the Wastewater Return Pumping Station. Additionally, the membranes would require a daily Chemically Enhanced Backwash (CEB) using sodium hypochlorite and citric acid solutions whilst the AWRP is in use.

A Clean in Place (CIP) plant would also be provided, designed for periodic (monthly, whilst in use) cleaning of the UF membranes to remove both organic and inorganic fouling through the use of chemicals. The system would consist of a CIP solution recirculation pumping system, heated water tank and dedicated chemical dosing pumps fed from the bulk sodium hypochlorite and citric acid storage tanks. The resultant spent CIP chemical solution effluent then would feed into the UF neutralisation tank where it would be neutralised using caustic soda and sodium bisulphite prior to discharge to the Wastewater Return Pumping Station.

Preservation and planned maintenance activities for membranes would be required when the plant is not in use.

2.2.3.3.4 Reverse Osmosis Membranes

Permeate from the UF system would pass forward into a RO Feed Tank, from which an RO Transfer Pumping Station would discharge flows through a cartridge filtration stage, prior to the Reverse Osmosis stage.

Each RO train would be fitted with a designated RO feed pump which feeds the RO train at the high pressure required for the chosen membrane selectivity. The RO projections indicate an initial RO feed pressure of approximately 120psi (8.3 bar). A minimum permeate recovery of 85% would be achieved using a 3- stage RO systems. Indicative RO plant configurations are shown in Table 2-7.

Table 2-7: Indicative RO Plant Configurations

Scheme Design		50Ml/d	100Ml/d
Permeate Capacity		50Ml/d	100Ml/d
Total No. Trains		3 No. Duty + 1 No. Standby	7 No. Duty + 1 No. Standby
Membrane Flux Rate		18Lmh	18Lmh
Total No. Pressure Vessels		712 (178 No. per Train)	1,224 (153 No. per Train)
Pressure Vessels per Train	Stage 1	101	87
	Stage 2	51	44
	Stage 3	26	22
Total Membrane Area (based on 6 elements per pressure vessel with 37.16m² each)		157,320m² (39,330m² per train)	269,696m² (33,712m² per train)

An interstage turbocharger, or other alternative energy recovery device (ERD), could be utilized with the RO system to capture energy from the residual pressure in the RO concentrate. To achieve a minimum system recovery of 85%, prevention of the formation of foulants and scalants, such as calcium phosphate, would be required by adjusting pH in the feed water. Feed water pH control could be in the form of a trim sulphuric acid dosing system prior to RO membrane feed.

Similarly, to the UF plant, redundant trains would be proposed to achieve desired output capacity during cleaning sequences.

A RO Permeate Flushing Tank which collects RO permeate for the purposes of RO cleaning operations would be required. The use of permeate reduces the risk of the formation of scale that is associated with the use of potable water at high pH conditions when sodium hypochlorite is added. This scaling could present issues with clogged chemical feed lines and dosing point diffusers.

In addition, RO permeate would be used as service water in the formation of monochloramine for biogrowth control. The monochloramine makeup water should have low to no bromide concentration to avoid the formation of bromamines which can form Disinfection By-products (DBPs). The use of RO permeate reduces the risk of bromamine formation.

A CIP system would also be provided for bi-monthly RO membrane cleaning whilst in use. The system would consist of a cleaning solution recirculation pumping system, heated water tank and dedicated chemical dosing pumps fed from the bulk sulfuric acid and scale inhibitor storage tanks. The resultant spent CIP chemical solution effluent then would feed into the RO neutralisation tank where it would be neutralised using caustic soda prior to discharge to the Wastewater Return Pumping Station.

Preservation and planned maintenance activities for membranes would be required when the plant is not in use.

2.2.3.3.5 UV Advanced Oxidation Process - Hydrogen Peroxide Dosing and UV Activation

In the UV/ H_2O_2 process, UV light dissociates hydrogen peroxide into hydroxyl radicals which subsequently oxidize organic contaminants. Advanced Oxidation Processes (AOPs), such as the UV/ H_2O_2 process, are effective for breaking down recalcitrant organic chemicals including 1,4-dioxane and N-Nitrosodimethylamine (NDMA) that are not readily degraded by other oxidation processes, for example ozonation.

UV systems for purposes of UVAOP require high UV doses, typically in excess of 500mJ/cm^2. The proposed UVAOP system would be capable of providing a minimum NDMA log destruction of 1.2 log and a 1,4-dioxane log destruction of 0.5 log based on final effluent data analysis from Mogden STW, which are common design criteria for UVAOP systems used in potable reuse applications.

Indicative UVAOP system configuration is provided in Table 2-8. Standby trains have not been assumed because maintenance requirements are limited and are likely to occur during plant shutdowns. A hydrogen peroxide dosing system would also be provided with dedicated dosing pumps fed by a bulk chemical storage tank.

Table 2-8: Indicative UVAOP Configurations

Scheme Design	50Ml/d	100Ml/d
Total No. Trains	2 No. Duty + 0 No. Standby	4 No. Duty + 0 No. Standby
Hydrogen Peroxide (H_2O_2) Dose	4mg/l	4mg/l
Total No. Lamps (low pressure, high output)	1,152	2,304
Total Duty Load	262.1kW	486.7kW

2.2.3.3.6 Remineralisation (Lime and CO_2)

Following UVAOP treatment, the disinfected water stream would require treatment to reduce the corrosivity and acidity of the water. Remineralisation using lime and carbon dioxide dosing would reduce the aggressivity of the water. The remineralisation process involves preparation of a saturated lime solution which would be mixed with carrier water (RO permeate) and dosed to the main RO permeate. After addition of lime, the RO permeate would then be dosed with CO_2. This would be done by saturating a small stream of carrier water with CO_2 (stored in liquid form onsite) and delivering this to a static mixer.

The following Recycled Water quality targets were assumed to determine remineralisation requirements:

- Alkalinity of 60mg/l as $CaCO_3$
- Langelier Saturation Index (LSI) of 0.15

The targets were set based on previous indirect potable reuse scheme designs and research findings for recommended water quality to reduce impacts of corrosion on transfer pipelines.

Furthermore, RO permeate with low pH and high CO_2 content could occur; therefore, CO_2 stripping may be required as part of the remineralisation process. Carbon dioxide stripping has not been assumed in Gate 2. Further consideration will be required to determine requirements.

2.2.3.3.7 Chemical Dosing

Chemical dosing would be required throughout the plant for optimum performance, water quality management and to maximise membrane lifetime. The main chemicals that would be used in the plant and their locations are listed below:

- Pre-formed monochloramine would be dosed upstream of the UF plant to provide anti-foulant protection to downstream processes. The monochloramine solution would be produced onsite using sodium hypochlorite and liquid ammonium sulphate.
- Sulphuric Acid (H_2SO_4)would be dosed upstream of the RO membranes. The acid would be dosed to provide pH correction to prevent the formation of scalants and precipitates within the RO membranes.
- Anti-scalant would also dosed upstream of RO membranes to prevent scaling.
- Sodium Bisulphite would be dosed downstream of the UV plant for the reduction in hydrogen peroxide and monochloramine residual prior to remineralisation feed.
- Hydrogen Peroxide (H_2O_2) would be dosed prior to UV irradiation to allow for the formation of the strongly oxidising hydroxyl radicals necessary within the UVAOP for the degradation of recalcitrant compounds.
- Lime, Calcium Hydroxide ($Ca(OH)_2$)), and Carbon Dioxide (CO_2) would constitute the chemicals used within the remineralisation process. Lime would be used to increase the alkalinity of the advanced Recycled Water to an acceptable level and to increase calcium content. CO_2 gas would be injected to control the corrosivity of the water by controlling the calcium carbonate saturation index, the Langelier Saturation Index (LSI). Remineralisation chemicals would be dosed downstream of the UVAOP.
- Sodium hypochlorite disinfection would potentially be required downstream of UVAOP also to provide best practice in virus removal. This would also require dechlorination prior to river discharge. Water quality analysis and agreed pathogen removal targets would further inform the proposed treatment process as work progresses.
- Cleaning Chemicals that would be used within the UF and RO membrane systems to maintain membrane performance through removal of scaling and biological fouling and provide membrane longevity are:

- UF Cleaning Solution: the CIP solutions include Sodium Hypochlorite (NaOCl) and Citric Acid. Daily Chemical Enhanced Backwashes (CEB) are completed using a Sodium Hypochlorite solution.
- RO Cleaning Solution: additional anti-foulants are required for RO CIP, and often include Citric Acid, Sodium EDTA, Sodium Tripolyphosphate and Sodium Dodecilsulphonate.

- Neutralisation agents would be Sodium Hydroxide (NaOH) and Sodium Bisulphite. Spent chemical cleaning solutions would need to undergo neutralisation prior to discharge to the wastewater return pumping station use these agents.

As noted above, chlorine dosing and dechlorination prior to conveyance may also be required.

Chemical deliveries to the AWRP would be via a common hard standing area which drains to a dedicated chemical spill tank so that any accidental spills can be contained, treated and disposed of in an appropriate manner. Two chemical spill tanks would be used: one for alkaline wastes and the other for acidic wastes. These tanks would be linked to the site washwater pumping station.

2.2.3.3.8 Process Unit Summary

Indicative process units are summarised in the following tables.

Table 2-9: Indicative 50Ml/d Process Unit and Structure Sizes

Process Item	Approximate Building / Structure Area (m^2)	Approximate Length (m)	Approximate Width / Diameter (m)	Approximate Height Above Ground (m)
Pump station shaft	-	-	9 (dia.)	-
Final Effluent Pumping Station	208	23	9	5
Equalisation Tank	968	45	22	10
UF Feed Pumping Station	347	23	15	6
Ultrafiltration Building	1987	39	51	8
RO Feed Tank	145	-	14 (dia.)	7
RO Feed Pumping Station	347	23	15	10
Reverse Osmosis Building	2587	65	40	12
UV Advanced Oxidation Building	588	37	16	6
Remineralisation	958	51	19	15
Chemical Storage	1283	32	40	12
Treated Water Pumping Station	347	23	15	6
Wastewater Return Pumping Station	74	12	6	6
RO Concentrate Pumping Station	74	12	6	6
Administration Building	569	37	15	8

*This table excludes transformer, standby power and fuel tank

Table 2-10: Indicative100Ml/d Process Unit and Structure Sizes

Process Item	Approximate Building / Structure Area (m^2)	Approximate Length (m)	Approximate Width / Diameter (m)	Approximate Height Above Ground (m)
Pump station shaft	-	-	13 (dia.)	-
Final Effluent Pumping Station	236	24	10	6
Equalisation Tank	1,829	70	27	10
UF Feed Pumping Station	401	24	17	6
Ultrafiltration Building	2830	68	41	10
RO Feed Tank	278	-	19 (dia.)	8
RO Feed Pumping Station	401	24	17	6
Reverse Osmosis Building	3,130	68	46	15
UV Advanced Oxidation Building	641	34	19	6
Remineralisation	1,092	36	30	17
Chemical Storage	1,666	33	46	15
Treated Water Pumping Station	401	24	17	6
Wastewater Return Pumping Station	74	12	6	6
RO Concentrate Pumping Station	74	12	6	6
Administration Building	569	37	15	8

*This table excludes transformer, standby power and fuel tank

2.2.3.4 Waste Streams Management

Waste streams are produced from the UF plant (including strainer backwash, UF backwash and neutralised CEB wastewater) and RO plant (including neutralised CIP wastewater and RO concentrate). Gate 1 conceptual design proposed the option of discharging RO concentrate to the Mogden STW final effluent channel whilst discharging UF plant waste to the head of the Mogden STW. In Gate 2, a possibility of combining all waste streams in the proposed Wastewater Return Pumping Station and discharging it into the head of the Mogden STW was investigated to reduce the costs.

However, further assessment of STW capacity to accept and treat the combined wastewater stream is required. Therefore, at this stage, conveyance designs have assumed requirements for separate pipelines for the wastewater from UF plant and the RO concentrate as adequacy of the capacity of Mogden STW has not been confirmed.

Table 2-11 and Table 2-12 show projected composition and load of combined waste stream flow based on 95%ile final effluent quality feed to the AWRP.

Table 2-11: Projected AWRP Combined Waste Stream Composition

Parameter	Units	Waste Stream Concentration
pH	-	7.6
Alkalinity (as CaCO3)	mg/l	917
Suspended Solids	mg/l	236
TDS	mg/l	4,249
Total Organic Carbon	mg/l	200
Nitrate (NO3)	mg/l	117
Total Nitrogen	mg/l	140
Phosphate	mg/l	54
pH	mg/l	7.6

Table 2-12: Projected AWRP Combined Waste Stream Flow and Load

Parameter	Units	50Ml/d Plant Design	100Ml/d Plant Design
Waste Stream Flow	Ml/d	13	26
Alkalinity (as CaCO3) Load	kg/d	11,758	23,521
Suspended Solids Load	kg/d	3,022	5,175
TDS Load	kg/d	54,586	109,194
Total Organic Carbon (TOC) Load	kg/d	2,562	5,126
Nitrate (NO_3) Load	kg/d	1,499	2,998
Total Nitrogen Load	kg/d	1,789	3,580
Phosphate (PO_4) Load	kg/d	697	1,393

2.2.4 Conveyance Design Components

2.2.4.1 Conveyance of Final Effluent from Mogden STW to AWRP

Further assessment of the likely construction options at Gate 2, considering third-party information including land designations, environmental reviews and planning assessments, indicated that the alignment would be constructed as a tunnel. There would be limited opportunity to lower the capital cost of the scheme with open-cut pipelines without introducing significant operational complexity with vertical changes in alignment and the need for additional pumping.

The tunnelling technology for this section could be pipe jacking which provides an appropriate trade-off between diameter and shaft spacing. The individual pipe jack lengths would be limited to less than 1km and would have an external diameter of 2.2m and an internal diameter of 1.8m.

The length of the route would be approximately 6.4km. Due to the constrained nature of the tunnel route, phased provision of the conveyancing infrastructure would not be practicable. The route may include 10 trenchless sections in between Mogden STW and the AWRP.

Potential sites for the proposed AWRP are being investigated at this stage. Therefore, the conveyance design is subject to change depending on the site selected for the AWRP.

2.2.4.2 Conveyance of Recycled Water from AWRP to the River Thames

A 5.9km trenched pipeline is proposed to pump the Recycled Water from the AWRP to the discharge location at the River Thames. This pipeline would also require short sections of trenchless installation for river and road crossings depending on location of the AWRP site.

The trenched sections would be constructed with 1.4m internal diameter, pressurised pipeline using open excavations and could use an approximately 8m wide corridor along the route. The width required during construction could be greater but may vary with the congestion of the corridor. Sections in road would have to be constructed using trench boxes which minimise the working width at the compromise of a reduced construction rate.

The road and watercourse crossings could require a 1.8m internal diameter pipe-jacked tunnel section for the trenchless crossings. The 1.4m-diameter internal pressurised pipeline would pass within the pipe jack tunnels at the road and watercourse crossings.

The open-cut trench section terminates at the discharge site near the River Thames and would not require a separate shaft connection.

There is a potential that this pipeline would be gravity fed; however, the pipeline internal diameter would need to be larger. A more detailed hydraulic assessment of this opportunity will be required following AWRP site selection.

2.2.4.3 Conveyance of Waste Streams

The waste stream from the AWRP cannot be discharged directly to the River Thames, so the following two conveyance pipelines are required from the proposed AWRP to the Mogden STW inlet works for treatment:

- **Wastewater Return Pipeline**: A 700mm pipeline to carry waste stream from the CIP system back to the Mogden STW. This would be discharged into the inlet works downstream of the storm weir. There is an opportunity to avoid routing this pipeline from the AWRP to the Mogden STW and instead discharge at the South Sewer near Kempton WTW, which ultimately discharges to Mogden STW.
- **RO Concentrate Return Pipeline**: A 600mm pipeline to carry a maximum of 36.3Ml/d RO concentrate back to Mogden STW. This would be discharged into the final effluent channel for Mogden STW. However, if the Mogden STW has sufficient treatment capacity, this pipeline could be combined with the Wastewater Return pipeline, and RO concentrate could be also discharged into inlet of the Mogden STW or to the South Sewer.

The conveyance of the waste streams would follow the same route as the Final Effluent Transfer Tunnel. This would be achieved by pipe jacking another 1.8m internal diameter tunnel in parallel to the Final Effluent Transfer Tunnel. The two pipelines (i.e., Wastewater Return Pipeline and RO Concentrate Return Pipeline) would be installed inside the single 1.8m internal diameter tunnel (Waste Stream Return Tunnel) with appropriate ‘spider’ spacers in place. The length of this route for the Waste Stream Return Tunnel is approximately 6.4km.

The opportunity of combining the pipelines for CIP wastewater and RO concentrate into one tunnel would require further study and confirmation at the next phase of the project on the Mogden STW’s capacity to accept and treat the waste stream.

2.2.4.4 Shafts

Indicative shaft details are listed in tables below:

Table 2-13: Mogden STW to AWRP Indicative Shaft Details

Shaft	Shaft Internal Diameter (m)	Approximate Ground Level (m AOD)	Approximate Shaft Depth (m)	Approximate Shaft Base Level (m AOD)
Mogden STW Shaft Site	10	6.1	13.8	-7.7
Shaft Site 2	10	9.4	16.9	-7.5
Shaft Site 3	10	10.0	17.4	-7.4
Shaft Site 4	10	11.7	18.7	-7.0
Shaft Site 5	10	13.4	20.3	-6.9
Shaft Site 6	10	13.4	19.9	-6.4
Shaft Site 7	10	19.6	24.9	-5.3
Shaft Site 8	10	19.9	24.6	-4.7
Shaft Site 9	10	17.7	21.3	-3.6
Shaft Site 10	10	17.6	20.6	-2.9
AWRP Shaft Site	10	15.8	18.0	-2.2

Table 2-14: AWRP to Walton Discharge Indicative Shaft Details

Shaft	Shaft Internal Diameter (m)	Approximate Ground Level (m AOD)	Approximate Shaft Depth (m)	Approximate Shaft Base Level (m AOD)
Shaft Site 13	8	11.0	3.3	7.7
Shaft Site 14	8	10.8	3.2	7.6
Shaft Site 15	8	9.1	2.4	6.7
Shaft Site 16	8	9.9	3.1	6.7

2.2.4.4.1 Mogden STW Shaft Site

The proposed shaft site at Mogden STW would be located within Thames Water-owned land at Mogden Sewage Treatment Works.

A shaft would be required for construction of the tunnel with the launch of the TBM and extraction of tunnel spoil. After commissioning, the shaft would be used to transfer final effluent from treatment works to the tunnel. Some amendments to normal operational access would be required during the works but those are manageable. The shaft at this compound would have an approximate internal diameter of 10.5m.

2.2.4.4.2 Mogden STW to AWRP Intermediate Shaft Sites

Several intermediate shafts would be required along the route to launch and receive the TBM undertaking the pipe jacking/tunnel construction. The shafts would be used to facilitate access to the tunnel, launch the TBM, remove spoil and provide ventilation during construction. The intermediate shafts would have an internal diameter of approximately 10m and would be capped with a concrete cover after completion of the works. The shaft concrete cover would be permanent, and would be positioned below the ground surface, with access covers for personnel access at ground surface.

2.2.4.4.3 AWRP Shaft Site

The final site in the tunnelling drive would be located inside the proposed AWRP site compound and could be used as a reception shaft to retrieve the TBM. After commissioning, the shaft would be used to transfer the final effluent from the tunnel into the AWRP site for further treatment processes. The shaft would be sized with an internal diameter of approximately 10m.

2.2.4.4.4 Shafts between AWRP and the River Thames

Significant parts of the conveyance section between the AWRP and the River Thames would be constructed using open-cut pipeline installation. Short sections would be pipe jacked in order to cross a road and a watercourse. The two sections of pipe jacking would be launched from approximately 8m internal diameter shafts.

2.2.4.5 Recycled Water Discharge Arrangement

It is proposed that Recycled Water would be discharged into the River Thames upstream of the Walton WTW Intake. The Recycled Water would then blend with the main river flow before being abstracted downstream.

The outfall would be designed to reduce the delivery velocity in the Recycled Water Transfer Pipeline to discharge velocity into the river at less than 0.3m/s. This low velocity is intended to minimise disturbance to river sediments as well as to avoid introducing turbulent currents that may disturb boats or other craft using the river.

The buried structure is intended to be unobtrusive, although access covers and covers to valve spindles would be visible at ground level in the embankment adjacent to the river. The Recycled Water would discharge at the surface of the river. The riverbank at this location would extend over the river edge as a vertical timber wharf. Vertical bars would be fitted under the wharf structure to prevent unauthorised access and to prevent accumulation of debris when not in use.

Modelling work is being carried out to confirm environmental impacts. Design of the outfall is to be further developed through feedback from modelling results and conversations with regulatory authorities and local communities.

2.2.4.6 Conveyance Profile and Existing Infrastructure

The conveyance profile from the Mogden STW to the AWRP is in a generally rising gradient. The conveyance would be built using 14 to 25m deep pipe jacks to avoid major services and the significant urban complexity along the route. The outfall discharge point at the River Thames would be lower than potential AWRP sites. Therefore, there could be an opportunity to convey Recycled Water in a gravity pipeline.

A utilities search was undertaken with relevant stakeholders. The information acquired was used to amend the proposed tunnel alignment and profiles, considering acceptable safe clearances from utilities such as power lines and gas mains.

The trenched sections of pipeline between the AWRP and the outfall could be more impacted by utilities diversions as the pipe would be constructed close to the ground level. At the future stage of design, engagement is required with utility providers to understand the likely mitigation measures and the extent of diversionary works required.

2.2.4.7 Pumping Stations

Pumping stations are required for the final effluent transfer, the wastewater stream returns from the AWRP, Recycled Water conveyance and the AWRP inter process piping. The key pumping requirements would be as follows.

- **UF Transfer Pumping Station**: To transfer UF waste generated through treatment in AWRP to the inlet of the Mogden STW for treatment. This PS would be located within AWRP.
- **RO Transfer Pumping Station**: To transfer RO concentrate generated through treatment in AWRP to the inlet of the Mogden STW for treatment. This PS would be located within AWRP.
- **Final Effluent Pumping Station**: To abstract final effluent from the existing final effluent channel in Mogden STW and transfer to the proposed Advanced Water Recycling Plant (AWRP) in proximity to the abstraction location within the STW. This PS would be located within Mogden STW.

- **Recycled Water Pumping Station**: To transfer Recycled Water generated through treatment in AWRP to the Outfall site at River Thames. This PS would be located within AWRP
- **Wastewater Return Pump Station**: To transfer waste stream generated through treatment in AWRP to the inlet of the Mogden STW for treatment. This PS would be located within the AWRP.

2.2.5 Operating Philosophy

The water recycling schemes would operate intermittently as required during periods of drought in the Thames Water Drought Plan framework. Anticipated operational utilisation rates are set out in section 4.1 in the Gate 2 Report.

It was assumed that the water recycling schemes would be utilised and operated as one of the strategic drought schemes in the Thames Water Drought Plan and that the trigger of utilisation would be same as the strategic drought schemes in the current Drought Plan. Strategic drought schemes are sources of water that are permitted for use during drought period but are not used as part of day to day' baseline supply. Thames Water Draft Drought Plan 2022 lists five strategic drought schemes including Thames Gateway Water Treatment Works (TGWTW).

In the Thames Water Drought Plan, utilisation of the strategic drought schemes is triggered by:

Naturalised flow over Teddington Weir receding down to 3000Ml/d on average for 10 days during the course of a drought event (defined as having a Drought Event Level (DEL) equal to or greater than DEL1), and

Reservoir storage levels having fallen to the 800-700/600Ml/d flow requirement at Teddington Weir.

2.2.5.1 Operating Modes

Operations of international and domestic water reuse and desalination plants, including Thames Water Gateway Desalination plant, were reviewed. Interviews with technical and operational staff from these plants were held to assess various operational modes

The types of operating modes considered were:

- **Normal Operation**: Treatment plant and conveyance assets are operating in normal automatic control (25-100% of maximum capacity) and delivering Recycled Water or Treated Effluent to the intended discharge location.
- **Hot Standby**: Operating mode where a plant runs at a proportion of total flow (25% or less of maximum capacity), with a 'duty' stream under Normal Operation and with parts of the plant in standby and is able to return into Normal Operation within a day to two weeks. Conveyance assets would transfer part of, or all Treated Effluent/ Recycled Water generated in the plants for "sweetening".
- **Cold Standby**: Operating mode where process units are available to return to Normal Operation mode within several weeks. Recycled Water or Treated Effluent would not be produced or be produced in minimal amount of flow which would be run to waste. Conveyance assets would be drained down.
- **Care and Maintenance**: Operating mode under which the asset is not delivering any water, but maintenance is carried out in order to keep the plant serviceable and able to return into Normal Operation mode within a few months. Process assets would be in preservation mode to allow maintenance only, and any maintenance flows from the plant would run to waste. Conveyance assets would be drained down.
- **Non-operational**: Treatment plant and conveyance element are out of service and there is minimal ongoing expenditure.

Non-operational mode would pose major risks to the treatment plant. Fully offline treatment assets are unlikely to be suitable for restart without major replacement works and timely re-commissioning which would be costly and not practicable. The Cold Standby mode may not be recommended as it would offer negligible benefits over the Hot Standby mode posing higher risks due to the conveyance assets being drained down.

2.2.5.2 Operating Models

Three operating models were assessed at Gate 2

Continuous Sweetening Flow Model: The system would be in Hot Standby mode during non-drought periods and would generate Treated Effluent/ Recycled Water at lower rate (i.e., 25% of full capacity or less) to enable timely recommissioning when supply is required.

Cautious Restart Model: The system would be in Hot Standby mode during non-drought periods for approximately 6 months of the year (in the months of high likelihood of droughts) to facilitate timely recovery to Normal Operation mode. During the other 6 months, the system would be in Care and Maintenance mode, with the conveyance drained and any flows through the plant for maintenance would be discharged back to the STW inlet. Alternatively, the conveyance system could be kept full, and a very small sweetening flow slowly discharges at the proposed outfall following periodic operation of the plant. However, additional chlorination would likely be required to prevent biomass build-up. The process and conveyance assets would require relatively complex ramp-up procedures each year from Care and Maintenance mode to Hot Standby mode.

Infrequent Restart Model: The system would be in Hot Standby mode during non-drought periods for approximately 3 months of the year (in the months of highest likelihood of droughts) to facilitate timely recovery to Normal Operation mode. During the other 9 months, the system would be in Care and Maintenance mode, with the conveyance drained and any flows through the plant for maintenance would be discharged back to the STW inlet. The process and conveyance assets would require relatively complex ramp-up procedures each year from Care and Maintenance mode to Hot Standby mode.

The Continuous Sweetening Flow model, which would have high operational costs, but with lower operational complexity and risks, would be recommended for all the London Effluent Reuse SRO schemes at this stage. Details of operating model will be further reviewed and optimised in terms of costs, carbon output, environmental impacts, operational complexity, reliability and security.

2.2.5.3 Advanced Water Recycling Plant Chemical Consumption

Chemicals required for operation of the AWRP for pre-treatment and cleaning purposes would include: Ammonium Sulphate, Sodium Hypochlorite, Sulphuric Acid, Anti-Scalant, Hydrogen Peroxide, Sodium Bisulphite, Lime, Carbon dioxide, Citric Acid, and RO CIP Chemicals (including Sodium Tripolyphosphate, Sodium Dodecilsulphonate and Sodium EDTA).

2.2.5.4 Maintenance Requirements

2.2.5.4.1 Advanced Water Recycling Plant

Advanced Water Recycling Plant would have multitude of ancillary systems which feed into the main process stages of Ultrafiltration (UF), Reverse Osmosis (RO) membrane, hydrogen peroxide dosing and UV treatment (UVAOP) and remineralisation. Key items for maintenance of AWRP would include the followings:

- **AWRP general maintenance –** continuous, automated WQ monitoring of feed water, permeate and concentrate. Frequent MEICA maintenance for all pumps, instruments, valves, etc. and normal fault finding and resolution to ensure strict WQ parameters.
- **Replacement of RO membranes –** expected every 5 years (assuming suitable maintenance including automated flushing cycles and chemical cleaning regimes (CIP))
- **Replacement of UF membranes –** expected every 5 years (assuming suitable maintenance including automated flushing cycles and chemical cleaning regimes (CIP))
- **Replacement of UV lamps –** expected every 5 years
- **Energy Recovery Devices –** turbines / pressure exchange modules require frequent inspections and troubleshooting to ensure efficient generation of recovered energy.

2.2.5.4.2 Conveyance

When in use the pressurised pipelines would operate as balanced systems with the pumps at the upstream end, ensuring the pipelines remain primed with adequate hydraulic head to drive flows to/from the AWRP. The flow rate and pressure in the pipelines could be controlled by using pumps with Variable Speed Drives.

The conveyance pumpsets would have duty and standby units and the control system would be designed to ensure utilisation is spread equally between the pumps to equalise wear.

When the scheme is in "Care & Maintenance" mode, the pipelines would be pumped dry, with residual volumes drained out manually at all wash-out hydrants and left drained.

Multiple discharge locations from each washout would be required, and all pumpsets may have a smaller "priming pump(s)" for use during the change from "Care & Maintenance" mode to "Hot Standby" for re-filling and priming the pipelines. The pumps would need regular maintenance and periodic operation and would need to be run on regular cycles to maintain operability when the system is in "Care & Maintenance" mode.

It has been calculated that it would be possible to pass forward the entire Recycled Water pipeline volume in a 24-hour period with the AWRP operated at 25% of the capacity regardless of scheme size, to reduce the likelihood of stagnation and bacteria development.

As the Final Effluent Transfer, Waste Streams Return and RO Concentrate Return pipelines would be installed within tunnels, these tunnels would remain dry and left drained continuously. Inspections of the tunnels would be required to assess condition. This could be done when the tunnels are in "Care and Maintenance" mode.

The Outfall Structure would be designed to require minimal maintenance. Inspection would be carried out to ensure that the structure including access covers has not been damaged. The valve operation would be checked, and a visual internal inspection of the buried structure would be carried out. The inspection would monitor the build-up of silt inside the structure and check for the accumulation of debris.

2.2.5.5 Fail Safe Shutdown System

In the event of a water quality failure, the scheme would "fail safe", via a run-to-waste back to the Mogden Sewage Treatment Works. The treatment facilities would be monitored at Critical Control Points (CCPs) for the required water quality parameters and will initiate an auto-shutdown/ diversion of flow in the event of registering out of bound ("critical limit") quality parameters or catastrophic failure of the plant.

If the AWRP fails (e.g., power loss, treatment/chemical failure) then there would be a lock in of flow passing through the plant (with offline balancing tanks to store pass forward flow during shutdown if necessary). The Final Effluent Pumping Station (FEPS) which would be feeding the AWRP would automatically shut down on failure.

The locked in process flow would then be run-to-waste where all flows would pass to the AWRP Waste Return Pump Station to return all locked-in flows to the Mogden STW inlet works for treatment.

2.2.6 Inter Site Control System Requirements

A communications link between the Final Effluent Pumping Station (FEPS) at the Mogden STW and the AWRP would be provided to ensure the final effluent transfer pumps are inhibited in the events of power loss at the AWRP or AWRP process failure or maintenance.

Connection to the wider Thames Water Production Planning system might be provided to regulate operating capacity based on the water levels in the river or the reservoirs.

2.2.7 Power Requirements

Electrical Power would be required at two locations. Firstly, at the Mogden STW for the FEPS, and secondly at the AWRP near Kempton WTW. The FEPS would utilize the existing electrical distribution at the Mogden STW whereas the AWRP would require a new 11kV supply provided by the local District Network Operator (DNO).

2.2.7.1 Potential Power Requirements at Mogden Water Recycling FEPS

It is assumed that Mogden STW electrical distribution is capable of providing a High Voltage (HV) supply to the FEPS; however, this may require upgrading the existing electrical infrastructure within the treatment works.

2.2.7.2 Potential Power Requirements at Mogden Water Recycling AWRP

The electrical supply and distribution for the proposed AWRP could be arranged as an 11kV supply terminating at a new HV switchboard, located within a new HV Electrical Switchroom. An 11kV radial supply from the AWRP HV Switchboard would feed local step-down transformers which in turn would provide power to sub-fed Low Voltage (LV) MCCs. All phasing options would have similar layouts with only variations being in number of local step-down transformers and sub-fed LV MCCs.

2.2.8 Greenhouse Gas Mitigation, Energy Recovery and Renewable Energy Opportunities

Estimates of capital carbon (embodied carbon) and operational carbon for London Effluent Reuse schemes could be found in section 6.5 of the Gate 2 Report and Annex A.5 of the Gate 2 Report.

To maximise alignment with PAS 2080 and the Water UK Net Zero 2030 Routemap, the emissions hierarchy, which is detailed in the figure below, would be followed when deciding which approach to prioritise to mitigate emissions. This prioritises in order demand reduction, efficiency gains and renewable energy integration before pursuing offsets to remove residual carbon emissions. Due to the complexity and long lifetime of these schemes, it is important to take a holistic approach to carbon mitigation, which uses a combination of approaches.

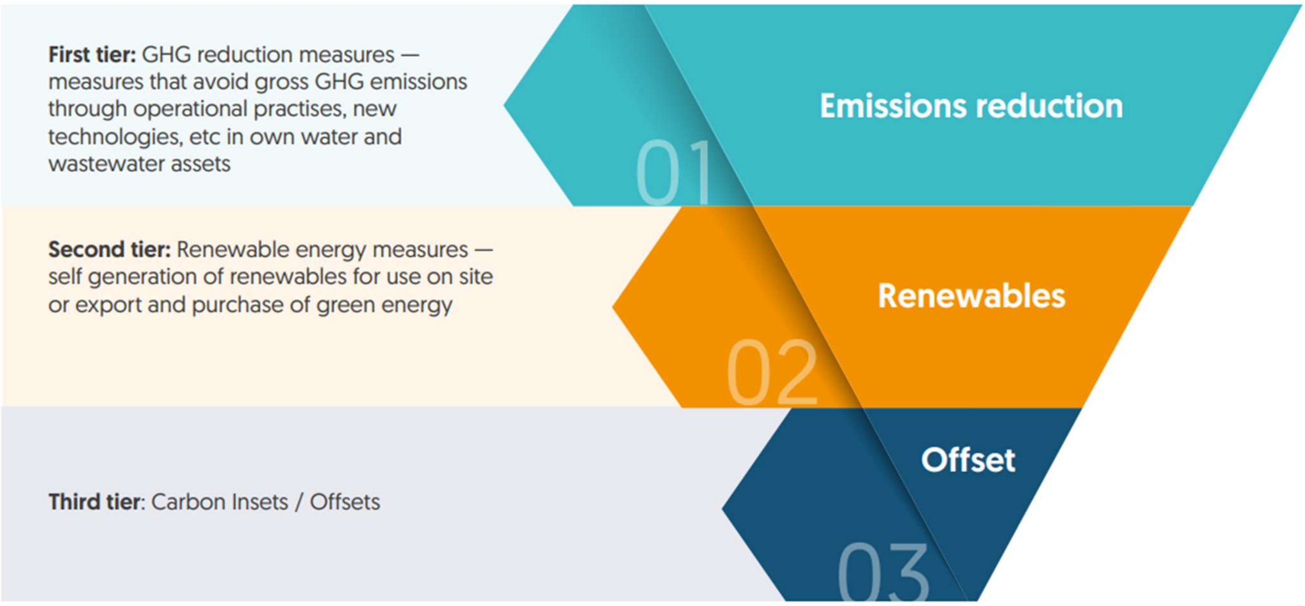

Figure 2-3 Emission Reduction Hierarchy

Capital emissions represent the majority share of total Greenhouse Gas (GHG) emissions in the short term - as such, focusing on reducing capital emissions will likely yield significant reductions across the early stage of a site's operational life. A focus on 'designing out' carbon can reduce both capital and operational emissions, in particular for building heating and plant efficiency.

While annual operational emissions are less than those released due to material sources, over time, across the lifetime of a site operational emissions would contribute significantly. Therefore, reducing operational emissions will achieve the great reduction of GHG emissions in the long term. This approach is also line with the Water UK and TWUL targets of net zero operational carbon by 2030.

It should be noted that operational GHG emissions from electricity demand would be zero for London Effluent Reuse SRO because all electricity purchased would be zero carbon via either a Renewable Energy Guarantee of Origin (REGO) contract or Power Purchase Agreement (PPA) as per Water UK Net Zero 2030 commitment.

However, carbon values reported in section 6.5 and Annex A.5 of Gate 2 Report include electricity carbons for operation.

Table below lists the potential GHG mitigation approaches, providing a high-level ranking of their potential impact on emissions reduction, including potential influence on reduction of scope 2 and scope 3 carbon, and alignment with the emissions hierarchy.

Table 2-15: Summary and Ranking of Potential Carbon Emission Reduction Approaches for London Effluent Reuse schemes

Approach to mitigate carbon emissions	Emissions Hierarchy Category	Potential for emissions reduction	Ability for Thames Water to Influence	List of options
Energy management & efficiency (highest priority)	Emissions reduction	High	High	- Improved pump efficiency - Metering - Smart control systems - Catchment level analytics
Renewable energy on site	Renewable energy	High	High	- Solar - Wind - Storage
Procured Renewable Energy	Renewable energy	High	High	- Sleeved power purchase agreement (PPA) - Synthetic PPA - Private Wire PPA - REGO-backed Green Tariffs
Resource Efficiency and Chemical Supply	Emissions reduction	High	Low	- Supply chain contracts - Reduced resource use
Embodied emissions reduction	Emissions reduction	Moderate	High	- Low carbon concrete - Low carbon steel - Recycled materials - Locally sourced materials
Engineering design	Emissions reduction	Moderate	Moderate	- Conveyance routes - Land use - Building size - Building heating
Construction emissions	Emissions reduction	Low	Moderate	- Reduced transport - Vehicle energy use - Renewable onsite power - Temporary buildings
Insets	Offset	Low	Moderate	- Peatland restoration - Grassland restoration - Tree planting
Offsets (lowest priority)	Offset	Low	High	- UK Emissions Trading Scheme (ETS) - Voluntary Offset Market

2.3 Opportunities and Future Benefits Realisation

Key opportunities identified in the conceptual design are listed in the table below.

Table 2-16: Key Opportunities - Mogden Water Recycling Conceptual Design

Category	Opportunity
Process System Design	Equalisation tanks were sized assuming 4-hour retention the new AWRP There may be an opportunity to reduce the retention time following further design work, such that volume and footprint of the tanks would be reduced.
Process System Design	There is an opportunity to reduce redundant RO membrane trains as the London Effluent Reuse schemes would need less redundancy in comparison to conventional water treatment plants because: ▪ The schemes would not supply water directly to the customers. Therefore, failure of the system would not immediately impact the customers. ▪ Supply from the schemes are required only during drought periods. This could significantly reduce the required RO plant footprint and costs. Reasonable Level of Service for this scheme would need to be investigated.
Process System Design	There is an opportunity to rationalise and develop best outcome treatment requirements through pilot work and/or full engagement with stakeholders with regards to expectation of treatment processes, customer acceptability and engagement and environmental outcomes. This may consider non-RO treatment trains and more detailed water quality risk assessment.
Conveyance Design	The conveyance between the Mogden STW and the AWRP as well as the AWRP and the discharge into the River Thames could potentially be designed as gravity pipelines.
Conveyance Design	Currently the Mogden STW to AWRP tunnels are dual 1.8m tunnels with final effluent and the other tunnel with 0.6m and 0.7m waste stream return pipelines. There is an opportunity to combine all three currently encased pipelines inside one larger 2.4m internal diameter tunnel.
Conveyance Design	There is an opportunity to transfer the waste stream for the CIP system to discharge at the South Sewer on the A316, which is discharging into the Mogden STW, instead of transferring to Mogden STW. This would result in a significantly shorter conveyance route. A detailed investigation on the potential impacts and spare capacity of the sewer network at this location needs to be investigated.

3 Scheme Delivery

3.1 Overview of Construction Process

3.1.1 Advanced Water Recycling Plant

The new AWRP would be constructed near Kempton WTW. Available sites are currently being reviewed and have not been determined at this stage.

If the proposed site is in undeveloped land, significant sitework would be required for site preparation including clearing, grubbing and stripping of the site. Site grading would be also required and should be properly designed and performed to achieve effective site drainage.

New utility servicing, such as electricity, gas, water, sewer and communications would need to be established. Construction of a new site access road or widening of an existing access road may be required depending on location of the selected site.

As the new AWRP would likely be outside of the existing STW or WTW sites, a new security system, including security gates, boundary fencing and security cameras, would also need to be installed at the site.

At this stage, it was assumed that construction elements for treatment facilities will be above ground, single storey and will be either reinforced concrete or steel-clad buildings housing treatment and mechanical, electrical and instrumentation control automation (MEICA) equipment. However, underground tanks and multi-storey building may need to be considered if size of available land is limited.

3.1.2 Conveyance

3.1.2.1 Final Effluent Transfer Tunnel Construction

Due to the constrained nature of this area of West London, the current proposal would be to construct the section between the Mogden STW and the AWRP as pipe jacked sections, each of which would be kept to a maximum length of 1km. For this tunnelling distance, the dimension of the tunnel is 1.8m internal diameter (2.2m external). This assumes a 200mm wall thickness for concrete segments which would form the outer layers of the tunnel. Since this would be a pressurised tunnel there is a possibility that an impermeable secondary lining would be required on the inner wall of the tunnel, but this is subject to further investigation at the next stage of design.

In order to construct the tunnel sections, drive and reception shafts would be needed. The proposal for the drive shafts would be to construct a circular shaft 10m internal diameter and varying depths between 14m and 25m. This depth has been chosen to avoid conflicting with buried services and providing adequate cover to major features at ground level. Two parallel tunnels would be constructed to allow for the Waste Stream Return Tunnel to be installed along the same route. The reception shafts would also be10m internal diameter. The area required for the drive and reception shafts would generally be between 25m x 25m and 50m x 50m but may vary depending on the available land at the proposed shaft sites.

Since the tunnels would be constructed in London Clay, open-mode Earth Pressure Balance TBM’s would likely to be used and therefore no slurry separation plant would be required to assist the drilling operations. However, a small volume of slurry would be required to act as the pipe jacking lubricant.

3.1.2.2 Recycled Water Transfer Pipeline Construction

The Recycled Water conveyance option between the AWRP and the outfall on the River Thames would be constructed using open-cut trenching methods. This pipeline section would be 1.4m internal diameter and approximately 5.9km in length. However, the site of the pipe is subject to change depending on ultimate capacity of the scheme. There are two areas of the pipeline which will likely require trenchless construction methods. Depending on the ground conditions and the land available at both the drive and reception shafts, these two trenchless sections could be constructed using a variety of methods such as Horizontal Directional Drilling, Auger Boring or Micro-tunnelling. The site compounds for these trenchless areas may be used for pipe and material storage during the construction of this pipeline section.

The working width in highways and urban areas would need to be reduced though as it could lengthen the construction schedule.

3.1.2.3 Waste Stream Return Tunnel Construction

The alignment route for this conveyance would identical to the Final Effluent Transfer Tunnel, except that the flow would be transferred from the AWRP to the Mogden STW. The two waste stream components would be the 700mm pipeline for the Clean In Place (CIP) waste and the 600mm pipeline for the RO concentrate. To avoid constructing 3 separate tunnels for the pipe jack section, both pipes would be installed in the same 1.8m-diameter tunnel. This would be achieved by welding the pipeline as it is pushed along the tunnel and fitting appropriate “spider” restraints to secure the two pipes in place.

3.1.2.4 Shaft Construction

This conceptual design indicates the most likely shaft construction method, but the final choice will depend on many factors, particularly details of the ground conditions that would emerge from ground investigations, as well as construction and operational health and safety considerations.

3.1.2.4.1 Segmental Shaft Construction

Segmental lining is the most common method of construction, and often preferred, as it is generally the quickest and least expensive, and it can be adapted to many ground conditions. Segments are installed by two methods, caisson jacking or underpinning, and the method used depends on the ground and groundwater conditions:

- Caisson jacking involves the assembly of segmental rings on the surface over a cutter head and jacking this into the ground. As the assembly advances, ground is excavated from inside and additional rings are placed on top. This method is particularly suitable in soft ground. After it reaches the required depth, the annulus around the shaft is grouted to limit further ground movements and mobilise friction with the surrounding soil. In wet ground, to balance water pressure, the shaft is left full of water, and ground is excavated below water. This is termed a ‘wet caisson’.
- Underpinning involves excavating ground below existing rings and installing segments beneath these. This process is repeated to the base of the shaft and then the annulus is grouted. The method is most applicable when the ground is stable on excavation and there are limited inflows of ground water.

It is common practice to start a shaft by caisson jacking in softer superficial soils and switch construction to underpinning, or Sprayed Concrete Lining (SCL) shaft construction, if ground conditions improve.

3.1.2.4.2 Sprayed Concrete Lining Shaft Construction

Sprayed Concrete Lining (SCL) requires good stable ground conditions with self-supporting soil such as London Clay and is therefore not suitable for all ground conditions. As openings are easier to create in SCL linings than segmental linings, it is sometimes advantageous to switch from segmental to SCL at the base of shafts where openings are most often located. Typically, SCL will be used to construct the lower part of the shaft once the segments are within the London Clay formation. The SCL will normally require a secondary in-situ concrete lining to form a smooth surface and for control of seepage.

3.1.2.5 Outfall Construction

The proposed outfall is intended to discharge Recycled Water into the River Thames. The outfall structure would be designed to be unobtrusive and would be mostly buried in the riverbank.

An open excavation would be required to construct the outfall structure. The work site and excavation would be secured during construction by security hoarding around the site perimeter and access to the site would be controlled.

The foundations of the structure would be below the river level and a temporary U-shaped steel sheet pile wall may need to be built out from the riverbank 2 to 3m into the river to allow a dry excavation for construction. Depending on the particular ground conditions at the site the steel sheet pile wall may be extended around the whole excavation perimeter. A blinding layer of concrete would be laid across the bottom of the excavation to give a stable working level.

The new outfall structure would be constructed from reinforced concrete. The Recycled Water Transfer Pipeline would be cast into the wall of the structure.

The structure base, walls and internal weir could be cast in situ. The top cover slabs are likely to be precast concrete planks and could be cast off site and craned into place. Once complete, the structure would be backfilled to the original ground profile and the temporary sheet piles would be removed. The riverbank profile on either side of the structure and over the outfall would be reinstated.

3.1.3 CDM Implementation

During the Gate2 process, the Principal Designer (i.e., Jacobs Engineering U.K. Limited) was appointed by TWUL in accordance with the Construction Design and Management (CDM) Regulations 2015.

Potential key and location-specific construction phase hazards have been identified by the design team. Site visits were carried out by the design team to verify feasibility of the conceptual designs as well as to gather information on site conditions which could potentially cause health and safety hazards. Hazard information was also gathered from geotechnical review and previous knowledge of the hazards associated with the ground and locations of the proposed works.

Potential measures which could be taken to eliminate the hazards or to mitigate the risks during Gate 2 were incorporated into the conceptual design, fundamentally through the route vertical and horizontal alignment process, and potential actions to facilitate elimination or mitigation actions to be taken at the future design stages were identified.

Particular significant or unusual health and safety risks associated with Mogden Water Recycling scheme include:

- A series of existing utilities such as gas mains and high-voltage electrical underground cables in the potential route for the proposed trenched Recycled Water Transfer Pipeline. There would be potential risks of explosion and electrocution during construction.
- Historic landfill sites along the potential route for the proposed trenched Recycled Water Transfer Pipeline. Therefore, there would be potential hazard of contaminated land and gas ingress during construction.

A new or extended appointment of Principal Designer would be required to be made on completion of Gate 2. The hazard information collected in Gate 2, as well as the potential measures identified to be taken at the future stages would be provided over to Principal Designer appointed at the next design stage.

Key activities following completion of Gate 2 will likely include the initial compilation of Pre-Construction Information. This includes identification and planning for intrusive ground investigations and monitoring to understand the site-specific risks. These hazards include contamination, complex hydrogeology, unexploded ordnance (UXO) and buried obstructions utilities.

From this action plans can be developed to address key hazards which apply across much of the conveyance route and shaft locations. Further enquiries would need to be made to establish records of key critical structures which impact the construction such as the foundations of bridges and gantries.

3.2 Transportation of Construction Materials and Spoils

Several temporary site compounds would be required along the route of the tunnels and the pipeline to facilitate the storage of construction materials and spoil from excavations and micro-tunnelling. At drive shaft sites, the spoil produced would normally be transported along the tunnel from the TBM by conveyors or by using rail-hauled skips hoisted to the surface at the drive shaft.

Areas would be required at the construction sites for temporary storage of the spoil to enable tunnelling work to proceed for 24 hours per day, while awaiting transport off site by lorry during daytime working hours.

If a slurry machine were to be used for tunnelling, further space would require for a plant to separate spoil from the slurry mix before it is transported off site. However, given the anticipated ground conditions it is unlikely that a slurry TBM would be used.

For open-cut trenching sections, a proportion of the excavated soil would be used as backfill for the trench embedment material. This spoil could be stored adjacent to the open pipeline trench during construction. The unused spoil would need to be moved to the temporary compound sites for storage prior to removal.

Spoil would generally be transported off site using Heavy Goods Vehicle (HGVs), which would have an impact on the surrounding road networks. The estimated number of HGV journeys has been calculated for the tunnel/shaft works at the individual sites. The quantities of spoil have been estimated based upon assumed depths of the tunnel/shafts stated earlier in the report and readily available ground information. Bulking factors have also been assumed for the different types of ground.

Table 3-1: Summary of Vehicle Movements for Shafts and Tunnel Construction

Shafts	Estimated total no. of HGVs for spoil	Estimated total no. of HGVs for segments	Comments
Mogden STW Site Shaft Construction	230	80	Shaft sinking at Mogden STW site
Mogden STW to AWRP Intermediate Shafts Construction	2550	880	Combined Intermediate Shaft Sites along the tunnel routes.
Mogden STW to AWRP Tunnel Construction	3100	1750	TBM drive between the Intermediate sites.
AWRP Site Shaft Construction	240	80	Shaft sinking at AWRP site.
AWRP to Walton Outfall Trenched Pipeline Installation	1400	660	Trenchless/open-cut pipeline installation along the route with intermediate pipe jacking pits for short-distance crossings

3.3 Delivery Programme

Table 3-2 shows approximate indicative duration of programme elements. Potential schedule for contract management elements could be found in Annex F of Gate 2 Report.

Realistic procurement periods have been assumed within delivery programme based on experience within the construction industry. Potential programme savings could be made by:

- Utilising standard products and equipment could result in shorter procurement durations.
- Work elements were assumed to be sequential with minor overlap (e.g. civil work followed by MEICA work in treatment plant construction, no concurrent shaft construction, etc.). This also represents the most robust schedule for project delivery. A contractor may decide to undertake works concurrently potentially leading to a shorter overall construction duration for these elements.
- There is 3 - 6 months of commissioning at the end of each main construction component (e.g. conveyance, treatment plant, river abstraction, etc.). Commissioning could happen concurrently as parts of construction stage. Therefore, there is an opportunity to reduce these periods when designs mature.
- The working calendar was assumed to be 5-day work week with no allowance for night working. If planning consent can be granted for 24-hour or weekend working, construction duration could be reduced.
- Conservative production rates for construction schedules were used.

Table 3-2: Indicative Duration of Programme Elements

Task Name	Approximate Duration (months)
Pre-Construction Stage	19
Detailed Design	19
Procurement	11
Enabling Works	10
Construction Stage	27
Commissioning Stage	13
System Commissioning Works	13
Performance Testing	6
Defects Period	11

4 Water Resources

The Deployable Outputs (DO) for Mogden Water Recycling were estimated as 46 and 88 Ml/d, for both the Dry Year Annual Average (DYAA) and the Dry Year Critical Period (DYCP), for the capacities of 50 Ml/d and 100 Ml/d respectively. Details of the estimation of DO for the London Effluent Reuse SRO could be found in the Thames Water draft Water Resources Management Plan 2024. This scheme will benefit the London WRZ.

5 Assumptions and Risks

The information presented in this document relates to material or data which is still in the course of completion. Should the solutions presented in this document be taken forward, Thames Water will be subject to the statutory duties pursuant to the necessary consenting process, including environmental assessment and consultation as required. This document should be read with those duties in mind.

5.1 Key Assumptions

Key assumptions that have been made in this conceptual design report are listed below:

- The AWRP site would be available near the Kempton WTW for development of the AWRP.
- There would be no obstacles with purchasing additional land required.
- UF and RO backwash and neutralised spent cleaning chemicals waste would be transferred and treated at Mogden STW. Further assessment is required to ensure this aligns with future capacity projections at Mogden STW.
- Mogden STW final effluent would not require further polishing to reduce suspended solids prior to feed the AWRP.
- The conveyancing could agree settlement limits, mitigation measures and monitoring with other existing tunnelled utilities on the alignment.

5.2 Key Risks

Key risks associated with this scheme are listed as follows:

- There is a risk that waste stream from AWRP could not be discharged into the Mogden STW inlet works.
- RO concentrate produced by the AWRP cannot be returned to Mogden STW inlet works and will require disposal to discharge.
- There is a risk that tunnel or shaft construction will encounter unexpected ground conditions.
- The proposed tunnel would cross several existing infrastructure networks. Mitigation measures for potential settlement need to be considered in more detail.
- The nature of the urban or sub-urban environment, and designated sites limits open-cut trenching pipeline options and constraints the potential shaft locations.

6 Glossary and Abbreviations

Term	Definition
London Effluent Reuse SRO	Term to describe the Strategic Resource Option group for all four schemes as set out in the PR19 Final Determination.
London Effluent Reuse Scheme	Term when describing an individual option of the SRO.
Beckton Water Recycling scheme	Option to develop a water reuse/recycling plant at Beckton STW including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Mogden Water Recycling scheme	Option to develop a water reuse/recycling plant at a site near Kempton WTW for Mogden STW effluent including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Mogden South Sewer scheme	Option to develop a sewage reuse/recycling plant at a site near Kempton WTW for untreated sewage from South Sewer which discharges into Mogden STW, including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Teddington DRA scheme	Option to develop a water reuse plant at Mogden STW taking effluent for tertiary treatment then discharging to River Thames including abstraction, treatment and conveyance scope. One of the four schemes in London Effluent Reuse SRO.
Final Effluent	Water treated and discharged from existing secondary treatment process in Beckton Sewage Treatment Works or Mogden Sewage Treatment Works
Treated Effluent	Water treated in the proposed Tertiary Treatment Plant (TTP)
Recycled Water	Water treated in the proposed Advanced Water Recycling Plant (AWRP)
catchment	The area of region where all water flows to a single point, e.g., for a wastewater catchment, all wastewater flows to a single STW for treatment.
component	The key engineering items that contribute to each option e.g. pipeline, advanced water recycling plant.
concentrate	The concentrated waste stream produced by the Reverse Osmosis membranes.
conveyance	Refers to the assets which make up a transfer of fluid from one location to another, e.g. pipeline, tunnel, pumping station and outfall.
scheme	Refers to the overall system for one of four 'Options' within the London Effluent Reuse SRO for providing water resource benefit to the region, e.g., Beckton Water Recycling, Water Recycling Reuse, Teddington DRA and Mogden South Sewer.

Acronym	Definition
ACWG	All Company Working Group
ADF	Average Daily Flow
AMP	Asset Management Plan
AOP	Advanced Oxidation Process
APS	Asset Planning System (Thames Water system)
AWRP	Advanced Water Recycling Plant
BAC	Biological Activated Carbon
BNG	Biodiversity Net Gain
BOD	Biological Oxygen Demand
CCPs	Critical Control Points
CDC	Coagulation Dosing Chamber
CDM	Construction Design Management
CDR	Conceptual Design Report
CEB	Chemically Enhanced Backwash
CEC	Contaminants of Emerging Concern
CIP	Clean in Place
CS	Chemical Storage

Acronym	Definition
DAF	Dissolved Air Floatation
DEL	Drought Event Level
Defra	Department for Environment, Food and Rural Affairs
DI	Ductile Iron
DNO	Distribution Network Operator
DO	Deployable Output
DPC	Direct Procurement for Customers
DRA	Direct River Abstraction
DWI	Drinking Water Inspectorate
dWRMP	Draft Water Resource Management Plan
DWSP	Drinking Water Safety Plan
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
EA	Environment Agency
EDC	Endocrine Disrupting Compound
EIA	Environmental Impact Assessment
ELV	Emission Limit Value
ENG	Environmental Net Gain
EPB	Earth Pressure Balance
EQS	Environmental Quality Standard
EQT	Equalisation Tank
FEPS	Final Effluent Pumping Station
GAC	Granular Activated Carbon
GIS	Geographic Information System
HGV	Heavy Goods Vehicle
HSE	Health and Safety Executive
HV	High Voltage
ICA	Instrumentation Control and Automation
ID	Internal Diameter
IPR	Indirect Potable Reuse
KGV	King George V Reservoir
LSI	Langelier Saturation Index
M&E	Mechanical & Electrical
MCC	Motor Control Centres
MCF	Mechanical Cloth Filter
MEICA	Mechanical, Electrical, Instrumentation, Control and Automation
Ml/d	Mega litres per day
NDMA	Nitrosodimethylamine
NIC	National Infrastructure Commission
NSFs	Nitrifying Sand Filters
NTU	Nephelometric Turbidity Unit
PACl	Polyaluminium Chloride
PCV	Prescribed Concentration or Value
PFAS	Per- and Polyfluoroalkyl Substances
PPA	Power Purchase Agreement

Acronym	Definition
PR19	Price Review 2019
PRoW	Public Right of Way
PS	Pumping Station
RAPID	Regulatory Alliance for Progressing Infrastructure Development
REGO	Renewable Energy Guarantee of Origin
REM	Remineralisation
RGF	Rapid Gravity Filtration
RO	Reverse Osmosis Building
ROPS	RO Feed Pumping Station
ROT	RO Feed Tank
RPv1	Regional Plan version 1
RWPS	Recycled Water Pumping Station
SAC	Special Area of Conservation
SCL	Sprayed Concrete Lining
SEA	Strategic Environmental Assessment
SINC	Sites of Importance for Nature Conservation
SOC	Strategic Outline Case
SOLAR	Strategic Overview of Long term Assets and Resources
SPA	Special Protection Area
SRO	Strategic Resource Option
SSSI	Site of Special Scientific Interest
STT	Severn Thames Transfer
STW	Sewage Treatment Works
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids
TEPS	Treated Effluent Pumping Station
THM	Trihalomethanes
TLT	Thames Lee Tunnel
TN	Total Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solid
TTP	Tertiary Treatment Plant
TWUL	Thames Water Utilities Ltd
T2AT	Thames to Affinity Transfer
UF	Ultrafiltration Building
UFPS	UF Feed Pumping Station
UV	Ultraviolet
UVAOP	UV Advanced Oxidation Process Building
WRMP19	Water Resource Management Plan 2019
WRMP24	Water Resource Management Plan 2024
WRSE	Water Resource South East
WRZ	Water Resource Zone
WTW	Water Treatment Works